# COURSES OF STUDY
# FOR
# POST GRADUATE PROGRAMMES

## (2023 – 2025)

**Defence Institute of Advanced Technology**
**(Deemed to be University), Pune – 411025**

# CONTENTS

## 1. M.Tech Programmes for the Academic Batch 2023-25



## 2. MASTER OF SCIENCE (M.Sc.) Programmes

# PREFACE

This book gives comprehensive information on the structure, curriculum and syllabus of various Post Graduate programmes. The Board of Studies and Academic Council Continuously monitor these Courses and makes appropriate modifications / improvements from time to time.

In order to keep pace with the rapid developments in science and technology and also to keep in view the requirements of the nation and the aspirations of students, it is imperative that the academic programmes of the institute are reviewed continuously.

The academic system is semester based and hence the students are required to follow certain procedures and meet certain academic requirement each semester. The academic performance is monitored by Postgraduate Graduate Committee (PGC), which also reviews status of individuals after reviewing their performance.

The advisory system plays a very important role in a flexible curriculum of the type offered under the various programmes of the Institute. The choice of courses being very wide and considerable flexibility in the programme being its characteristic feature, students normally need guidance to formulate a meaningful and well knit programme for each of them.

# *Academic Calendar*

## ACADEMIC CALENDAR 2023-24(ODD SEMESTER)

**(AUG 2023 –DEC 2023)**

| Sl. No. | Activity | Dates |
|---|---|---|
| 1. | Registration (M. Tech. / MS (by Research)/ MSc/ PGD/ Ph.D)<br>Re-examination for Even semester courses<br>Add/Drop Courses & Finalizing Electives and Orientation Programme | $17^{th}$ July – $28^{th}$ July 2023<br>(All Students) |
| 2. | Last date of Late Registration with late fee | $31^{st}$ Aug 2023 |
| 3. | Sending Certified list of courses (Regular, Self study, Audit etc) registered by the students - by Jt. Reg. (ACs) to COE | $30^{th}$ Sep 2023 |
| 4. | Classes including Preparation | $17^{th}$ July – $24^{th}$ Nov. 2023<br>(19 weeks) for $1^{st}$ year |
| 5. | Project Work-$2^{nd}$ Year | $17^{th}$ July – $19^{th}$ Nov. 2023<br>(18 Weeks) |
| 6. | PhD progress review by DRMC | $17^{th}$ July – $31^{st}$ July 2023 |
| 7. | Sending the Panel of Examiners to COE | $8^{th}$ Sep. 2023 |
| 8. | Last date of submission of Examination form and Admit Card to COE by the Students. | $29^{th}$ Sep. 2023 |
| 9. | End Semester Examination | $27^{th}$ Nov. – $8^{th}$ Dec. 2023 |
| 10. | Oral Examination Committee approved by Vice- Chancellor to be sent to COE (Thesis first Phase evaluation) | $15^{th}$ Nov 2023 |
| 11. | Thesis first evaluation Phase I (M.Tech. $3^{rd}$ Sem) | $20^{th}$ Nov. – $1^{st}$ Dec. 2023 |
| 12. | Last date for submission of certified Statement of Marks to COE (Courses / Seminar / Lab / Thesis) | $15^{th}$ Dec. 2022 |
| 13. | Winter Vacation For Faculty and $1^{st}$ year PG Students<br>(Not Applicable for M.Tech. $2^{nd}$ year students) | $18^{th}$ Dec. 2023 – $31^{st}$ Dec. 2023 (2 Weeks) |
| 14. | Result Declaration – Autumn Semester | $29^{th}$ Dec. 2023 |
| 15. | Outstation Instructional Tour (Optional) | During the period provided for classes without affecting any academic activities. |

Note:

1. The Classes may be conducted Online/Offline (Class Roorn) or Blended mode (Onlinc + offline) following the prescribed protocols / guideline related to pandemic.

## ACADEMIC CALENDAR 2023-24 (EVEN SEMESTER)

**(Jan. 2024 – June 2024)**

| Sl. No. | Activity | Dates |
|---|---|---|
| 1 | Registration (M. Tech. / MS (by Research)/ MSc/ PGD/ Ph.D)<br>Re-examination for Odd semester courses<br>Add/Drop Courses & Finalizing Electives and Orientation Programme | 1st Jan. – 12th Jan 2024 (2nd Semester)<br>18th Dec. 2023 – 31st Dec. 2023 (4th Semester) |
| 2. | Last date of Late Registration with late fee | 31st Jan. 2024 |
| 3. | Sending Certified list of courses (Regular, Self study, Audit etc) registered by the students – by Jt. Reg. (Acs) to COE | 1st Mar. 2024 |
| 4. | **Classes (Phase I)/Dissertation/Project** | 1st Jan. –2nd Feb. 2024(2nd Semester)<br>**(5 weeks)**<br>18th Dec. 2023 – 2nd Feb. 2024<br>(4th Semester) **(7 Weeks)** |
| **5.** | Sport/Cultural/NSS/Other student related activities | 3rd Feb. -11th Feb. 2024 (1 week) |
| 6. | **Classes (Phase II) including Preparation/ Dissertation/Project** | 12th Feb. - 10th May 2024(2nd Semester) **(13 Weeks)**<br>12th Feb. 2024 – 26th April 2024<br>(4th Semester) **(11 Weeks)** |
| 7. | PhD progress review by DRMC | 1st Jan. – 31st Jan. 2024 |
| 8. | Sending the Panel of Examiners to COE | 8th Mar. 2024 |
| 9. | Last date of submission of Examination form and Admit<br>Card to COE by the Students. | 12th April 2024 |
| 10. | End Semester Examination/Submission of Marks-2nd Semester | (13th May – 29th May 2024)/31st May 2024 |
| 11. | Oral Examination Committee approved by Vice-Chancellor to be sent to COE (Thesis first Phase evaluation) | 1st April 2024 |
| **12.** | **Thesis evaluation (M.Tech. 4th Sem)** | **29th April – 3rd May 2024** |
| **13.** | **Last date for submission of certified Statement of Marks to COE (4th Semester)** | **6th May 2024** |
| 14. | Summer Vacation For Faculty and Students | 3rd June– 30th June 2024 (4 weeks) |
| 15. | Result Declaration – Even Semester | 5th July 2024 |
| 16. | Outstation Instructional Tour (Optional) | During the period provided<br>for classes without affecting<br>any academic activities |

**Note:** 1. The Classes may be conducted Online/Offline (Class Roorn) or Blended mode (Onlinc + offline) following the prescribed protocols / guideline related to pandemic.

# Programmes Structure
# &
# Syllabus of Courses

# DEPARTMENT OF AEROSPACE ENGINEERING

The Department of Aerospace Engineering, formerly known as Faculty of Guided Missiles was established with a mission to impart knowledge to scientists and service officers to take up the challenges in design, development and use of Guided Missiles. Later scope was widened to Air Armaments & UAVs.

**Vision of the Department:** To be a centre of excellence for education, training and research in Aerospace Technologies.

**Mission of the Department:** To impart higher education and pursue research in the field of Aerospace Engineering and Technology having a bearing on the defence requirements for the officers of the Ministry of Defence, Armed Forces, Public Sector Undertakings, other related organizations and general public.

**Research Areas:**

- Flight Guidance and Control, Robust and Nonlinear Control
- Flight Dynamics and Trajectory Optimization
- Experimental Aerodynamics
- Aero-elasticity
- Flow Control
- UAV Design

Currently, the department offers M.Tech. in Aerospace Engineering with three specializations namely Guided Missiles, UAVs and Air Armaments. The details of the programmes are given below:

## M. Tech. in Aerospace Engineering (Guided Missiles)

**Brief Description:** The department has been involved in conducting post-graduate programme in Aerospace Engineering with specialization in Guided Missiles Technology. This programme consists of courses in areas of aerospace engineering with relevance to guided missiles. Curriculum of the programme was formulated to meet the needs of Tri-services, Defence R&D Organization, and Public Sector Undertakings dealing with missiles and related technologies. From academic year 2009-10 onwards, the programme was also opened up for civilian GATE qualified students.

**Eligibility:** B.E./B. Tech. degree in Aerospace, Aeronautical or AeSI / Mechanical/ Electrical/ Electronics/ Electronics and Communication / from recognized university.

**Organization:** The programme will be of four-semester duration. In the first semester there are six courses. In the second semester there are six courses out of which four courses are electives. The third and fourth semesters are completely devoted for dissertation. All courses will have three tests and a final examination. Half yearly evaluation of the dissertation takes place at the end of the third semester. At the end of the final semester the student submits his/her thesis and makes a presentation which is evaluated by a committee consisting of Internal and External examiners. Visits to various DRDO labs, National Laboratories, etc are planned to enhance student’s appreciation & understanding of the subject.

The details of the courses offered under the programme are given below:

## M. Tech. in Aerospace Engineering (Guided Missiles)

### Semester I

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AM 607 | Mathematics for Engineers | 3 | 1 | 4 |
| 2 | AE 601 | Aerospace Propulsion | 3 | 1 | 4 |
| 3 | AE 602 | Aerodynamics | 3 | 1 | 4 |
| 4 | AE 603 | Navigation, Guidance & Control | 3 | 1 | 4 |
| 5 | AE 604 | Aerospace Structures | 3 | 1 | 4 |
| 6 | AE 605 | Flight Mechanics | 3 | 1 | 4 |
| 7 | PGC 601 | Research Methodology & IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

### Semester II

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AE 606 | Flight Instrumentation | 3 | 1 | 4 |
| 2 | AE 607 | Missile Propulsion | 3 | 1 | 4 |
| 3 | | Elective – I [From Department] | 3 | 1 | 4 |
| 4 | | Elective – II [From Department] | 3 | 1 | 4 |
| 5 | | Elective – III | 3 | 1 | 4 |
| 6 | | Elective – IV | 3 | 1 | 4 |
| 7 | PGC 602 | Audit 1and 2 | 0 | 0 | 0 |
| | | **Total** | **18** | **6** | **24** |

Note: 04 weeks Practice school during summer vacation for scholarship students.

### Semester III

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 3 | AE 651 | M.Tech. Dissertation Phase I | 28** | | 14 |
| | | **Total** | **28** | | **14** |

### Semester IV

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AE 652 | M.Tech. Dissertation Phase II | 28** | | 14 |
| | | **Total** | **28** | | **14** |

***Contact Hours/week**

**List of Electives**

| Sl. No. | Course Code | Course |
|---|---|---|
| 1 | AE 608 | UAV Design |
| 2 | AE 609 | Guidance & Control for Aerospace Vehicles |
| 3 | AE 610 | Missile Guidance & Control |
| 4 | AE 611 | UAV Guidance & Control |
| 5 | AE 612 | Experimental Aerodynamics |
| 6 | AE 613 | Computational Aerodynamics |
| 7 | AE 614 | Structural Dynamics and Aero-elasticity |
| 8 | AE 615 | Estimation and Tracking for Aerospace Applications |
| 9 | AE 616 | Nonlinear and Robust Control |
| 10 | AE 617 | Avionics |
| 11 | AE 618 | Robotic Control |
| 12 | AE 619 | Signals and Systems |
| 13 | AE 620 | Optimal Control with Aerospace Applications |
| 14 | AE 621 | Advanced Missile Guidance |
| 15 | AE 622 | Ducted Rocket & Combustion |
| 16 | AE 623 | Experimental Methods in Fluid Mechanic |
| 17 | AE 624 | Aircraft Assembly, Inspection & Tests |
| 18 | AE 625 | Hypersonic Flow |
| 19 | AE 626 | Compressible Fluid Flow |
| 20 | AE 627 | Flow Stability and Turbulence |
| 21 | AE 628 | Missile Aerodynamics |
| | | Open electives from other Departments |

## M. Tech. in Aerospace Engineering (UAVs)

**Brief Description:** This programme was commenced in 2016 and consists of courses in areas of aerospace engineering with relevance to UAVs. The curriculum of the program was formulated to meet the needs of the tri-services, Defence R&D Organization, and Public Sector Undertakings dealing with UAVs and related technologies.

**Eligibility:** B.E./B. Tech. degree in Aerospace, Aeronautical or AeSI / Mechanical/ Electronics/ Electrical/ Electronics and Communication from recognized university.

**Organization:** The programme will be of four-semester duration. In the first semester there are six courses. In the second semester there are six courses out of which four courses are electives. The third and fourth semesters are completely devoted for dissertation. All courses will have three tests and a final examination. Half yearly evaluation of the dissertation takes place at the end of the third semester. At the end of the final semester the student submits his/her thesis and makes a presentation which is evaluated by a committee consisting of Internal and External examiners. Visits to various DRDO labs, National Laboratories, etc are planned to enhance student's appreciation & understanding of the subject.

The details of the courses offered under the programme are given below:

**M. Tech. in Aerospace Engineering (UAVs)**

**Semester I**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AM 607 | Mathematics for Engineers | 3 | 1 | 4 |
| 2 | AE 601 | Aerospace Propulsion | 3 | 1 | 4 |
| 3 | AE 602 | Aerodynamics | 3 | 1 | 4 |
| 4 | AE 603 | Navigation, Guidance & Control | 3 | 1 | 4 |
| 5 | AE 604 | Aerospace Structures | 3 | 1 | 4 |
| 6 | AE 605 | Flight Mechanics | 3 | 1 | 4 |
| 7 | PGC 601 | Research Methodology &IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

**Semester II**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AE 606 | Flight Instrumentation | 3 | 1 | 4 |
| 2 | AE 608 | UAV Design | 3 | 1 | 4 |
| 3 | | Elective – I [From Department] | 3 | 1 | 4 |
| 4 | | Elective – II [From Department] | 3 | 1 | 4 |
| 5 | | Elective – III | 3 | 1 | 4 |
| 6 | | Elective – IV | 3 | 1 | 4 |
| 7 | PGC 602 | Audit 1and 2 | 2 | 0 | 0 |
| | | **Total** | **20** | **6** | **24** |

Note: 04 weeks Practice school during summer vacation for scholarship students.

**Semester III**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 3 | AE 651 | M.Tech. Dissertation Phase I | 28** | | 14 |
| | | **Total** | **28** | | **14** |

**Semester IV**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AE 652 | M.Tech. Dissertation Phase II | 28** | | 14 |
| | | **Total** | **28** | | **14** |

****Contact Hours/week**

**List of Electives**

| Sl. No. | Course Code | Course |
|---|---|---|
| 1 | AE 607 | Missile Propulsion |
| 2 | AE 609 | Guidance & Control for Aerospace Vehicles |
| 3 | AE 610 | Missile Guidance & Control |
| 4 | AE 611 | UAV Guidance & Control |
| 5 | AE 612 | Experimental Aerodynamics |
| 6 | AE 613 | Computational Aerodynamics |
| 7 | AE 614 | Structural Dynamics and Aero-elasticity |
| 8 | AE 615 | Estimation and Tracking for Aerospace Applications |
| 9 | AE 616 | Nonlinear and Robust Control |
| 10 | AE 617 | Avionics |
| 11 | AE 618 | Robotic Control |
| 12 | AE 619 | Signals and Systems |
| 13 | AE 620 | Optimal Control with Aerospace Applications |
| 14 | AE 621 | Advanced Missile Guidance |
| 15 | AE 622 | Ducted Rocket & Combustion |
| 16 | AE 623 | Experimental Methods in Fluid Mechanic |
| 17 | AE 624 | Aircraft Assembly, Inspection & Tests |
| 18 | AE 625 | Hypersonic Flow |
| 19 | AE 626 | Compressible Fluid Flow |
| 20 | AE 627 | Flow Stability and Turbulence |
| 21 | AE 628 | Missile Aerodynamics |
| | | Open electives from other Departments |

# M.Tech. in Aerospace Engineering (Air Armaments)

**Brief Description:** The aim of the program is to impart advanced training and to update knowledge in the field of design, development, quality assurance and Inspection of air armaments to engineering officers from Air Force, Army, Navy & DRDO. At the end of the program the officer should be able to undertake R&D work and/or inspection, testing and evaluation of armament systems.

**Eligibility:** Bachelor's Degree in Aerospace, Aeronautical/Mechanical Engineering of a recognized Institute/University.
**Organization:** The programme will be of four-semester duration. In the first semester there are six courses. In the second semester there are six courses out of which four courses are electives. The third and fourth semesters are completely devoted for dissertation. All courses will have three tests and a final examination. Half yearly evaluation of the dissertation takes place at the end of the third semester. At the end of the final semester the student submits his/her thesis and makes a presentation which is evaluated by a committee consisting of Internal and External examiners. Visits to various DRDO labs, National Laboratories, etc are planned to enhance student's appreciation & understanding of the subject.

The details of the courses offered under the programme are given below:

## M.Tech. in Aerospace Engineering (Air Armaments)

**Semester I**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AM 607 | Mathematics for Engineers | 3 | 1 | 4 |
| 2 | AFW 601 | Ballistics of Bombs & Projectiles | 3 | 1 | 4 |
| 3 | AFW 602 | Design of Air Armament - I | 3 | 1 | 4 |
| 4 | AE 601 | Aerospace Propulsion | 3 | 1 | 4 |
| 5 | AE 602 | Aerodynamics | 3 | 1 | 4 |
| 6 | AE 605 | Flight Mechanics | 3 | 1 | 4 |
| 7 | PGC 601 | Research Methodology & IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

**Semester II**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AFW 603 | Airborne Weapon System Effectiveness | 3 | 1 | 4 |
| 2 | AFW 604 | Warhead Design and Mechanics | 3 | 1 | 4 |
| 3 | | Elective – I [From Department] | 3 | 1 | 4 |
| 4 | | Elective – II [From Department] | 3 | 1 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| 5 | | Elective – III | 3 | 1 | 4 |
| 6 | | Elective – IV | 3 | 1 | 4 |
| 7 | PGC 602 | Audit 1and 2 | 0 | 0 | 0 |
| | | **Total** | **18** | **6** | **24** |

Note: 04 weeks Practice school during summer vacation for scholarship students.

**Semester III**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AFW 651 | M. Tech Dissertation Phase I | 28** | | 14 |
| | | **Total** | **28** | | **14** |

**Semester IV**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AFW 652 | M.Tech Dissertation Phase II | 28** | | 14 |
| | | **Total** | **28** | | **14** |

****Contact Hours/week**

**List of Electives**

| Sl. No. | Course Code | Course |
|---|---|---|
| 1 | AFW 605 | Air Armaments Control and Guidance |
| 2 | AFW 606 | Design of Air Armament – II |
| 3 | AFW 607 | Testing and Certification of Air Armament Stores |
| 4 | AFW 608 | Fire Control Systems |
| 5 | AE 604 | Aerospace Structures |
| 6 | AE 606 | Flight Instrumentation |
| 7 | AE 607 | Missile Propulsion |
| 8 | AE 608 | UAV Design |
| 9 | AE 609 | Guidance & Control for Aerospace Vehicles |
| 10 | AE 610 | Missile Guidance & Control |
| 11 | AE 611 | UAV Guidance & Control |
| 12 | AE 612 | Experimental Aerodynamics |
| 13 | AE 613 | Computational Aerodynamics |
| 14 | AE 614 | Structural Dynamics and Aero-elasticity |
| 15 | AE 615 | Estimation and Tracking for Aerospace Applications |

| | | |
|---|---|---|
| 16 | AE 616 | Nonlinear and Robust Control |
| 17 | AE 617 | Avionics |
| 18 | AE 618 | Robotic Control |
| 19 | AE 619 | Signals and Systems |
| 20 | AE 620 | Optimal Control with Aerospace Applications |
| 21 | AE 621 | Advanced missile guidance |
| 22 | AE 622 | Ducted Rocket & Combustion |
| 16 | AE 623 | Experimental Methods in Fluid Mechanic |
| 17 | AE 624 | Aircraft Assembly, Inspection & Tests |
| 18 | AE 625 | Hypersonic Flow |
| 19 | AE 626 | Compressible Fluid Flow |
| 20 | AE 627 | Flow Stability and Turbulence |
| 21 | AE 628 | Missile Aerodynamics |
| | | Open electives from other Departments |

**AE 601 Aerospace Propulsion**

**Introduction:** Classification & mode of operation of various Propulsion Systems.

**Basic Thermodynamics & Fluid Dynamics:** Thermodynamic Laws, Conservation laws for mass, momentum and energy, Thrust Equation, Compressible flow, Isentropic Relations, Normal & Oblique Shock Waves, Quasi One-Dimensional flow through variable area ducts, Flow with Friction and Heat Transfer.

**Gas Turbine Engine:** Parametric Analysis of Ideal Turbojet, Turbofan & Turboprop engine, Specific Fuel Consumption, Propulsive, Thermal & Overall Efficiency, Component Performance (Subsonic & Supersonic Inlets, Axial and Centrifugal Compressors, Combustor, Turbine & Nozzle)

**Piston Engines:** Cycle Analysis, Engine Components and Classification, Engine Systems (Fuel Injection, Ignition, Lubrication, Supercharging, Inter Cooling)

**Propellers:** Classical Momentum Theory, Blade Element Theory, Variable Speed Propeller, Propeller Charts, Performance Selection & Matching, Ducted Propellers.

**UAV Propulsion:** Electric Motors, Solar Cells, Advanced Batteries, Fuel Cells, Future Technology.

**References**

1. Saeed Farokhi , “Aircraft Propulsion” 2nd Edition, Wiley
2. Jack L. Kerrebrock, “Aircraft Engines & Gas Turbines” 2nd Edition, MIT Press
3. J. Mattingly & H. von Ohain, “Elements of Propulsion: Gas Turbines & Rockets” AIAA Education,
4. Philip Hill & Carl Peterson, “Mechanics and Thermodynamics of Propulsion” 2nd Edition, Prentice Hll
5. Gordon C Oates, “Aerothermodynamics of Gas Turbine and Rocket Propulsion” 3rd Edition, AIAA Education,
6. Maurice J Zucrow , “Aircraft and Missile Propulsion”, Vol 1 & 2, Wiley

**AE 602 Aerodynamics**

Introduction, Governing equations, Flow kinematics, Elementary flows, Non-lifting and lifting flows, Flow over airfoils; Kutta-Joukowski theorem, Kutta conditon, Kelvin's theorem, Thin airfoil theory; Flow over wings; Prandtl's lifting line theory; Viscous fluid flow, Turbulent flow, flow separation, Boundary layer.

Governing equations for compressible fluid flow; Normal shock waves, Oblique shock and expansion waves, Prandtl-Mayer waves, Shock-Expansion Theory. Flow over supersonic airfoils and wings; Shock Wave – Boundary Layer interactions.

Introduction to hypersonic flow.

Aerodynamic characteristics of aerospace vehicles.

Introduction to experimental aerodynamics.

**Text/References:**

1. John D. Anderson, Fundamentals of Aerodynamics, 4th Edition, McGraw Hill, 2006.
2. E. L. Houghton and P. W. Carpenter, Aerodynamics for Engineering Students, 5th Edition, Butterworth-Heineman, Oxford, 2003.
3. John D. Anderson, Introduction to flight, 5th Edition, McGraw Hill, 2005.
4. F. M. White, Viscous Fluid Flow, McGraw Hill, 2006.
5. F. M. White, Fluid Mechanics, McGraw Hill, 2003.
6. Fox and MacDonald, Introduction to Fluid Mechanics, 5th Edition, John Wiley & Sons, inc, 2003.
7. John D. Anderson, Modern Compressible Flow: With Historical Perspective, 3rd Ed, McGraw Hill, 2004.
8. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, McGraw Hill, 2006.
9. Maurice Rasmussen, Hypersonic Flow, John Wiley & Sons, inc, 1994.
10. S. S. Chin, Missile Configuration Design, McGraw Hill, 1961.
11. **Michael R. Mendenhall**, Tactical Missile Aerodynamics,2nd Ed., AIAA Publications, 1992.
12. Reg Austin, Unmanned aircraft Systems: Uavs design, development and deployment, John Wiley & Sons, inc, 2010.

**AE 603 Navigation, Guidance & Control**

**Navigation:** Navigation systems and principles of operation, Continuous waves and frequency modulated radars, MTI and Doppler radars; types of navigation; ILS, Optical landing, VOR, INS, and GPS.

**Guidance:** Classification and phases of missile guidance. Guidance laws: pursuit, LOS, CLOS, BR and PN laws. Advance Guidance Systems such as Imaging, Scene Correlation, Millimeteric wave, Non-LOS Guidance Systems, Laser Based Guidance Systems.

**Control:** Classical linear time invariant control systems, transfer function representations, stability, Time domain characteristics, Frequency domain characteristics, Root Locus, Nyquist and Bode plots, Introduction to state space analysis.

**Texts/References:**

1. Ching Fang Lin, Modern Navigation, Guidance and Control Processing, Prentice Hall, 1991
2. P. Zarchan, Tactical & Strategic Missile Guidance, American Institute of Aeronautics and Astronautics, 2007
3. G. M. Siouris, Missile Guidance and Control Systems, Springer, 2004
4. John H. Blakelock, Automatic Control of Aircraft and Missiles, Wiley, 1991

5. Anthony Lawrence, Modern Inertial Technology, Springer, 1998
K. Ogata, Modern Control Engineering, Prentice Hall of India, 1995.

**AE 604 Aerospace Structures**

Review of Strength of Materials.
Introduction to Aerospace Materials – Metal Alloys and Fiber Reinforced Composite.
Introduction to different types of constructions: Monocoque, Semi-Monocoque, Truss, and Corrugated shell.
Introduction to Aircraft and Missile Structural Components: Spars; Ribs; Stringer; Longerons.
Analysis of stress; Analysis of strain.
Material Constitutive Relations; Analysis of pressure vessels; Bending, Shear and torsion of thin-walled members; Buckling of Columns; Failure Theories;
Introduction to Vibration and Fatigue.

**Texts/ References:**

1. David J. Peery, Aircraft Structures, Dover Publications, 2011
2. E. F. Bruhn, Analysis and Design of Flight Vehicle Structures, S.R. Jacobs, 1973
3. T. H. G. Megson, Aircraft Structures for Engineering Students, Butterworth-Heinemann, 2010.
4. G. F. Titterton, Aircraft Materials and Processes, Himalayan Books, 2013.

**AE 605 Flight Mechanics**

**Flight Performance:** Standard Atmosphere. Aerodynamics of airfoils and wings. Brief history of flight. Introduction to performance. Equations of motion. Thrust required, thrust available & maximum velocity for level un-accelerated flight. Power required, power available and max. velocity. Altitude effects on power required and available. Rate of climb. Gliding Flight. Absolute ceiling. Time to climb. Range and Endurance. Takeoff and Landing performance. Turning Flight and v-n diagram.
**Flight Stability and Control:** Definition of stability and control: static stability, dynamic stability, control, the partial derivative. Moments on missile, absolute angle of attack, Criteria for longitudinal static stability. Contribution of wings to moment about center of gravity, Contribution of tail to moment about center of gravity.Total pitching moment about center of gravity. Equations for longitudinal static stability. The neutral point. The static margin. Aerodynamic derivatives. Cross coupling. The concept of static longitudinal control. Lateral stability: Induced rolling moments, Various configurations. Aerodynamic damping. Stability margins. Control forces and moments.

**Text/References:**

1. B. Etkin, Dynamics of Atmospheric Flight, Dover, 2005 .
2. Robert C. Nelson, Flight Stability and automatic control, Tata McGraw-Hill, New Delhi, 2007
3. Bandu N. Pamadi, Performance, Stability, Dynamics and control of airplanes. AIAA Educational Series.
4. John D Anderson, JR, Introduction to Flight, Tata McGraw-Hill, New Delhi.

**Suggested References:**

1. Michael R. Mendenhall**,** Tactical Missile Aerodynamics, , 2nd Ed., AIAA Publications, 1992.
2. Eugene L. Fleeman, Missile Design and System Engineering, AIAA Education Series, 2012.
3. J.J. Jerger, System Preliminary Design, D. Van Nostrand Co., Inc., Princeton, New Jersey, 1960.
4. A.E. Puckett and Simon Ramo, Guided Missile Engineering, McGraw Hill, 1989.

**AE 606 Flight Instrumentation**

**Basic concepts of measurements:** Generalized characteristics of sensors, instruments, and measurement systems. Measurement of physical quantities such as pressure, force, altitude, temperature, flow, strain and vibration, and angle of attack. Inertial sensors: gyroscope and accelerometer with recent advancements therein.

**Signal processing:** Operational amplifiers, instrumentation and Charge amplifiers. Analog to digital and digital to analog converters. Data acquisition system.

**Data transmission:** Signal transmission by analog and digital means, methods of modulation and demodulation, multiplexing time division and frequency division, telemetry systems and trajectory tracking devices such as Electro-optic tracking systems.

**Tracking and data fusion:** Thermal imagining system, scanning techniques, detectors and range analysis and multi sensor data fusion for trajectory analysis.

**Texts/References:**


1. E.O. Doebelin, Measurement Systems: Application and Design, 4thEd, McGraw Hill International, New York, 1990
2. J.M. Lloyd, Thermal imaging system, Plenum Pub., New York, 1975
3. D. Patranabis, Telemetry Principles, Tata McGraw Hill, New York, 2000.


**AE 607 Missile Propulsion**

**Introduction:** Classification and characteristics of various propulsive devices used for Missiles & Weapon Systems.

**Thermodynamic Cycle Analysis:** Engine cycles (Turbojet, Turbofan, Pulsejet, Ramjet and Rocket Engine). Thrust equation, specific impulse & fuel consumption. Thermal efficiency, propulsive efficiency & overall efficiency of propulsion systems.

**Gas Dynamics:** Equation of state, internal energy, enthalpy & entropy of an ideal gas. Laws of conservation of mass, momentum and energy. Wave equation and velocity of sound. Quasi one-dimensional gas flows. Characteristic parameters. Methods of solving one-dimensional problem of gas dynamics. Flow across Shock waves and Expansion waves. Flow through variable area ducts.

**Reacting Flows & Heat Transfer:** Reactant and product mixtures, stoichiometry, absolute enthalpy, enthalpy of formation, chemical equilibrium, Gibbs function, Adiabatic Flame Temperature, shifting equilibrium and frozen flow assumptions. One-dimensional flows with friction and heat transfer. Conduction, convection & radiation heat transfer processes in one-dimensional gas flows.

**Chemical Rockets:** Gravity free flight of rockets. Performance Parameters (Total & Specific Impulse, Thrust Coefficient, Characteristic Velocity, Effective Exhaust Velocity, Combustion Parameter, Characteristic Length, Residence Time). Methods for evaluating performance parameters. Evaluation of chemical composition of combustion products and chamber temperature. Introduction to Solid and Liquid Propellants.

**Solid Rocket Motor:** Solid propellant burning mechanism and combustion models. Burning rate of solid propellants under steady-state and transient conditions. Calculation of equilibrium chamber pressure under steady-state and transient conditions. Burning surface evolution. Erosive burning. Heat transfer and chamber wall temperature. Grain ignition and igniter assembly. Stability condition for steady-state operation of solid rocket motor. Combustion instability and frequency of acoustic pressure oscillations in the motor.

**Liquid Rocket Engine:** Burning mechanism of liquid propellants. Combustion of mono & bi propellant systems. Droplet vaporization combustion model. Ignition delay. Pressure transients in liquid rocket motors. Combustion Instability. Heat transfer and cooling. Design of liquid propellant engines (Propellant feed systems, Propellant tanks, Tank pressurization, Turbopumps, Engine integration)

**Hypersonic Air Breathing Propulsion:** Aerothermodynamics of Ramjet & Scramjet Engines, Performance Measures, Compression, Expansion and Combustion systems.

**Text/References:**


1. George P. Sutton, Rocket Propulsion Elements, Wiley-Interscience; 7th edition, 2000
2. M. J. Zucrow, Aircraft and Missile Propulsion, vol 1& 2, John Wiley, 1958
3. M. Barrere, Rocket Propulsion, Elsevier Pub. Co., 1960
4. M. J. Zucrow, Gas Dynamics, John Wiley & Sons; Volume 1, 1976
5. James E. A. John, Gas Dynamics, Prentice Hall, 3rd edition, 2006
6. P. Hill & C. Peterson, Mechanics & Thermodynamics of Propulsion, Prentice Hall, 2nd edition,1991
7. G. C. Oates, Aerothermodynamics of Gas Turbines and Rocket Propulsion, AIAA Education Series, 1989
8. W. Heiser, D. Pratt, D. Daley, U. Mehta, Hypersonic Airbreathing Propulsion, AIAA Education Series, 1994


**AE 608 UAV Design**

Terminology. Requirements. Certification approaches: aircrafts and UAVs. Airworthiness of aircrafts and UAVs. Airsafety issues. Handling qualities. Maneuverability requirements.

Aircraft design; UAV system design. UAV system identification. UAV project life cycles. Stages of Aircraft design. Initial sizing: aircrafts and of UAVs. UAV aerodynamics, structures and propulsion. Ground control systems. Ground and flight testing of UAVs. UAV guidance and Navigation. Design for reliability.

Introduction to UAV system Development.

**Text books:**


1. Daniel P. Raymer, Aircraft Design: A Conceptual Approach. AIAA Education Series, 2012
2. J. Jayaraman, Unmanned Aircraft Systems: A Global View, DRDO, 2014.
3. Reg Austin, Unmanned Aircraft Systems, Wiley Publication, 2010.
4. Eugene L. Fleeman, Missile Design and System Engineering, AIAA Foundation Series, 2014.
5. John Anderson Jr., Aircraft Performance & Design, McGraw-Hill2014.


**AE 609 Guidance & Control for Aerospace Vehicles**

**Mathematical Modelling:** Rigid body force and moment equations, Aerodynamics forces and moments representation, linearization, Transfer function generation and stability analysis.

**Control:** Aerodynamic and thrust vector control, polar and Cartesian control classical approach to control/ Autopilot design such as successive loop closer, three axes autopilot longitudinal, lateral and directional, three loop auto pilot and roll, lateral autopilot. Modern methods using state space approach, Controllability and Observability. Pole Placement techniques. Introduction to structure control interaction.

**Servo Systems:** Hydraulic, Pneumatic & electromechanical

**Guidance:** Missile & UAV guidance, Optimal guidance, Comparative study of PN guidance techniques, guidance laws for UAVs, path following, vision-based guidance, interception and avoidance; Collision detection and avoidance strategies. Introduction to cooperative control. Inertial Guidance: Intro, Inertial sensor, coordinate systems and transformations, Schuler tuning and gimbaled platform systems. INS – GPS integration, Data fusion.

**Text/References:**


1. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, New Delhi, 2001.
2. P Zarchan, Tactical and Strategic Missile Guidance, Vol 199 of Progress in Astronautics and Aeronautics, AIAA, Reston, VA, 2002.
3. P. Garnell, Guided Weapon Control Systems, 2nd Ed, Pergamon Press, London, 1980.
4. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, New York, 2004.
5. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
6. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
7. Amitava Bose, Somnath Puri, Paritosh Banerjee**,** Modern Inertial Sensors and Systems, Prentice-Hall of India, 2008.
8. Ian Moir, Allan Seabridge, Malcolm Jukes, Military Avionics Systems, Wiley, 2006.
9. Jay Gundlach, Designing Unmanned Aircraft Systems: A comprehensive Approach, AIAA Education Series, AIAA, 2012.
10. Rafael Yanushevsky, Guidance of Unmanned Aerial Vehicles, CRC Press, 2011.
11. Randal W. Beard and Timothy W. McLain, Small Unmanned Aircraft Theory & Practice, Princeton University Press, 2012.
12. N. V. Kadam, Practical design of flight control systems for launch vehicles and missiles, Allied Publishers, 2009
13. Rasmussen, S., and Shima, T. (Eds.), UAV Cooperative Decision and Control: Challenges and Practical Approaches, SIAM Publications, 2008.


**AE 610 Missile Guidance & Control**

**Missile Kinematics**: Kinematics of various courses, time of flight, lateral acceleration demand and turning rate spectrum for each case.

**Guidance Laws:** Optimal guidance, Advanced PN guidance laws, comparative study of different guidance schemes.

**Inertial Guidance:** Introduction, inertial sensors, coordinate systems and its transformation, Schuler tuning and gimbaled platform systems. Guidance used for ballistic missiles.

**Missile control methods**: Aerodynamic and thrust vector control, Polar and Cartesian control

**Mathematical modeling**: Force and moment equations. Linearization. Transfer function representation of airframe

**Missile servo system:** Hydraulic, Pneumatic and Electromechanical

**Missile instruments**: accelerometer, gyroscopes, altimeter, resolvers

**Autopilot design based on classical approach**: Roll stabilization. Lateral autopilots based on various combinations of rate gyro and accelerometer feedbacks. Three loop autopilot.

**Modern control of missile**: State space representation of missile dynamics. Controllability and Observability. State feedback control, Pole placement techniques, Design of observers. Missile autopilot designs based on state space methods.

**Text/References:**


1. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, New Delhi, 2001.
2. P Zarchan, Tactical and Strategic Missile Guidance, Vol 199 of Progress in Astronautics and Aeronautics, AIAA, Reston, VA, 2002.
3. P. Garnell, Guided Weapon Control Systems, 2nd Ed, Pergamon Press, London, 1980.
4. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, New York, 2004.
5. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
6. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.


**AE 611 UAV Guidance & Control**

**UAV Guidance:** Overview of UAV guidance techniques, General guidance laws for UAVs , Kinematic models for guidance, Path planning, Way-point guidance, Path following for straight line and orbits, Guidance of swam of UAVs, obstacle avoidance guidance. Vision Based Navigation and Target Tracking for Unmanned Aerial Vehicles

**Inertial guidance:** Introduction, inertial sensors, coordinate systems and its transformation, Schuler tuning and related issues. INS systems , GPS-INS Integration, Data fusion.

**Servo systems** : Electromechanical

**UAV Mathematical Modeling:** Equations of Motion for an Unmanned Aerial Vehicle, Coordinate Systems, Small Perturbation Theory, linearization and transfer function representation. Stability Analysis for Unmanned Aerial Vehicles.

**UAV Control:** Classical Controller Design for Unmanned Aerial Vehicles**,** Lateral-directional and longitudinal autopilot design using success loop closure. Modern control of UAVs: State space representation of UAV dynamics. Controllability and Observability. Design of UAV autopilots based on State feedback, Design of observers. Advanced modern techniques for UAV autopilot design.

**Text/References:**


1. Amitava Bose, Somnath Puri, Paritosh Banerjee**,** Modern Inertial Sensors and Systems, Prentice-Hall of India, 2008.
2. Ian Moir, Allan Seabridge, Malcolm Jukes, Military Avionics Systems, Wiley, 2006.
3. Jay Gundlach, Designing Unmanned Aircraft Systems: A comprehensive Approach, AIAA Education Series, AIAA, 2012.
4. Rafael Yanushevsky, Guidance of Unmanned Aerial Vehicles, CRC Press, 2011.
5. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
6. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
7. Randal W. Beard and Timothy W. McLain, Small Unmanned Aircraft Theory & Practice, Princeton University Press, 2012.


**AE 612 Experimental Aerodynamics**

Need and Objectives of Experimental study, Fundamentals of Aerodynamics, Governing equations.

**Wind Tunnels:** Classification of wind tunnels, Subsonic wind tunnel, Transonic wind tunnel, Supersonic wind tunnel, Hypersonic wind tunnel, Special purpose wind tunnels: Icing tunnel, plasma tunnel, shock tubes, atmospheric tunnel, automobile wind tunnel etc., Wind Tunnel Instrumentation & Calibration, Wind tunnel balances.

**Pressure Measurements:** Manometers, Pressure Probes, Pressure transducers, Pressure sensitive paints.

**Velocity measurements:** Pressure-based velocity measurements, Hot-wire anemometers (CTA & CCA), Laser Doppler anemometer (LDA), Particle Image Velocimetry (PIV).

**Temperature Measurements:** Thermocouples, RTD, Temperature sensitive paints, Pyrometers.

**Flow Visualization:** Surface flow visualization, Tufts, Particle tracer methods: Smoke or Die injection method, Smoke wire, Helium or Hydrogen bubble technique, Optical methods: Shadowgraph, Schlieren photography and Interferometry. Measurement of aerodynamic forces and moments.

Specific experimental environments & measurement techniques, flight testing, data acquisition, Data processing, Uncertainty analysis.

**Text/References:**


1. Alan Pope & John J. Harper, Low-speed Wind Tunnel Testing, John Wiley & Sons, 1966.
2. Alan Pope & Kennith L. Goin, High-Speed Wind Tunnel Testing, John Wiley & Sons, 1965.
3. Bernhard H. Goethert, Transonic Wind Tunnel Testing, Pergamon Press, 1961.
4. E. Rathakrishnan, Instrumentation, Measurements and Experiments in Fluids, CRC Press, Taylor & Francis Group, 2009.
5. Doeblin.E.O. Measurement systems Applications and design. 5th ed. McGrawHill, 2003


**AE 613 Computational Aerodynamics**

Governing equations, model equations and classification of PDEs. Euler equations, Navier Stokes equations, Burger’s equation.

Introduction to finite difference, finite element and finite volume methods.

Basics of grid generation. Structured grid, unstructured grid

Analysis of numerical schemes for accuracy, stability, dispersion and dissipation. RK method, schemes with spectral-like resolution, Riemann solver, TVD, and ENO. Implementation of boundary conditions.

Boundary layer, shock-capturing, turbulence, aeroacoustic and aeroelastic computations.

**Text books :**


1. C. Hirsch, *Numerical Computation of Internal and External Flows*, Volumes 1 & 2, Butterworth-Heinemann, Oxford, 2007
2. J. F. Thompson, B. K. Soni, N. P. Weatherill, *Handbook of Grid Generation,* CRC press, Taylor & Francis, 1998
3. E. F. Toro, *Riemann Solvers and Numerical Methods for Fluid Dynamics*, 3rd Ed, Springer, 2009
4. S. B. Pope, *Turbulent Flows*, Cambridge University Press, 2000
5. J. Blazek, *Computational Fluid Dynamics: Principles and Applications*, 2nd Ed, Elsevier, 2006


**AE 614 Structural Dynamics and Aero-elasticity**

**Single, Double and Multi-Degree-of-Freedom Systems:** Review of SDOF systems, Free/forced and damped/undamped vibrations, Determination of modal parameters (natural frequencies, mode shapes, and damping), Orthogonality of modes, Steady state and transient response using modal analysis.

**Continuous systems:** Vibration of strings, bars, and beams (Euler and Timoshenko beam theories); Various boundary conditions; Determination of natural frequencies and modes; Modeling of damping, Rayleigh method, Steady state and transient response using modal analysis, Approximate methods for computing natural frequencies and modes.
**Aeroelasticity:** Static and dynamic aeroelasticity, Discrete models for aeroelastic problems, Steady state aeroelastic phenomenon with specific reference to wing divergence and control system reversal. Flutter analysis and prediction.

**Texts/ References:**


1. D. H. Hodges & G. Alvin Pierce, Introduction to Structural Dynamics and Aeroelasticity, Cambridge University Press, 2002
2. Raymond L. Bisplinghoff, Holt Ashley & Robert L. Halfman, Aeroelasticity, Courier Dover Publications, 1996


**AE 615 Estimation and Tracking for Aerospace Application**

**Prolog:** Historical Review Of Estimation Theory, Application of Estimation Theory in Engineering. Application to Aerospace Problem (Offline and Online Estimation).

• **Review of probability theory and random variables:** Vector and matrices, Probability and random process, Correlation function, Stationary process, Ergodic process, Power spectral density, Uniform distribution, Random distribution, Gauss Markov process, Random noise model.

• **Classical Offline Estimation Theory:** Cramer-Rao lower bound, Minimum variance unbiased estimation, Least squares estimation, Method of Maximum likelihood Estimation (MMLE).

• **Online Estimation Theory:**

a) **Linear dynamical systems with random inputs:** Linear stochastic systems, objectives. Continuous-time linear stochastic systems: state space model and solution of continuous-time state-space representation. Discrete-time linear stochastic systems: state space model and solution of discrete-time state-space representation.

b) **Linear estimation in linear static and dynamic systems:** Linear minimum mean-squared error estimation. Principle of orthogonality. Least squares (LS) recursive estimation. Kalman filter (KF). Derivation. Matrix Riccati equations. Innovations process. Orthogonality issues. Gauss Markov Process

c) **Estimation for kinematic models:** Discretized continuous-time kinematic modes. Direct discrete kinematic models. LS and KF estimation for noiseless kinematic models. Steady state filters (($\alpha$, $\beta$)) tracker for noisy kinematic models .Process and Measurement Noise

d) **Adaptive Nonlinear Estimation and maneuvering targets:** Derivation of Extended Kalman Filter (EKF) Equations, Filter Divergence, Adaptive estimation of process and measurement noise, and its objectives. Different Kinematic Models, Innovations as a linear measurement of unknown input. Estimation of unknown input. Variable State Dimension approach. Comparison of adaptive estimation for Maneuvering Targets. Use of Extended Kalman Filter (EKF) for simultaneous state and parameter estimation.

e) **Introduction to navigation applications:** Complimentary filtering for navigation. Global Position Systems (GPS)-models, GPS positioning and its accuracy. State space model for navigation. Integrated navigation estimation. Centralized/distributed estimation fusion. Extended Kalman filter for navigation.

• **Application of Estimation Theory To Aerospace Problem:** Parameter Estimation of Spring mass damper system, Aerodynamic Parameter Estimation, Sensor bias estimation, Design of Radar and Seeker online Tracker

Solving the assignment problems using MATLAB tool boxes is mandatory. This proposed course is modification of current elective **AE 615 Estimation with Applications to Tracking and Navigation**

**References**

1. Dan Simon: Optimal State Estimation, Willey Inter science, First Edition, (2006).
2. Arthur Gelb: Applied Optimal estimation ,The MIT Press, Sixteenth Reprint Edition, (2001).
3. Yaakov Bar-Shalom, X. Rong Li and Thiagalingam Kirubarajan: Estimation with Applications to Tracking and Navigation: Theory Algorithms and Software, John Wiley and Sons Inc. First Edition, (2001).
4. Frank L Lewis, Lihua Xie and Dan Popa: Optimal and Robust Estimation with an introduction to Stochastic Control Theory, CRC Press, Second Edition, (2008).

**AE 616 Nonlinear and Robust Control**

Introduction to Nonlinear Systems, Stability analysis, Feedback linearization, Input-State and Input-Output Linearization, Robust Feedback Linearization. Sliding Mode Control and Sliding Mode Observers. Uncertainties, variation and unmodelled lags. Robust control based on Uncertainty and Disturbance Estimation. Time Delay Control, Inertial Delay Control. Disturbance Observer. State and Disturbance Observers. Applications in missile and aircraft autopilot design.

**Texts/ References:**

1. J.J.E. Slotine and W. Li, Applied Nonlinear Control, Prentice-Hall, NJ, 1991.
2. P. Garnell: Guided Weapon Control Systems, Pergamon Press, London, 1980.
3. A. Sabanovic, L. Fridman, and S. Spurgeon, Variable Structure Systems: From Principles to Implementation, IEE Control Series No. 66, 2004.

**AE 617 Avionics**

Maps and geodesy; co-ordinate systems and transformations; great circle and rhumb line navigation; dead reckoning; INS-gyroscopes and accelerometers, platform stability and strapped down INS; horizontal and vertical mechanizations in INS; baro-altimeter, air speed indicator, compass and gyro compass; radio navigation - beacons, VOR, DME, LORAN and other nav-aids; primary and secondary surveillance radars; Doppler navigation; GPS principles - space and control segments architecture; DOP and computation of position and velocity; GPS in air, surface and space navigation; considerations in air traffic control. Aids to approach and landing. Head-Up displays: Helmet mounted displays; Headdown displays. Data fusion. Displays Technology. Control and data entry. Radar and communication FMS. Avionics system integration. Data bus. Introduction to safety systems.

**Texts/References:**

1. Albert Helfrick, Principles of Avionics, Avionics Communications, 2009
2. Myron Kayton & Walter R. Fried, Avionics Navigation Systems, John Wiley & Sons, 1997.

**AE 618 Robotic Path Planning and Control**

**Unit I: Time Response**: Transient response and steady state error analysis of first and second order systems. Stability analysis Frequency response, Root locus analysis, Nyquist Criteria, design of compensators - state space method: Introduction to State space representation of dynamical systems. Solution of state equation. Controllability and observability, State feedback control, Pole placement techniques and design of observers.
**Unit II: Trajectory Planning:** Definitions and Planning tasks, Joint Space techniques, Cartesian Space techniques, Joint Solace versus Cartesian Space Trajectory Planning –Obstacle Avoidance, Path Planning, Control of Manipulators: Open and Close Loop Control, The Manipulator Control problem, Linear control Schemes, Characteristics of second order linear systems.
**Unit III:** Linear Second Order-Order SISO Model of a Manipulator Joint, Joint Actuators, Partitioned PD Control Scheme, PID Control Scheme, Computed Torque Control, Force Control of Robotic Manipulators, Description of force control tasks, Force control strategies, Hybrid Position/ Force Control, Impedance Force/ Torque Control.

**Textbooks:**

1. K. Ogata, Modern Control Engineering, 5th Edition, Prentice Hall, 2010.
2. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
3. J.J.E. Slotine and W. Li, Applied Nonlinear Control, Prentice-Hall, NJ, 1991.
4. M. W. Sponge and M. Vidyasagar, Robot Dynamics and Control, John Wiley & Sons, New York, USA, 2004.

**AE 619 Signals and Systems**

Representation of Signal: Continuous and discrete time signals - definition and mathematical representation of basic signals- step, impulse, ramp and exponential signals. Classification of Signals Periodic, aperiodic, even, odd, energy and power signals. Deterministic and random signals, complex exponential and sinusoidal signals, periodicity. Transformations: time scaling, time shifting. Determination of Fourier series representation of continuous time and discrete time periodic signals. Explanation of properties of continuous time and discrete time Fourier series.

• Analysis of continuous time signals and systems: Continuous time Fourier Transform and Laplace Transform: analysis with examples, basic properties-Linearity, Time Sift, frequency shift, time scaling, Parsevals relation and convolution in time and frequency domains. Basic properties of continuous time systems with examples: linearity, causality, time invariance, stability. Magnitude and Phase representation of frequency response of LTI systems. Analysis and characterization of LTI systems using Laplace transform. Computation of impulse response and transfer function using Laplace transform.

• Sampling theorem and Z-transform: Representation of continuous time signals by its samples. Sampling theorem. Reconstruction of a Signal from its samples. Aliasing. Ztransform: definition of Z-transform, region of convergence, examples, Poles and Zeros. Properties of Z-transform with examples.

• Inverse Z-transform: Inverse Z-transform using Contour integration. Residue Theorem. Power Series expansion and Partial fraction expansion. Relationship between z-transform and Fourier transform. Computation of Impulse, response and Transfer function using Z Transform.

• DFT and discrete time systems: Definition, properties and examples, Discrete time LTI systems. Properties: - linearity, causality, time invariance, stability, static and dynamic. Characterization using difference equation. Block diagram representation,examples, Properties of convolution, interconnection of LTI Systems Causality and stability of LTI Systems. Realtime implementation issues and fast Fourier transform (FFT).

• Design of Frequency Domain Filters. Design of low-pass, high-pass, notch filters. Solving the assignment problems using MATLAB tool boxes is mandatory.

**References**


1. Vinay Ingle and John G Proakis: *Digital Signal Processing Using MATLAB* , Congage Learning, Third Edition, (2012).
2. E Oran Brigham: *The Fast Fourier Transform and Its Applications*, Prentice Hall, First Edition, (1988).
3. A V Oppenheim, R W Schafer and John R Buck: *Discrete Time signal Processing*, Prentice Hall, Second Edition, (1999).
4. A V Oppenheim, A S Willsky and S Hamid: *Signals and Systems*, Prentice Hall, Second Edition, (1996).


**AE 620 Optimal Control with Aerospace Applications**

- **Introduction and review of basic concepts**: Introduction, motivation and overview, matrix algebra, review of numerical methods.

• **Static optimization:** Unconstrained optimization, constrained optimization - Lagrange multiplier, equality constraints, inequality constraints, neighboring optimum solutions. Nu- merical solutions. Linear programming problems. Nonlinear programming, Kuhn Tucker condition, Direct optimization by gradient methods. Solutions of static optimization prob- lems for both constrained and unconstrained case.

• **Optimal control of continuous time system by indirect method:** Optimal control through calculus of variation, EulerLagrange necessary condition, Legendre necessary condi- tion, Jacobi necessary condition, Bolza problem, Mayer problem, Lagrange problem, Some sufficiency conditions to the simplest problem, Transversability conditions, Complete opti- mal control formulation using calculus of variation. Fixed terminal time and free terminal time problem, Continuous-time linear quadratic regulator (LQR). Steady-state closed-loop control and suboptimal feedback, Numerical solution of two-point boundary value problem.

**• Optimal control of continuous time system by direct method:** Simple shooting method, Multiple shooting method, Collocation method, Pseudo spectral methods.

• **Comparison of direct and indirect method of solution:** Solution of Brachistochrone problem, Flight Vehicle trajectory optimization using both methods with in flight path constraints and terminal constraints. Advantages and disadvantages of indirect and direct methods.

Solving the assignment problems using MATLAB tool boxes is mandatory.

**References:**


1. R Venkatraman: Applied Optimization with MATLAB Programming , John Willey and Sons, Second Edition, (2004).

2. S S Rao: Engineering Optimization, Theory and Practice ,John Willey and Sons, Fourth Edition, (2009).
3. Kalyanmoy Deb: Optimization for Engineering Design (Algorithms and Examples), Eastern Willey Edition, Second Edition, (2012).
4. John T Betts: Practical Methods for Optimal Control and Estimation Using Nonlinear Programming , SIAM Publishers, Second Edition, (2010).
5. Frank L Lewis, D L Vrabie and V L Syrmos: Optimal Control, John Willey and Sons, Third Edition, (2012).

**AE 621 Advanced Missile Guidance**

**Inertial Navigation Systems:** Kinematics, Angular Velocity and torque equations of gimballed system, errors in INS; Strap Down Inertial Navigation System: Inertial Alignment System, flow diagram and direction cosine computation algorithm of SDINS.

**Global Positioning System:** Introduction, modes of operations, signals and codes, position fixing, Differential GPS and GPS coordinate transformation. Kalman filtering and integration of GPS and INS.

Missile Guidance loop design studies, Guidance loop model, Normalised homing time and normalised miss distance, variants of PN Laws, Optimal guidance Law, performance comparison of different guidance Laws.

**Guided missile design:** Top down approach; Guidance & control systems specifications, specifications on aerodynamics, Roll dynamics & rolling moment gradient limit, Autopilot & it’s hardware. Requirements, Seeker specifications- Range, Antenna & radome slope error specs

RF & IR Seeker based Guidance, Seeker angle tracking and stabilization systems – Isolation & Decoupling; Nominal scheme & Decoupling loop scheme based approach for guidance – Generic performance comparison; LOS reconstruction approach for faster cost effective homing guidance, performance comparisons of different schemes through 3-DOF simulations.

Radome error modelling, Guidance & control system with radome error-static effects and dynamic effects, Deleterious effects of radome error on guidance, Radome error characterization and compensation

**Seeker estimator:** Inside and outside seeker mechanization, performance comparison, eclipsing effects & performance-Multiple PRF seeker

**Text/References**

1. P. Garnell, Guided weapon control systems, 2nd ed, pergamon press, London, 1980
2. G.M. Siouris, Missile Guidance and control systems, springer verlag, New Yor, 2004
3. Merill I. Skolnik, Introduction to Radar system, Tata Mc Hill, New Delhi, 2001

**AE 622 Ducted Rocket & Combustion**

**Ramjet and integral rocket ramjet:** Thrust and thrust coefficients, effective jet velocity, Combustion efficiency, Classification and comparison of IRR propulsion system. Two-phase nozzle flows, Scramjet, Solid fuel ramjets, Advances in Propulsion Technology.

**Experimental techniques for rocket testing:** General layout of solid, liquid, and IRR Thrust stand, auxiliaries, safety measures. Thrust, pressure, flow and temperature measurements. Evaluation of tests.

**Combustion:** Pre-mixed flames - flame speed, inflammability limits, one dimensional flame propagation, Diffusion flames, Detonation and deflagration.

**Texts/ References:**

1. M.J. Zucrow and J.D. Hoffman, Gas dynamics, Vol. I, John Wiley and sons, New York, 1976
2. M.J. Zucrow, Aircraft and Missile Propulsion, Vol  II, John Wiley and Sons, New York, 1958
3. K. Kuo, Principles of Combustion, 2nd Ed, John Wiley   & Sons, 2005
4. I. Glassman, Combustion, Ist Ed, Academic Press, San Diego, California 1997

**AE 623 Experimental Methods in Fluid Mechanics**

Introduction: Review of concepts of Fluid Mechanics, Introduction to experimental methods, Basic concept of dynamic measurements.
Pressure Measurements: Manometers, Barometers, Pressure transducers, Pitot probe, Pitot-static probe, High and low pressure Gauges, Dynamic pressure gauges, Pressure sensitive paints, Sound measurement.
Velocity Measurements: Velocity and Mach number from pressure measurements, Laser Doppler Anemometer (LDA), Hot-Wire Anemometer (HWA), Particle Image Velocimetry (PIV), Particle Tracking Velocimetry (PTV).
Temperature Measurements: Thermometers, Thermocouples, Pyrometers, Planar laser-induced fluorescence (PLIF).
Force and Moment Measurements: Strain gauges, Piezoelectric transducers, Accelerometers, Force/torque sensors, External and Internal wind tunnel balances.
Shear stress measurements: Floating element method, momentum integral method, Preston tube, Fence Technique, Heat Transfer Gauge.
Mass and Volume Flow measurements: Direct and Indirect methods, Rotameters, Drag-Body meters, Ultrasonic flow meters, Vortex-Shedding flow meters, Direct mass flow meters.
Measurements in Turbo machineries; Wind Tunnel Testing; Water Tunnels Testing;
Flow visualization: Wool tufts, dyes, smoke wire, smoke rake, smoke tunnel, shadow graph, Schlieren, particles, bubbles, Fluorescence.
Data Acquisition and Processing; Uncertainty Analysis.

**Texts/ References:**

1. Cameron Tropea, Alexander L. Yarin, John F. Foss (Eds), Hand book of experimental fluid mechanics, Springer 2007.
2. E Rathakrishnan, Instrumentation, Measurements and Experiments in Fluids.
3. Robert A. Granger, Experiments in Fluid Mechanics, Holt, Rinehart and Winston, Inc,1988
4. Raffel, M., Willert, C.E., Scarano, F., Kähler, C., Wereley, S.T., Kompenhans, J., Particle Image Velocimetry, Springer 2018.

**AE 624 Aircraft Assembly, Inspection & Tests**

**Aerospace manufacturing:** A Systems approach and standards, Incoming inspection, documentation, record keeping, identification & traceability, safety in workplace.
**Engineering drawing awareness:** Basic knowledge of Engg. Drawing: Components & assemblies-Electric, Fuel, Lubrication, Hydraulic, Pneumatic systems  and symbols used.
**Materials & resources for assembly:** Different materials & consumables. Jigs and fixtures, Calibration, Jig less assembly, case studies. Manual vrs automated assembly.
**Sub-assembly & Final assembly:** Type of fits, Tolerancing , Basics of  joining--Welding, Brazing, Soldering & Riveting, Modern joining methods. Set making ,Static & Dynamic Balancing ,Transmission

assembly, Bearings , Assembly and failures, Modular constructions, Interchangeability, Selective assembly. Digital/Virtual technologies in assembly, Augmented reality. Pipe lines operations, Clamping/ cleating of pipelines, Electrical cables and conduits, Continuity, insulation, and bonding, Inspection, Functional Tests, Certification, Boroscopy/Fibroscopy, Case studies. Care during maintenance, Statistical Process controls/ Process capability, Control charts & Trouble shooting.
Painting, Coating, Surface treatments and corrosion prevention.

**Text/References:**


1. Aircraft Production Technology And Management ,: Keshu S C and Ganapathi K K , Interline Publisher
2. Aircraft Production Technology , Douglas F. Horne , ISBN: 9780521265539 , July 1986
3. Aircraft Manufacturing and Assembly, Branko Sarh, James Buttrick, Clayton Munk, Richard Bossi , Springer Berlin Heidelberg
4. Aerospace Manufacturing Processes – 26 August 2016 , Pradip K. Saha
5. Airbus A380 Owner's Workshop Manual, 2005 to present ,Robert Wicks,2017


**AE 625 Hypersonic Flow**

**Introduction:** Governing equations and hypersonic relations.

**Inviscid hypersonic flow:** Shock wave and expansion wave relations, local surface inclination methods, modified Newtonian Law, Newtonian theory, tangent wedge or tangent cone and shock expansion methods, Calculation of surface flow properties. Approximate methods for hypersonic inviscid flow field. Exact methods for hypersonic inviscid flow field.

**Viscous hypersonic flow:** Navier–Stokes equations, boundary layer equations for hypersonic flow, hypersonic boundary layer, hypersonic boundary layer theory and non-similar hypersonic boundary layers, hypersonic aerodynamic heating, entropy layers effects on aerodynamic heating. Strong and weak viscous interactions, hypersonic shockwaves and boundary layer interactions Experimental

**Hypersonic test facilities and measurements:** Shock tubes, hypersonic wind tunnels

**Text/References:**


1. John. D. Anderson. Jr, "Hypersonic and High Temperature Gas Dynamics", 2nd edition, AIAA education series, 2006.
2. John J. Bertin, "Hypersonic Aerothermodynamics", AIAA education series, 1994.
3. John. D. Anderson. Jr, "Modern Compressible Flow: With Historical Perspective", 3rd edition, Mcgraw Hill, 2004.
4. John J. Bertin, Russell M. Cummings, Aerodynamics for Engineers, 6 thedition,Prentice Hall, 2013
5. Ernst Heinrich Hirschel, "Basics of Aerothermodynamics", 2nd edition, Springer, 2015
6. R. N. and L. F. Crabtree Cox, "Elements of Hypersonic Aerodynamics" Academic Press, 1965
7. Wallace D. Hayes and Ronald F. Probstein, "Hypersonic Flow Theory", Academic Press Company, 1959
9. Wallace D. Hayes and Ronald F. Probstein, "Hypersonic Inviscid Flow", Dover Publications,2004
10. W. Hankey, "Re-Entry Aerodynamics", AIAA education series, 1988


**AE 626 Compressible Fluid Flow**

**Introduction:** Review concepts of Aerodynamics, Fluid Mechanics and Thermodynamics

**Subsonic compressible flows:** Linearized Velocity Potential Equation, Linearized Pressure Coefficient, Linearized Subsonic Flow, Improved Compressibility Corrections, Critical Mach Number.

**Transonic flows:** Physical and Theoretical aspects of transonic flows, Solutions of the Small-Perturbation Velocity Potential Equation, Solutions of the Full Velocity Potential Equation, Solutions of the Euler Equations.

**Supersonic flows:** Normal Shock, Oblique Shock and Expansion waves, Source of Oblique Waves, Oblique Shock Relations, Supersonic Flow over Wedges and Cones, Shock Polar, Regular Reflection from a Solid Boundary, Intersection of Shocks waves, Mach Reflection, Detached Shock Wave in Front of a Blunt Body, Three-Dimensional Shock Wave, Prandtl-Meyer Expansion Waves, Shock-Expansion Theory, Shock boundary layer interactions.

**Hypersonic Flows:** Hypersonic Shock Wave Relations, A Local Surface Inclination Method: Newtonian Theory, Mach Number Independence, The Hypersonic Small-Disturbance Equations, Hypersonic Similarity Compressible flow test facilities and measurements

**Text/References:**

1. John D. Anderson, Modern Compressible Flow: With Historical Perspective, 3rd Ed, McGraw Hill, New York, 2004.
2. Michel A. Saad, Compressible Fluid Flow, 1992
3. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, American Institute of Aeronautics & Astronautics, New York, 2000.
4. Roelof Vos and Saeed Farokhi, Introductin to transonic aerodynamics: 110 (Fluid Mechanics and Its Applications), Springer, 2015
5. John D. Anderson, Fundamentals of Aerodynamics, $4^{th}$ Edition, McGraw Hill, 2006.
6. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, McGraw Hill, 2006.

**AE 627 Flow Stability and Turbulence**

Introduction, Mechanisms of Instability, Fundamental concepts of stability, Stability of parallel shear flow, Stability of free shear flow. Stability of Boundary Layer flow, Linear & Non Linear stability, Transition. Introduction to turbulence, turbulent transport, dynamics of turbulence, free shear flows, wall-bounded flows, statistical description of turbulence, spectral dynamics, turbulent flow modeling and simulation.

**Texts/ References:**

1. P. G. Drazin & W. H. Reid, Hydrodynamic Stability, 2nd Ed., Cambridge University Press, 2004.
2. Peter J. Schmid & D. S. Henningson, Stability and Transition in Shear Flows, Springer, 2001.
3. Henk Tennekes & John Lumley, A First Course in Turbulence, MIT Press (MA), 1972.
4. Stephen B. Pope, Turbulent flow, Cambridge University Press, 2000.

**AE 628 Missile Aerodynamics**

Introduction to missile airframe, Different missile configurations, bodies of revolution, non circular shapes, lifting surfaces,

Low Aspect Ratio characteristics, wing – body – tail interference, prediction of overall characteristics of body dominated configurations and lifting surface dominated configurations,

High angle of attack aerodynamics, Shock wave – boundary layer interactions; aerodynamic heating, intake aerodynamics.

Engine airframe integration, airframe flexibility effects on aerodynamics, Stage separation dynamics. Configuration design methodology of tactical missiles. Design methodology of multistage vehicles. Wind tunnel testing

**Text/References:**


1. Jack N Nielsen, Missile Aerodynamics, McGraw Hill, 1960
2. Chin S S, Missile Configuration Design, McGraw-Hill, 1961
3. Eugene L. Fleeman, Missile Design and Systems Engineering, AIAA Education Series, 2000
4. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, American Institute of Aeronautics & Astronautics, New York, 2000.
5. John D. Anderson, Modern Compressible Flow: With Historical Perspective, 3rd Ed, McGraw Hill, New York, 2004.
6. John D. Anderson, Fundamentals of Aerodynamics, 4th Edition, McGraw Hill, New York, 2006.
7. E. L. Houghton and P. W. Carpenter, Aerodynamics for Engineering Students, 5thEdition, Butterworth-Heineman, Oxford, 2003.


**AFW 601 Ballistics of Bombs & Projectiles**

Basics of Ballistics of any projectile, Difference between precision, accuracy and CEP. Internal Ballistics (Guns): Burning of propellants, Vielle's mode and rate of burnings, form function, Resalls' Energy Equation. Internal ballistic solutions, effect of vibrations in loading conditions, Similarity relations. External Ballistics (Guns): Aerodynamic force system. Normal equations. Numerical methods of trajectory computation, Meteorological corrections. Angular motion of the Centre of mass. Drift and deflection, Dispersion of fire. External Ballistics of Rockets: Launch dynamics, plane trajectory, boost plane trajectory models, rocket accuracy (dispersion and stability), rocket-assisted projectiles. Bomb Ballistics: Aerodynamic forces and moments acting on a bomb, Drag co-efficient, Terminal velocity and Ballistic index, Trajectory of bombs, Simulated stores (similitude) and their trajectories, Bomb stability derivatives and analysis (in roll, pitch and yaw), wind tunnel testing, Bomb trajectory calculations with point mass and Six Degrees of Freedom Equations. Calculation of Moment of Inertia and Centre of Gravity of bombs.

**Text/References:**


1. Text Book of Ballistic & Gunnery, Vol I & II, HMSO Publication,1987,.
2. Ballistics Theory and Design of Guns & Ammunition, DE Carlucci & SS Jacobson, CRC Press. 2007,
3. Military Ballistics: A Basic Manual (Brassey's New Battlefield Weapons Systems and Technology Series into 21st Century), CL Farrar, DW Leeming, GM Moss, Brassey's (UK) Ltd. 1999,
4. Modern Exterior Ballistics, ,Robert L McCoy, Schiffer Publishing. 2001


**AFW 602 Design of Air Armament - I**

**Aerodynamics Decelerators:** definitions, types, applications of parachute for escape, recovery and armaments systems. Supersonic inflatable decelerators.

**Parachute characteristics:** opening characteristics, aerodynamic drag &wake effect, shock load, snatch force, inflation process, reefing, clustering, pressure distribution, deployment methods, critical speeds, parachute stability, stress analysis, trajectory and motion of deployed parachutes, impact attenuators. Parachute malfunctions.

Parachute materials, porosity of fabric. Parachute & reefing system design, Case study on design of parachute recovery and landing system. Testing of Parachutes

**Design of aircraft bombs & tail units:** Classification, design data, factors affecting bomb design, spatial functioning considerations, bomb design for stability and accuracy requirements. Design and use of cluster bomb.

**Design of HE Bomb**: Bombs case design, analysis of stresses in thin and thick cylinders, various failure theories, stages of manufacturing of forged bomb case

**Design of penetration bomb**: description of concrete, crushing strength, setting & hardening. Behavior of concrete on impact of projectile, factors affecting penetration, effect of reinforcement, mathematical calculation of residual velocity, time of penetration and resistive pressure**.** Analysis of stresses in bomb case during normal impact on concrete. Calculation of penetration & depth resistive pressure in rock & soil.

**Fuses :**Classification, general design considerations, principles of fuse initiation, design, working and safety features of mechanical fuses, safety & arming devices. Introduction to electrical, electronic fuses, proximity and long delay fuses. Latest trends in fuse development

**Guided Bombs:** Classification and types, Design Criteria, Working principle, Type of Lasing equipment (LDP, PLDs, UAV assisted). Range Enhancement techniques.

**Chaffs, flares, EAX and power cartridges**: Basic principles, design aspect and lifting methodology.

**Text/References:**

1. Text Book of Air Armament, Royal Air Force publication.
2. Irwin, Recovery System design Guide, 2006.
3. Air Force Wing Précis on Stores Separation.
4. Knacke TW, Parachute Recovery System Design Manual, 2008.
5. Performance & Design criteria for Deployable Aerodynamic Decelerators (*N*TIS).
6. Air Force Wing Précis on Bomb and Fuse Design.

**AFW 603 Airborne Weapon System Effectiveness**

**Basic tools and methods used in Weaponeering:** Weaponeering process, elementary statistical methods, weapon trajectory, delivery accuracy of guided & unguided armaments, target vulnerability assessment, introductory and advanced methods.

**Weaponeering process of air launched weapons against ground targets:** single weapon directed against point & area target, Stick deliveries, projectiles, cluster munitions, Weaponeering for specific target (bridges, building, tunnels etc), simple collateral damage modeling, and direct & indirect fire system.

**Introduction to Fire Control System**: definitions, classification, applications of modern FCS.

**Text/References:**

1. Feller W, An Introduction to Probability Theory and Its Applications, Vol. I & II, 3rd Edition, John Wiley, 2000.
2. Driels M, Weaponeering, AIAA Education series, 2004.

**AFW 604 Warhead Design & Mechanics**

**Introduction to warhead**: Configuration and classification. Formation of kill mechanisms and target interaction. Omni-directional, directional and directed energy warheads. Explosives used in warheads.

**Blast warheads:** Explosion dynamics. Specifications of blast wave. Propagation of blast wave in air. Evaluation and parametric study of blast. Empirical relations and scaling laws. Peak over pressure, Impulse and Damage Number concept. Damaging aspect and target damage criteria of blast warhead. Thermo Baric weapons.

**Fragmentation Warheads:** Principles, classifications and design considerations. Natural, preformed and controlled fragmentation. Fragment initial velocity and direction of projection calculation. Fragment mass distribution and computation. Aerodynamic effects on fragment motion. Warhead shape design and geometric modeling of fragmentation warhead. Focused mass fragmentation. Kinetic energy rod warheads. Fragment and target interaction mechanics.

**Shaped charge warheads**: Configuration and classifications. Hollow charge, Flat cone charge and projectile charge warheads. Liner collapse and jet formation mechanism. Jet and slug characterization: Birkhoff theory, PER theory. Jet and slug velocity, mass distribution. Jet radius. Jet break up. Target interaction and jet penetration dynamics. Hydrodynamic theory and rod penetration model. Stretching jet penetration theory. Parameters affecting performance of shaped charge warheads. Wave shapers. Mechanisms to defeat shaped charges. Introduction to Warhead Simulation techniques.

**Text/References:**


1. Joseph Carleone, Tactical Missile Warheads, Vol. 155, Progresses in Astronautics and Aeronautics, 1993.
2. Richard M Lloyd, Conventional Warhead Systems Physics and Engineering Design, Vol. 179, Progresses in Astronautics and Aeronautics, 1998.
3. W. P. Walters and J. A. Zukas, Fundamental of Shaped Charges, Wiley- Inter Science Publication,1989.
4. Richard M Lloyd, Physics of Direct Hit and Near Miss Warhead Technology, Vol. 194, Progresses in Astronautics and Aeronautics, 2001.
5. DIAT Air Wing Précis I – 14.


**AFW 605 Air Armament Control & Guidance**

Basic design features, Design Criteria, Classification and types of Air Launched Missiles, Specific design requirements.

**Missile Controls**: Missile control methods: Aerodynamic and thrust vector control, Polar and Cartesian control.

**Mathematical modeling:** Force and moment equations. Linearization, Transfer function representation of airframe.

**Missile servo system:** Hydraulic, Pneumatic and Electromechanical.

**Missile instruments:** Accelerometer, gyroscopes, altimeter, resolvers.

**Autopilots Design:** Autopilot design based on classical approach: Roll and roll rate stabilization. Lateral autopilots based on various combinations of rate gyro and accelerometer feedbacks. Three loop autopilot.

**Introduction to sensors & signal processing**

**Radar Systems**: Fundamentals of Radar, Introduction to Pulse, CW, FM-CW & MTI Radar, Tracking Techniques.

**Guidance System**: Classification of guidance system, phases of guidance, command guidance, MMW seeker head, image infra-red, scene correlation area navigation system and laser based system. Introduction to INS and SDINS.
**GPS:** Introduction, description of satellite coordinates and calculation of user coordinates. Concept of GPS INS integration.
**Missile Kinematics**: Trajectory computation, time of flight, Lateral acceleration demand and turning rate for various courses.

**Text/References:**


1. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, 2001.
2. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, 2004.
3. G.C. Goodwin, S.F. Graebe, and M.E. Salgado, Control System Design, Prentice-Hall, New Delhi, 2002.


**AFW 606 Design of Air Armament – II**
**Aircraft Guns:** Design Criteria, Specific design requirements, Energy requirements in aircraft guns (automatic, blowback, recoil and gas operation), Gatling guns, kinematics diagram. Design of buffers & recuperators, Gun barrels designing and rifling, muzzle breaks & boosters, Current trends in aircraft automatic gun design.
**Aircraft Ammunition:** Classification and types of ammunition, Design Criteria, Specific design requirements, Gun ammunition propellant and their characteristics, optimization of grain size for a given weapon. Cartridge case design, Ignition system design, Stability of projectile, driving band design, stresses in shells. Terminal considerations and design of ac gun ammunition fuses. Modern trends in ammunition design.
**Aircraft Rockets:** Design considerations, proof and testing of aircraft rockets.

**Text/References:**


1. Jacobson SS, Ballistics, CRC Press, 2008.
2. Engineering Design Handbook: Automatic Weapons, AMCP No. 706 – 260, US Army Material Command, Washington, 1990.
3. Brassey’s Essential Guide to Military Small Arms: Design Principles and Operating Methods, D Allsop, L Popelinsky et al, 1997.
4. The Machine Gun: Design Analysis of Automatic Firing Mechanisms and Related Components, GM Chinn, Bureau of Ordnance, Department of Navy, US, 1955.
5. Aerodynamics, Propulsion and Structure, E. A. Bonney, M. J. Zucrow, and C. W. Besserer, D.Van Nostrand, New York,1956.
6. Rapid Fire, 2005, William AG, The Crowood Press, UK.


**AFW 607 Testing and Certification of Air Armament Stores**
Ground Testing: Gun Ammunition, Rockets, Bombs, Fuses, Parachutes, Missiles. Procedure and Instrumentation setup for Testing & Proof of Air Armament stores, Environmental Testing of Air Armament stores, Airworthiness Certification & Failure Investigation Procedure of Air Armament.
**Weapon Accuracy Analysis**: Concept of probability, probability distribution, systematic and random errors, error in fire dispersion, probability of kill SSKP, CKP, CEP, (SE, PE, MAE,CPE, CD, EPE,SPE).

**Carriage & Release:** Design criteria for location of weapon station, Effects of external Carriage and Advanced Carriage concepts, calculation of lug & sway brace reactions for single & twin suspension configuration, Bomb carriers. MIL STD 8591, 7743, 1289.

**Mathematical Concept of Stores Separation & Towed body:** Similarity concept, stores trajectory simulation, modeling of stores separation.

**DDPMAS -2002:** Definition, Process of development, Development Phase, Production Phase, Indigenization, Flight Testing by user services.

**Procurement Policy:** Principals of public buying, preparation and approval of ASQRs, Capital & Revenue procurement of stores.

**Composite Materials and polymers for AA applications**

**Materials:** Materials for Bomb/ Rocket and Missile Structures. Introduction to Nano materials for military application.

**Text/References:**


1. DIAT Air Force Wing Précis and MIL STD 8591, 7743, 1289.
2. Joint services guide on Environmental testing of armament stores and missile JSG-0102-1984 and JSS_0256-01.
3. DDPMAS -2002 and Defence Procurement manual -2008.


**AFW 608 Fire Control Systems**

**Introduction to fire control system**: Definitions, classification, application of modern FCS, brief description of aircraft and helicopter FCS.

**Theoretical aspects of the FCS problems and its solution**

**Functional elements of FCS** : Acquisition and tracking system, fire control computing system, weapon pointing system, command control & communicating element, data transmitting element, integration of functional element into FCS, compatibility problem.

**Design Philosophy**: Development of mathematical model & simulation, Model verification & validation, filtering and prediction, accuracy consideration and analysis, hit & kill probability theory, error analysis in FCS, fire control testing.

Designing for reliability, maintainability, ease of operation and safety

**Text/References:**


1. Department Of Defense Handbook, Fire Control Systems—General, Mil-Hdbk-799(Ar), 1996.
2. BS Dhillon, Design Reliability: Fundamental Applications, CRC Press, 2004.
3. Air Force Wing Précis.

# DEPARTMENT OF MECHANICAL ENGINEERING

**About the Department**: The Mechanical Engineering Department seeks to combine excellence in education and research with service to Defence. The goal of our academic programmes in mechanical engineering is to provide students with a balance of intellectual and practical experiences that enable them to address a variety of Defence needs. The Department is one of the largest departments.

The Department is known for research and projects in fluid dynamics, heat transfer, finite element methods, vibrations, experimental stress analysis, vehicle dynamics and other areas. Experimental and computational facilities are being continuously upgraded. The Department has established, over the years, a close interaction with the DRDO laboratories and industry. It has carried out a large number of consultancy and sponsored research projects, which have been successfully completed. A number of sponsored research projects are ongoing.

The Department has carried out significant curriculum development work in Mechanical Engineering. Apart from the regular courses the department offers, on a continual basis, a wide variety of short-term intensive programmes for personnel from DRDO laboratories, Armed Forces and industrial establishments. User-oriented M. Tech programmes on Armament/Combat Vehicles and Marine Engineering has been formulated as per the needs of the Defence sector. The Programmes offers a wide choice of specializations, electives and research areas. The department has laboratories in Mechanical System Design and Analysis lab, Vibration lab, Fluid & Thermal Engg lab and Manufacturing and Precision Engg lab etc.

**Vision of the Department:**

"The Department endeavours to become Centre of Excellence in Armaments/Combat vehicles, Marine engineering, Mechanical Systems Design and Robotics"

**Mission of the Department:**

To impart advanced training, update knowledge, and develop skillset required for R&D, design, development, production, quality assurance, and inspection of efficient and economical equipment/systems of armament, combat vehicles, marine systems for DRDO and Defence Services, other industries and society in large.

**Program Educational Objectives (PEO's):**

**PEO1**: Provide basic and advanced technical knowledge to the students in the field of Armament and Combat Vehicles, Marine Engineering, Mechanical System Design and Robotics.

**PEO2**: Students should be capable to undertake R&D, inspection, testing and evaluation of equipment/systems of Combat vehicles, Armaments, Marine and Robotic systems and other industries.

**Program Outcomes (POs)**

**PO1**: An ability to independently carry out research /investigation and development work to solve practical problems

**PO2**: An ability to write and present a substantial technical report/document

**PO3**: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

**Program Specific Outcomes (PSOs)**

**PSO1:** The specific outcome of the program is to provide human resources equipped with advanced applied knowledge in the field of armaments & combat vehicle technology, marine engineering and mechanical system design to fulfill the needs of DRDO, Army, Navy and Defence PSU's and other industries thereby making the country self-reliance.

**PSO2**: To be able to apply advanced engineering principles and concepts to design of equipment/systems of armament & combat vehicles, marine and other industries within realistic constraints.

**PSO3:** To be able to design and device new procedures to arrive at a solution for design or troubleshooting problems at the system/component level.

## M. Tech. in Mechanical Engineering [Marine]

**Brief Description:** The aim of the programme is to impart advanced training and to update knowledge in the field of marine systems like gas turbine, engines, tribology, warship transmissions and nuclear engg etc, to engineering officers from Indian Navy, Coast Guard, DRDO scientists, DPSUs and GATE qualified students. At the end of the programme the officer/student should be able to undertake R&D work and evaluation of Marine Engineering Equipment systems.

**Eligibility:** Bachelor's Degree in Mechanical/Marine Engineering of a recognised Institute/University.

**Organization:** M. Tech Mechanical Engineering with specialisation Marine Engineering is a four-semester programme. In the first semester there are six courses. In second semester, there are six courses. In each of these semesters, there will be three tests and a final semester examination of every course. In 3rd and 4th semester dissertation work is to be completed. Half yearly evaluation of the project takes place at the end of the third semester. At the end of the final semester, student submits a thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners.

Visits to various DRDO labs like NSTL, ARDE, GTRE, VRDE, Industry like MDL, GSL involved with Indian navy and naval technical facility are planned to enhance student's appreciation & understanding of the subject and provide them with opportunity to get hands on experience on various test equipment and procedures related to design, manufacturing and testing of Marine Engineering Equipments.

**The details of the courses offered under the programme:**

## M. Tech. in Mechanical Engineering [Marine]

**Semester I**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | ME 602 | Advanced Mechanics of Materials | 3 | 1 | 4 |
| 2 | ME 603 | Fluid Flow and Heat Transfer | 3 | 1 | 4 |
| 3 | ME 641 | Warship Transmission & Tribology | 3 | 1 | 4 |
| 4 | ME 609 | Mechanical Vibrations | 3 | 1 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| 5 | ME 643 | Ship Dynamics & Marine Systems | 3 | 1 | 4 |
| 6 | AM 607 | Mathematics for Engineers | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

**Semester II**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | ME 644 | Marine Diesel & Steam Engines | 3 | 1 | 4 |
| 2 | ME 645 | Marine Gas Turbines | 3 | 1 | 4 |
| 3 | -- | Department Elective-I | 3 | 1 | 4 |
| 4 | -- | Department Elective-II | 3 | 1 | 4 |
| 5 | -- | Elective III | 3 | 1 | 4 |
| 6 | -- | Elective IV | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | **Total** | **20** | **6** | **24** |

**Semester III**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | ME 651 | M.Tech. Dissertation Phase I | 14 | | 14 |
| | | **Total** | **14** | | **14** |

**Semester IV**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | ME 652 | M.Tech. Dissertation Phase II | 14 | | 14 |
| | | **Total** | **14** | | **14** |

*** 1 credit in Theory/Tutorial means one contact hour per week and 1 credit in Practice/Project Thesis means two contact hours per week.**

**List of Department Electives (I & II)**

| Sr. No. | Course Code | Course Title |
|---|---|---|
| 1 | ME 607 | Computational Fluid Dynamics |
| 2 | ME 608 | Finite Elements Methods |
| 3 | ME 627 | Fatigue, Fracture and Failure Analysis |
| 4 | ME 630 | Design of Machinery |
| 5 | ME 631 | Product Design and Development |
| 6 | ME 637 | Design of Pressure Vessels |

| | | |
|---|---|---|
| 7 | ME 646 | Nuclear Reactor Engg. |
| 8 | ME 654 | Convective Heat & Mass Transfer |
| 9 | ME 660 | Heat Exchanger Design |

**List of Electives (III & IV)**

| Sl. No. | Course Code | Course Name |
|---|---|---|
| 1. | ME 604 | Advanced Materials and Processing |
| 2. | ME 608 | Finite Elements Methods |
| 3. | ME 611 | Design for Manufacturability |
| 4. | ME 615 | Trials & Evaluation of Weapon Systems |
| 5. | ME 616 | Thermal Management of Defence Equipment |
| 6. | ME 617 | Kinematics and Dynamics of Machinery |
| 7. | ME 618 | Composite Structures |
| 8. | ME 619 | Tribology for Design |
| 9. | ME 627 | Fatigue, Fracture and Failure Analysis |
| 10. | ME 628 | Design of Hydraulic and Pneumatic Systems |
| 11. | ME 629 | Design of Experiments |
| 12. | ME 630 | Design of Machinery |
| 13. | ME 631 | Product Design and Development |
| 14. | ME 632 | Design Optimization |
| 15. | ME 633 | Mechanical behavior of materials |
| 16. | ME 634 | Experimental Stress Analysis |
| 17. | ME 635 | CAD |
| 18. | ME 636 | MEMS: Design, Fabrication and Characterization |
| 19. | ME 637 | Design of Pressure Vessels |
| 20. | ME 642 | Automatic Control Systems |
| 21. | ME 654 | Convective Heat & Mass Transfer |
| 22. | ME 655 | Performance Testing and Instrumentation |
| 23. | ME 657 | Marine Hydrodynamics |
| 24. | ME 658 | Additive Manufacturing |
| 25. | ME 659 | Rapid Prototyping |
| 26. | ME 660 | Heat Exchanger Design |
| 27. | AM 602 | Mathematical Modeling & System Analysis |
| 28. | AM 603 | Adv Optimization Techniques |
| 29. | AM 604 | Advanced Statistical Techniques |
| 30. | AM 623 | Machine Learning |
| 31. | AM 624 | Advanced Numerical Methods |
| 32. | TM 602 | R&D Management |
| 33. | TM 603 | Project Management |
| 34. | TM 604 | Strategic Management |
| 35. | TM 609 | System Engineering |
| 36. | MS 601 | Introduction to Materials |

| | | |
|---|---|---|
| 37. | MS 607 | Design of Materials |
| 38. | MS 606 | Advanced Physical and Mechanical Metallurgy |
| 39. | MS 612 | Non Destructive Evaluations |
| 40. | MS 611 | Advanced Functional Materials |
| 41. | MS 613 | Advanced Steel Technology |
| 42. | AC 603 | Thermodynamics and Combustion Process |
| 43. | AP 610 | Nanotechnology |
| 44. | CE696A | Artificial Intelligence & DSS |
| 45. | CE699 | Internet of Things |
| 46. | | Open Electives from other departments |

**Notes:**

1. Department has to decide which subjects should be offered as Elective I, II in the Semester II.
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

## M. Tech. in Mechanical Engineering [Mechanical System Design]

**Brief Description:** M. Tech. in Mechanical Engineering (Mechanical System Design) plays a vital role in the field of Mechanical Engineering discipline from the fundamentals to applications in industrial/Defence practices. The importance of this program is vivid from understanding basics, design, development and implementation of mechanical system.

The objective of entire program is to impart knowledge to Engineers/ Scientists pertaining to Mechanical system design from the basics of engineering to final machine or equipment design ready to use in engineering system. This can be achieved by teaching a candidate different range of subjects for enhancing their analytical skills related to Machine design. Other objective of the program is to produce quality design engineers to cater to the needs of the relevant industry. The programme is conducted by well-versed faculty, invited experts from reputed institutions and industries.

**Eligibility:**

Bachelor's Degree in Mechanical/Production/Automobile/Mechatronics/Metallurgy and materials/Mining/Aerospace Engineering of a recognized Institute/University.

This programme is open for civilian GATE qualified candidates, DRDO Scientists/Officers and Officers from Tri-services. This programme is also open to foreign nationals from the countries approved by GOI.

**Organization:** M. Tech Mechanical Engineering with specialisation in Mechanical System Design is a four-semester programme. In the first semester, there are six courses. Second semester consists of six courses. In each of these semesters, there will be three tests and a final semester examination for every course. In third semester, M. Tech. (phase I) dissertation is there and in fourth semester, phase-II dissertation work is to be completed. Half yearly evaluation of the project takes place at the end of the third semester. At the end of the final semester, student submits a thesis and makes a presentation about the M. Tech. project, which is evaluated by the Internal and External examiners.

The details of the courses offered are:

**The details of the courses offered under the programme:**

## M. Tech. in Mechanical Engineering [Mechanical System Design]

### Semester I

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | ME 602 | Advanced Mechanics of Materials | 3 | 1 | 4 |
| 2 | ME 603 | Fluid Flow and Heat Transfer | 3 | 1 | 4 |
| 3 | ME 604 | Advanced Materials and Processing | 3 | 1 | 4 |
| 4 | ME 609 | Mechanical Vibrations | 3 | 1 | 4 |
| 5 | ME 618 | Composite Structures | 3 | 1 | 4 |
| 6 | AM607 | Mathematics for Engineers | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

### Semester II

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | ME 630 | Design of Machinery | 3 | 1 | 4 |
| 2 | ME 631 | Product Design and Development | 3 | 1 | 4 |
| 3 | -- | Department Elective-I | 3 | 1 | 4 |
| 4 | -- | Department Elective-II | 3 | 1 | 4 |
| 5 | -- | Elective-III | 3 | 1 | 4 |
| 6 | -- | Elective-IV | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | **Total** | **20** | **6** | **24** |

### Semester III

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | ME 651 | M.Tech. Dissertation Phase I | 14 | | 14 |
| | | **Total** | **14** | | **14** |

### Semester IV

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | ME 652 | M.Tech. Dissertation Phase II | 14 | | 14 |
| | | **Total** | **14** | | **14** |

*** 1 credit in Theory/Tutorial means one contact hour per week and 1 credit in Practice/Project Thesis means two contact hours per week.**

**List of Department Electives (I & II)**

| Sr. No. | Course Code | Course Title |
|---|---|---|
| 1 | ME 608 | Finite Elements Methods |
| 2 | ME 619 | Tribology for Design |
| 3 | ME 627 | Fatigue, Fracture and Failure Analysis |
| 4 | ME 629 | Design of Experiments |

**List of Electives (III & IV)**

| Sr. No. | Course Code | Course Title |
|---|---|---|
| 1 | ME 607 | Computational Fluid Dynamics |
| 2 | ME 608 | Finite Elements Methods |
| 3 | ME 611 | Design for Manufacturability |
| 4 | ME 617 | Kinematics and Dynamics of Machinery |
| 5 | ME 619 | Tribology for Design |
| 6 | ME 627 | Fatigue, Fracture and Failure Analysis |
| 7 | ME 628 | Design of Hydraulic and Pneumatic Systems |
| 8 | ME 629 | Design of Experiments |
| 9 | ME 632 | Design Optimization |
| 10 | ME 633 | Mechanical behavior of materials |
| 11 | ME 634 | Experimental Stress Analysis |
| 12 | ME 635 | CAD |
| 13 | ME 636 | MEMS: Design, Fabrication and Characterization |
| 14 | ME 637 | Design of Pressure Vessels |
| 15 | ME 654 | Convective Heat & Mass Transfer |
| 16 | ME 658 | Additive Manufacturing |
| 17 | ME 659 | Rapid Prototyping |
| 18 | ME 660 | Heat Exchanger Design |
| 19 | ME 662 | CAM |
| | | Open Electives from other departments |

**Notes:**

1. Department has to decide which subjects should be offered as Elective I, II in the Semester II.
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

## M. Tech. in Mechanical Engineering [Armament and Combat Vehicles]

**Brief Description:** DRDO has been involved in the design and development of efficient and economical Combat Engineering & Armament Systems for Indian Armed Forces. The programme is designed to provide students with the principles of Combat Vehicle Technology and Armament Engineering. The programme pays special attention to:

- The study of advances in combat vehicle technology and armament engineering.
- Developing skills in the analysis and evaluation of new concepts against changes and developments in the threat.
- The user requirements needed to meet the threat and its implications.

**Eligibility:**

The eligibility for the postgraduate programme will be Bachelor's degree in **Mechanical/ Production/ Automobile/ Materials/ Metallurgy/ Mechatronics** Engineering disciplines from recognized university.

This programme is open for civilian GATE qualified candidates, DRDO Scientists/Officers and Officers from Tri-services. This programme is also open to foreign nationals from the countries approved by GOI.

**Organization:** M. Tech Mechanical Engineering with specialisation in Armament and Combact Vehicles is a four-semester programme. In the first semester there are six courses, in second semester, there are six courses. In each of these semesters, there will be three tests and a final semester examination for every course. In third semester M. Tech. (phase I) dissertation is there and in fourth semester, only dissertation work is to be completed. Half yearly evaluation of the project takes place at the end of the third semester. At the end of the final semester, student submits a thesis and makes a presentation about the M. Tech. project, which is evaluated by the Internal and External examiners.

**The details of the courses offered under the programme:**

## M. Tech. in Mechanical Engineering [Armament and Combat Vehicles]

**Semester I**

| Sl. No. | Course Code | Course | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | ME 601 | Armament & Combat vehicles-I | 3 | 1 | 4 |
| 2 | ME 602 | Advanced Mechanics of Materials | 3 | 1 | 4 |
| 3 | ME 609 | Mechanical Vibrations | 3 | 1 | 4 |
| 4 | ME 604 | Advanced Materials and Processing | 3 | 1 | 4 |
| 5 | ME 605 | Introduction to Combat Systems | 3 | 1 | 4 |
| 6 | AM 607 | Mathematics for Engineers | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

**Semester II**

| Sl. No. | Course Code | Course | Credits L | Credits T/P | Total Credits (*) |
|---|---|---|---|---|---|
| 1 | ME 610 | Armament & Combat Vehicles-II | 3 | 1 | 4 |
| 2 | ME 613 | Armour Protection Systems | 3 | 1 | 4 |
| 3 | -- | Department Elective-I | 3 | 1 | 4 |
| 4 | -- | Department Elective-II | 3 | 1 | 4 |
| 5 | -- | Elective-III | 3 | 1 | 4 |
| 6 | -- | Elective-IV | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | **Total** | **20** | **6** | **24** |

**Semester III**

| Sl. No. | Course Code | Course | Credits L | Credits T/P | Total Credits (*) |
|---|---|---|---|---|---|
| 1 | ME 651 | M.Tech. Dissertation Phase I | 14 | | 14 |
| | | **Total** | **14** | | **14** |

**Semester IV**

| Sl. No. | Course Code | Course | Credits L | Credits T/P | Total Credits (*) |
|---|---|---|---|---|---|
| 1 | ME 652 | M.Tech. Dissertation Phase II | 28** | | 14 |
| | | **Total** | **28** | | **14** |

*** 1 credit in Theory/Tutorial means one contact hour per week and 1 credit in Practice/Project Thesis means two contact hours per week.**

**List of Department Electives (I & II)**

| Sr. No. | Course Code | Course Title |
|---|---|---|
| 1 | ME 660 | Heat Exchanger Design |
| 2 | ME 661 | Computational Fluid-Structure Interaction and its Applications |
| 3 | ME 616 | Thermal Management of Defence Equipment |
| 4 | ME 625 | Combat Vehicle Technology |

**List of Electives (III & IV)**

| S. No. | Course Code | Course Name |
|---|---|---|
| | | **Elective I and II** |
| 1. | ME 607 | Computational Fluid Dynamics (CFD) |

| | | |
|---|---|---|
| 2. | ME 608 | Finite Element Methods (FEM) |
| 3. | ME 611 | Design for Manufacturability |
| 4. | ME 612 | Modeling and Simulation of Military vehicles |
| 5. | ME 654 | Convective Heat and Mass Transfer |
| 6. | ME 614 | Unmanned Ground Vehicles |
| 7. | ME 615 | Trials & Evaluation of Weapon Systems |
| 8. | ME 616 | Thermal Management of Defence Equipment |
| 9. | ME 617 | Kinematics and Dynamics of Machinery |
| 10. | ME 618 | Composite Structures |
| 11. | ME 619 | Tribology for Design |
| 12. | ME 620 | High Energy Material Technology |
| 13. | ME 621 | Dynamics & Armament Mechanisms |
| 14. | ME 622 | Ballistics of bombs and projectiles |
| 15. | ME 623 | Design of ordnance, basic structure and super structure |
| 16. | ME 624 | Small arms and cannons |
| 17. | ME 625 | Combat Vehicle Technology |
| 18. | ME 626 | Vehicle Dynamics |
| 19. | ME 627 | Fatigue, Fracture and Failure Analysis |
| 20. | ME 628 | Design of Hydraulic and Pneumatic Systems |
| 21. | ME 629 | Design of Experiments |
| 22. | ME 630 | Design of Machinery |
| 23. | ME 642 | Automatic Control System |
| 24. | | Open Electives from other departments |

**Notes:**

1. Department has to decide which subjects should be offered as Elective I, II in the Semester II.
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

**Course Name-** ***Armament and Combat Vehicles- I***
**Course Code-** ***ME 601***
**Course Outcome:**
**CO1:** Understand the basics of Vehicle Classification, Systems of Automotive Vehicles, Stability, Modularity, Transportability, Critical dimensions, Terramechanics, Power packs, Transmission, Steering and gear system, human response to vibrations of combat vehicles.
**CO2:** Understand the off road and amphibious vehicle design, Chassis design, different type of power packs, transmission system, quarter car and half car models. Evaluate Terramechanics behavior, relative performance of power packs, Hydrokinetic and Hydro static Drives. Apply constitutive equations for Terramechanics analysis and calculations of critical dimensions and evaluate engineering constants and analyze combat vehicle behavior at macro level.
**CO3:** Analyze the different components and their functions in connection with combat vehicle design and apply the understanding to the design of future systems

**CO4:** Understand and evaluate the requirement of different components as per futuristic combat vehicle design and proposing solution to the existing problems persisting in current inventory of combat vehicles.

**Unit I: Introduction to Automotive systems:** Vehicle Classification – On-Road (multi axle, trailer), Off Road (wheeled, tracked), Amphibious; Systems of Automotive Vehicles - Chassis / Body of vehicle; Power plant, Transmission; Additional design considerations: Vehicle stability, Modularity, Transportability to area of operation (by road, rail or by air), logistics for operation.

**Unit II: Combat Vehicle design and Performance:** Critical dimensions – NGP, MMP, Steerability ratio, Pitch ratio, Angle of approach, Angle of Departure, No. of Axles, No. of road wheels, Buoyancy for Amphibious vehicles; Terramechanics - soil strength, bearing capacity, Tractive effort, rolling resistance, draw bar pull and slip.

**Unit III: Power packs for Combat Vehicles:** Power plants - Reciprocating engines, Military Specials, Component technology advances, Space consideration (packaging subsystems), supercharging turbo charging; Cooling and air filtration systems; Engine management systems; Gas turbines (Rotary Engine) - Types for Combat vehicle use, Air handling, Fuel management system; Wankel Engines - Sealing and Lubrication systems; Non-conventional power plants - Types of electric traction motors, onboard power generation, storage and distribution system; Introduction to Fuel cells.

**Unit IV: Transmission and Steering:** Tractive requirement for wheeled and Tracked vehicles; Design of Clutches, Hydrokinetic and Hydro static Drives; Multi Axle all-wheel drive steering system for wheeled vehicles, Double differential steering for tracked vehicles, Skid steering for both wheeled and tracked vehicles; Electric / Hybrid transmission system; Brake system for combat vehicles.

**Unit V: Running gear:** Suspension system requirement - Quarter car and Half car analysis for displacement and force transmissibility; Ride - pitch and bounce behavior and optimization using damping; Types - Coil Spring, Torsion bar, Hydro Gas, Active, semi-active; Terrain characteristics. Human response to vibration, Suspension system requirements, Ride and handling of vehicles, Passive suspension system, hydro-gas suspension. Pitch and bounce behavior, Suspension system transmissibility, Suspension system optimization, Introduction to semi-active and active suspension.

**Text Books/References:**

1. Tank Technology (Vol I & II) by RM Ogorkiewicz – Jane's information Group, 1991 –
ISBN: 0710605951, 9780710605955.
2. TANKS: Main Battle and Light tanks (Brassey's Modern Military Equipment) , ISBN-13: 978-1857531688
3. Armoured Fighting Vehicles: Brassey's Modern Military Equipment, ISBN-13: 978-1857532036
**4. Military Ballistics (Brassey's New Battlefield Weapons Systems & Technology Series into the 21st Century), ISBN-13: 978-18575308841**5. Theory of Ground Vehicles by J.Y.Wong – John Wiley & Sons, INC., 3rd Edition, ISBN: 0-471-35461-9

**Course Name-** ***Advanced Mechanics of Materials***
**Course Code-** ***ME 602***
**Course Outcome:**
**CO1:** Understand the fundamental concepts of stress and strain and the relationship between both through the strain-stress equations in order to solve problems for simple tri-dimensional elastic solids.
**CO2:** Determine Stress/strain invariants, principal strains and their directions.Analyze theories of failure to design components for safe operation.
**CO3:** Solve problems relating to non-uniform beams and thin-walled open section. Analyze the stresses in rotating discs, thick cylinder and bars subjected to torsion.
**CO4:** Develop constitutive relationships between stress and strain for linearly elastic solid and apply the concepts of energy methods in solving structural problems.

**Unit I: Theory of Elasticity-**Introduction, Stress. Differential equations of equilibrium, strain, compatibility conditions, plane problems of elasticity, stress strain relations, stress functions and applications in 2D problems. Pressurized cylinders & rotating disks, Governing equations, Stresses in thick walled cylinder under internal and external pressures. Introduction to experimental stress analysis.
**Unit II: Energy Methods-**Work done by forces and strain energy, reciprocal relations, Castigliano's theorems, Fictitious load method, statically indeterminate structures, theorem of virtual work, generalization of Castigliano's theorem.
**Unit III: Asymmetrical Bending of beams-**Bending of prismatic bars and unsymmetrical bending. Concept of shear centre in symmetric and un-symmetric bending, Plate bending, bending of curved beams.
**Unit IV: Torsion of non-circular sections-**Introduction, torsion of general prismatic solid section like circular, elliptical, rectangular, triangular shafts, membrane analogy, torsion of thin walled tubes, torsion of thin walled multiple cell closed sections.

**Text Books/References:**

1. Theory of Elasticity, 1970, Timoshenko SN & GoodierJN, McGraw Hill.
2. Advanced Mechanics of Materials, 2$^{nd}$ Ed., 1998 Cook RD & Yound WC, Prentice Hall.
3. Advanced Mechanics of Materials, 5$^{th}$ Ed., 1995 Boresi AP, Sidebottom OM, John Wiley.
4. Experimental Stress Analysis, 3$^{rd}$ Ed., 2005, Dally JW & Riley WF, College House Enterprises.


**Course Name-** ***Fluid Flow & Heat Transfer***
**Course Code-** ***ME 603***
**Course Outcome:**
**CO1:** Understand and review of basics of fluid mechanics.
**CO2:** Understand the basic governing equations of fluid flow and heat transfer, Application of dimensional analysis in fluid flow and heat transfer problems.
**CO3:** Application of governing equations in various process, Problem solving skills of fluid flow and heat transfer.
**CO4:** Understand the turbulent models for CFD, knowledge of compressible flow and heat transfer, Application of governing equations of fluid flow and heat transfer.

**Unit I:** Review of concepts in kinematics of Fluid Motion, Vorticity, Circulation, Velocity potential and Stream function. Reynolds transport theorem, Governing equations in integral form, Momentum Theorem, Applications in Propulsion, Energy equations, Applications.

**Unit II:** Potential flows, Applications, Integration of Euler's equations of motion. Governing Equations of fluid flow in differential form, Navier-Stokes Equations and exact solutions, Energy Equation and solution of fluid flow with thermal effects.

**Unit III:** Dimensional Analysis. Prandtl's Boundary Layer equations, Laminar Boundary Layer over a Flat Plate, Blausius solution. Turbulent flows in two-dimensional channels and pipes, Velocity field, Smooth and Rough pipes, Drag reduction in pipes, Turbulent Boundary Layer over a Flat Plate, logarithmic Law of wall, Effect of Pressure gradient, Boundary Layer control.

**Unit IV:** Speed of sound and Mach number, Basic equations for one dimensional flows, Isentropic relations, Normal-shock wave, Rankine-Hugoniot relations, Fanno and Rayleigh curve, Mach waves, Oblique shock wave, Prandtl-Meyer expansion waves, Quasi-one dimensional flows, Compressible viscous flows, Compressible boundary layers.

**Unit V:** Introduction to Heat Transfer.

**Practice:**

- Steady State Determination of heat transfer temperature difference and surface heat transfer coefficient for a single tube in a transversely flowing air stream.
- Determination of the Relationship between Nusselt and Reynolds Number for the forward stagnation point on a cylinder in cross flow using the Direct Heat Transfer Cylinder.
- Determination of the heat transfer rate and the exchanger effectiveness.
- Measure the distribution of Total pressure and Static Pressure along the duct and to compare these with the predictions of Bernoulli's equation
- Measure the Temperature of Furnace by using the thermal Image Camera.

**Text books:**

1. "Introduction to Fluid Mechanics**"** by R.W. Fox and A.T. McDonald, McGraw Hill
2. "Fluid Mechanics" by Kundu & Cohen, Elsevier Publications
3. Heat Transfer by J P Holman and Souvik Bhattacharyya ($10^{th}$ Edition, McGraw Hill Education)

**References:**

1. Viscous Fluid Flow, 2005, F. M. White, McGraw-Hill.
2. Boundary Layer Theory, $8^{th}$ ed, 2000, Herrmann Schlichting, Springer

**Course Name-** ***Advanced Materials and Processing***

**Course Code-** ***ME 604***

**Course Outcome:**

**CO1:** Understand the advanced materials and its manufacturing processes for engineering applications and analyze Piezoelectric materials (PZT).

**CO2:** Analyze the Shape memory alloys (SMA), Electro rheological (ER) and magneto-rheological (MR) materials.

**CO3:** Understand the Composite materials and Micro-electro-mechanical (MEMS) systems.

**CO4:** Understand the Powder metallurgy and Advanced Material processing techniques.

**Unit I:** Introduction of advanced materials and its manufacturing processes for engineering applications. Piezoelectric materials (PZT)- Piezoelectric effect, Di-electric hysterisis, piezoelectric constants, piezoelectric charge constants, dynamic behaviour of PZT transducers, piezoelectric materials and manufacturing techniques (stability, poling and depolarisation).

**Unit II: Shape memory alloys (SMA)-** Shape memory effect and the metallurgical phenomenon of SMA, Temperature assisted shape memory effect, Visco-elastic behaviour, magnetic shape memory effect. Various shape memory alloys. Manufacturing technology of SMAs.

**Unit III: Electro rheological (ER) and magneto-rheological (MR) materials-** Characteristics of ER and EM fluids. ER and EM materials.

**Unit IV: Composite materials-** Design and manufacturing of polymer matrix, metal matrix and ceramic matrix composites. Various forms and type of reinforcements, fillers and additives. Design of composites for structural, wear resistance and high temperature applications.

**Unit V: Micro-electro-mechanical (MEMS) systems-** Introduction, characteristics of silicon wafers and other materials for MEMS applications. Various manufacturing techniques of MEMS components Materials for high temperature applications - Ni-Cr alloys, ODS materials, Ni base and Co based super alloys, carbon-carbon composites.

**Unit VI:Powder metallurgy-** Introduction and feature of powder metallurgy processes. Advanced solidification techniques: directional solidification, single crystal growth and levitation melting.

**Unit VII: Advanced Material processing techniques-** Thermal spraying, Ion beam machining, Laser and Electron beam processing, Friction Stir Welding, Special alloys machining, Superplastic forming, Flow forming, Explosive forming, Thin films and their deposition, Diamond coating techniques-tribological applications, Diffusion bond coating of high temperature materials.

**Text Books/References:**


1. Gandhi, M.V. and Thompson, B.S., Smart materials and Structures, Chapman and Hall, 1992.
2. Otsuka, K. and Wayman, C. M., Shape memory materials, C.U.P, 1998
3. Taylor, W., Pizoelectricity, George Gorden and Breach Sc. Pub., 1985
4. Mallick, P.K., Fiber Reinforced Composites Materials, Manufacturing and Design Marcel Dekker Inc, New York, 1993.
5. William D Callister: Materials Science and Engineering: An Introduction, 6th Edition, Wiley Publication.
6. S. Kalpakjian and S. Schmid: Manufacturing Engineering and Technology, 4$^{th}$ Edition, Pearson Education.
7. M. P. Grover: Fundamentals of Modern Manufacturing: Materials, Processes & Systems , Prentice Hall.


Course Name- **Introduction to Combat Systems**

Course Code- **ME 605**

**Course Outcome:**

**CO1:** Understand the basics of threat spectrum depending upon types of conflicts, types of conventional threats, close combat and peace keeping missions.

**CO2:** Understand battle field environment in reference to firepower mobility and protection, Command-Control-Communication-Computer-Intelligence (C4I) - Network Centric Warfare - Battlefield Management System. Evaluate battle field environment and apply constitutive equations for firepower and protection analysis and calculations related to C4I and analyze the combat vehicle behavior at macro level.

**CO3:** Analyze different types of combat vehicle configurations and their role in connection with the battlefield requirements, man machine interface and apply the understanding to the design of future combat systems.

**CO4:** Understand and evaluate the requirement of maintainability of a combat system and Combat Vehicle Evaluation Techniques with different types of trials required for futuristic combat vehicle design and finding solution to the existing problems in current inventory of combat vehicles.

Unit I: Threat Spectrum - Types of Conflicts - Low level, Medium level, Heavy conflicts - Combat Vehicle during World Wars I & II - Post world wars Combat Vehicles. Conventional threats - Tank threat, Mine threat, Missile threat; Non-conventional threats - Ariel threat - Aircrafts, Helicopters, Drones - Precision munitions delivered from various platforms - Nuclear threat - Conflicts in builtup areas - Close combat - peace keeping missions.

Unit II: Battle Field Environment - Firepower - Non lethal, low calibre, Heavy calibre (tank / Arty), Cannon launched Missiles; Mobility - Tactical, Strategic, Battle field Mobility - weight, transportability, logistics; Protection - Small arms, Splinters, KE attack, CE Attack, Passive and Active, camouflage and stealth; Command-Control-Communication-Computer-Intelligence (C4I) - Network Centric Warfare - Battlefield Management System - Situational awareness through sensors.

Unit III: Vehicle Configuration - On Road and Off Road vehicles; Soft skinned - logistics, strategic transport (special railway wagons and multi-axle road trailers), Medium Armoured (both wheeled and Tracked) - Infantry Combat Vehicles (ICV), Missile / Mortar Carrier Vehicle, Artillery Vehicles, Armoured Repair and Recovery Vehicle (ARRV), Bridge Layer, Main Battle Tank (MBT).

Unit IV: Man Machine Interface - Human System Integration - Ergonomics - Environmental Control System - Packaging of systems.

Unit V: Maintainability - Design for maintenance - Maintenance Repair and Overhaul (MRO) - Modularity in design - Adaptability to different missions, Line Replaceable Units.

Unit VI: Combat Vehicle Evaluation Techniques - Automotive trials - Specialized test track for automotive trials; Weapon Trials - Special equipment for proving weapon, proving Ammunition and Proving Combat system as a whole; Different types of Trials - Development trials, User trials, Usage trials, Deployment trials.

**Text Books/References:**

1. Fighting vehicle, TW Terry, Brassey’s, 1991
2. The Greenhill Armoured Fighting Vehicles Data Book - Ian Hogg – Greenhill books - ISBN: 1853673919, 978-1853673917
3. The Encyclopedias of Tanks and Armored Fighting Vehicles – Chris Foss, Will Fowler – Thunder Bay Press (CA) – ISBN: 1571458069, 978-1571458063
4. Tanks inside Out – Michael E. Haskew – ISBN: 1607101106, 978-1607101109 Modern Tanks & Armoured Fighting Vehicles by Simon Dunstan – The Crowood Press, 2005 ISBN:1840371900, 9781840371901.

**Course Name- *Computational Fluid Dynamics (CFD)***

**Course Code-** ***ME 607***
**Course Outcome:**
**CO1:** Understand and review of basics of fluid mechanics, turbulence models etc
**CO2:** Understand the basic governing equations of fluid flow and heat transfer.
**CO3:** Understand Finite Difference, Finite element and Finite Volume methods.
**CO4:** Understand Grid generation, errors and uncertainties, Practical's on CFD software (FLUENT) for better understanding

**Unit I:** Basic of Computational Fluid Dynamics. Governing Equations of fluid mechanics and heat transfer: Continuity, momentum and energy equations, physical boundary conditions, basic aspects of Discretization.
**Unit II:** Finite Difference, Finite element and Finite Volume formulation of steady/transient one-dimensional conduction equation, Finite Volume formulation of steady one-dimensional convection and diffusion problems: CDS, Upwinding scheme, hybrid scheme, unsteady problems: explicit scheme and Implicit scheme.
**Unit III:** Solution algorithms for pressure-velocity coupling in steady and unsteady flows. Discretization equations for two-dimensional convection and diffusion. Unsteady heat conduction.
**Unit IV:** Numerical methods for the Navier-Stokes equation. Turbulence, Turbulence models: mixing length model, one equation model, Two equation (k-epsilon) models, LES, DNS.
**Unit V:** Grid generation, errors and uncertainties, Practical's on CFD software (FLUENT).

**Practice in Ansys Workbench:**
1. Turbulent Flow in a 2D elbow. (use water)
2. Laminar Flow in a 2D Pipe. (use water)
3. Flow over an Airfoil. (use air)
4. Laminar flow over a flat plate.
5. Flow through a pipe bend
6. Flow in multichannel

**Text books:**

1. An introduction to Computational Fluid Dynamics, 2$^{nd}$ edition, 2007, HK Versteeg & W Malalasekera, Pearson Education.
2. Computational Fluid Dynamics & Heat Transfer, 1984, Anderson, Dale A, John C Tanehill and Richard H Pletcher, McGraw Hill.


**References:**

1. Introduction to Computational Fluid Dynamics, 2005, Anil W Date, Cambridge University Press, NY, USA.
2. Numerical Heat Transfer and Fluid Flow, 1980, Patankar SV, Hemisphere, New York.


**Course Name-** ***Finite Element Methods***
**Course Code-** ***ME 608***
**Course Outcome:**
**CO1:** Understand the Prerequisites to Finite Element Methods, analyze the 1-D structural problems related to FEM and Introduction to Finite Elements in Engineering.

**CO2:** Analyze the 1-D structural problems including Analysis of Trusses and beams. Develop the understanding of 2D stress analysis using CST.
**CO3:** Analyze the Scalar field problems including 1-D and 2-D heat conduction problems. Analyze the 3-D problems using Tetrahedron element - Jacobian matrix - Stiffness matrix.
**CO4:** Understand the FEM through Case Studies including Modeling & Simulation of structural and non-structural problems using ANSYS, ABAQUS manuals.

**Unit I: Prerequisites to FEM-**Application of FEM, Strain- displacement relations, Stress-strain relations, Differential equations of equilibrium, Co-ordinates, basic element shapes, interpolation function, Minimum potential energy. Properties of stiffness matrix, treatment of boundary conditions, solution of system of equations, shape functions and characteristics.
**Unit II: 1-D structural problems-*Analysis of axial bar element*** - stiffness matrix, load vector, temperature effects, Quadratic shape function. ***Analysis of Trusses-*** Plane Truss elements, Transformation matrix, stiffness matrix, load vector Analysis of Beams - Hermite shape functions – beam stiffness matrix - Load vector - Problems
**Unit III: 2-D stress analysis using CST-**Plane stress, Plane strain, Force terms, Stiffness matrix and load vector, boundary conditions. Axisymmetric body subjected to axisymmetric loading-Numerical problems, Isoparametric element - quadrilateral element, linear shape functions.
**Unit IV: Scalar field problems-**1-D Heat conduction through composite walls, fins of uniform cross section, 2-D heat conduction problems, Torsional problems.
**Unit V: Dynamic Considerations-**Dynamic equations - consistent mass matrix – Eigen values, Eigen vector, natural frequencies - mode shapes - modal analysis.**3-D problems-**Tetrahedron element - Jacobian matrix - Stiffness matrix, CAD softwares and its applications, Brief description to analysis of Plates & Shells.
**Practice:**
(i) Stress Analysis of Plate with Cut-outs using ANSYS/ABAQUS Software
(ii) Modal Analysis Of Cantilever Beam using ANSYS/ABAQUS Software
(iii) Case Studies etc.

**Text Books/References:**

1. Introduction to Finite Elements in Engineering, Tirupathi R.Chandrupatla and Ashok D. Belagundu, Pearson Education (Singapore) Pte Ltd, 2006.
2. An Introduction to Finite Element Methods, J.N. Reddy, Tata Mc Graw Hill, 2008.
3. A First Course in the Finite Element Method by Daryl L. Logan.
4. Concepts and Applications of Finite Element Analysis, Robert Cook, Wiley India, Pvt., Ltd., 4$^{th}$ Edition-2007.
5. An Introduction to Finite Element Methods, J.N. Reddy, Tata Mc Graw Hill, 2008.
6. Finite Element Procedures, K.J. Bathe, PHI Learning, 2009.
7. The Finite Element Methods in Engineering / SS Rao / Pergamon.


**Course Name-** ***Mechanical Vibrations***
**Course Code-** ***ME 609***
**Course Outcome:**

**CO1:** Understand the basics of single degree of freedom (DOF) systems such as free and forced vibrations of damped and undamped systems, Simple harmonic excitation, steady state response, torsional vibrations.
**CO2:** Understand vibration of systems with 2-DOF such as free and forced vibration of spring-mass-damper systems, torsional vibrations, modal analysis of undamped and damped systems.
**CO3:** Analyze the vibration of multi-DOF and continuous systems including free and forced vibration of beams, flexibility and stiffness influence coefficients with understanding of numerical methods.
**CO4:** Understand the experimental methods in vibration analysis with case studies including vehicle dynamics, fluid-structure interaction problems, vibration of suspension bridges.

**Unit I: Single Degree of Freedom Systems-** Free and forced vibrations of damped and undamped systems; Simple harmonic excitation; steady state response; torsional vibrations.
**Unit II: Vibration of Systems with Two Degrees of Freedom-** Free and forced vibration of spring-mass-damper systems; torsional vibrations; modal analysis of undamped and damped systems; numerical methods: Matrix iteration, Holzer's method, Dunkerley's lower and Rayleigh's upper bound approximations; Dynamic vibration absorbers
**Unit III: Vibration of Multi-degree of Freedom and Continuous Systems:** Vibrating string; Longitudinal and torsional vibration of rods; Free and forced vibration of beams; Properties of vibrating systems: Flexibility and stiffness influence coefficients; Reciprocity theorem; Eigenvalue analysis; Orthogonality of eigenvectors; Modal matrix
**Unit IV: Experimental methods in vibration analysis:** Vibration instruments: exciters, transducers, analysers, measurement devices: vibrometers, velocity meters and accelerometers; Signal analysis techniques: time domain analysis, frequency domain analysis, amplitude and power spectra, coherence, auto and cross correlations, amplitude and frequency modulations; Tests for free and forced vibrations
**Unit V: Case studies (A) -**Vehicle dynamics: introduction to nonlinear and random vibrations, vehicle subjected to random vibrations (for example an uneven road); Fluid-structure interaction problems: vibration of suspension bridges. **Case studies (B) -** Introduction to nonlinear and random vibrations, structures subjected to random vibrations, Noise control and acoustics.
**Practice:**
1. Undamped free vibration test of Single degree of freedom on Vibration Fundamental Trainer (VFT)
2. Frequency response function of spring mass damper system for various damping mediums: air, water, and oil.
3. Beam lateral experiment.

**Text Books:**

1. Introductory Course on Theory and Practice of Mechanical Vibrations, J.S.Rao, K.Gupta, Revised second edition, New Age International Publishers
2. Theory of Vibration with Applications, William T. Thomson, Marie Dillon Dahleh, Pearson Low Price Edition.
3. Mechanical Vibrations, J.B.K. Das & P.L.S.Murthy, Sapna book house.

**Reference Books:**

1. Principles and Techniques of Vibrations, Leonard Meirovich, Prentice Hall Inc.
2. Engineering Vibration, DJ Inman, Prentice Hall International Inc.
3. Mechanical Vibration and Shock Measurements, J.T.Broch, Bruel and Kjae Publication.

4. Applications of Random Vibrations, N. C. Nigam, S. Narayanan, Narosa Publishers.

**Course Name-** ***Armament and Combat Vehicles II***
**Course Code-** ***ME 610***
**Course Outcome:**
**CO1:** Understand the basics of Armament Systems and ballistics, learn fundamentals of Weapon System and its classification, Principles and Factors affecting Design of Weapon, Weapon mount, Projectile and Turret, Ammunition & Missile Feed Systems, Extraction and Ejection Systems. Learn fundamentals of Gun and Rocket; Internal, Intermediate, External and Terminal ballistics and actors affecting performance of the weapon.
**CO2:** Understand about Gun and Rocket; Internal, Intermediate, External and Terminal ballistics and factors affecting performance of the weapon. Learn and understand about Warhead Mechanisms, Ammunition and Design aspects of various types of fuzes. Apply constitutive equations for Internal, Intermediate, External and Terminal ballistics and evaluate engineering constants and analyze combat vehicle behavior at macro level.
**CO3:** Analyze the different components and their functions in connection with Weapon Sighting and Fire control system. Understand and analyze types of Sighting Systems and their roles along with fire control systems. Emerging trends and feature of sighting and fire control system.
**CO4:** Understand the requirement of different components as per futuristic combat vehicle design and proposing solution to the existing problems persisting in current inventory of combat vehicles.

**Unit I:Armament Systems:** Weapon System classification, Characteristics and Operating, Principles (Large caliber & Small caliber, Rockets, Missiles & Directed Energy Weapons (DEW)); Introduction to Turret and Weapon System (TWS), Principles and Factors affecting Design of Weapon, Weapon mount, Projectile and Turret; Automatic Fire - Blowback, Recoil System, Gas Operation systems and externally driven; Subsystems - Ammunition & Missile Feed Systems, Trigger and Firing Systems, Extraction and Ejection Systems, Locking, Mechanical Safety and Muzzle Attachments.
**Unit II: Introduction to ballistics: Gun and Rocket**; Internal, Intermediate, External and Terminal ballistics; Factors affecting performance of the weapon.
**Unit III: Warhead Mechanisms**: Configuration and classification of Warhead; Kill mechanisms – Kinetic Energy (long rod, fragmentation), Chemical Energy (Blast, Shaped Charge– HEAT, HESH, Explosive dynamics.); Explosives used in warheads.
**Unit IV: Ammunition:** Charge systems BL and QF. Primers and explosive trains; Design aspects of various types of fuzes.
**Unit V: Introduction to Weapon Sighting system**
Types of Sighting Systems and their roles, Building Blocks, Night Vision Systems, Infrared Imaging, Elements of thermal imaging systems, Day vision systems-Charged Coupled Devices (CCD) and CMOS Vision Systems, Elements of Day Vision Camera, Laser systems-Laser range finders, Laser Guidance & Designator, safety issues, Line of Sight Stabilization, Interfaces Types of Displays, Emerging trends and feature of sighting System.
**Unit VI: Introduction to Fire Control System**
Different Configurations of Fire Control systems, Building Blocks of IFCS, Features and salient Specifications, Gunner’s Main Sight (GMS)-Elements of GMS, Configurations of GMS, Automatic target

tracker, Commander's Sight- Salient Features and configuration, Panorama generation and Auto queuing, Ballistic computation, Gun Control system and its types.

**Text Books/References:**


1. "Handbook of Infantry Weapons", Part – 1, RMCS, UK, 1987
2. D Allsop, L Popelinsky et al, "Brassy's Essential Guide to Military Small Arms: Design Principles and Operating Methods", Brassy's, UK, 1997
3. "Engineering Design Handbook: Automatic Weapons", AMC Pamphlet No. 706 – 260,
4. US Army Material Command, Washington, 1970
5. Military Ballistics: A Basic Manual (Brassy's New Battlefield Weapon System and Technology Series) 1999, CL Farrar, DW Leeming, GM Moss, Brassey's (UK) Ltd.
6. Surveillance and Target Acquisition Systems: Brassey's Land Warfare, 1997, MA Richardson, IC Luckraft and RF Powell, London:Brassey's, ISBN 978-1857531374
7. Richard M Lloyd, "Conventional Warhead Systems Physics and Engineering Design", Vol. 179, Progresses in Astronautics and Aeronautics, 1998
8. Guided Weapons: Including Light, Unguided Anti-Tank Weapons, 3rd edition, 1998, RG Lee, TK Garland Collins, CA Sparkes and E Archer, London: Brassey's, ISBN 978-1857531527
9. Richard M Lloyd, "Conventional Warhead Systems Physics and Engineering Design", Vol. 179, Progresses in Astronautics and Aeronautics, 1998
10. MYH Bangash, "Impact and Explosion Dynamics Analysis and Design", Blackwell Scientific Publications, 1993.


**Course Name-** ***Design for Manufacturability***
**Course Code-** ***ME 611***
**Course Outcome:**
**CO1:** Understand the Design for manufacture overview, GD&T, Processing techniques and limitations.
**CO2:** Understand the Design for Manufacturing (DFM) and Fundamental principles of DFM.
**CO3:** Understand the Design for Assembly (DFA) and Concurrent engineering approach.
**CO4:** Analyze the Design Evaluation Tools/Softwares.

**Unit I: Manufacturing Considerations in Design-** Design for manufacture, Tolerencing and tolerance analysis. Processing techniques and limitations for metals, polymers and ceramics. Influence of materials in processing and tooling on the design of components. Finishing, surface coatings and surface modifications of materials.
**Unit II: Engineering Design-** Design of cast, forged, sheet metal parts and welded constructions. Design for assembly and dismantling, modular constructions. Erection, operation, inspection and maintenance considerations, Ergonomics.
**Unit III: Machining considerations-** Design for accuracy, locating pins and registers, machining in assembly, adjustment. Backlash and clearance adjustment. Examples illustrating the various principles. Available design variants for some of the common basic functional requirements.

**Text Books/References:**


1. Ashby, M. F. "Materials Selection in Mechanical Design", Pergaman Press, 1992.
2. Bralla J., "Handbook of Product Design for Manufacture", McGraw Hill, 1988.
3. Levy S., and Dubois, L. H, "Plastics Production Design Engineering Handbook, Methuen Inc., 1985.

4. Dieter G E, Engineering Desing, McGraw-Hill, 1991.
5. Yotaro Hatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.
6. Ertas Atilia and Jones J C, The Engineering Design Process, John Wiley & Sons, 1996.
7. Waldron B M and Kenneth J W, Mechanical Design: Theory and Methodology, Spriinger, 1996.

**Course Name-** ***Modeling and Simulation of Military Vehicles***
**Course Code-** ***ME 612***

**1. Introduction to Multi Body Dynamics.**
**2. Vehicle dynamics evaluation using commercial software**
(i) LMS Virtual Lab (or)
(ii) ADAMS, ADAMS (ATV) (or)
(iii) Recurdyn
2(a). Modelling of Track
- Super Element Track Modelling
- Discrete track modelling

2(b). Modelling of tyre
2(c). Modelling of Terrain
- 3D Surface modelling
- Representation of soft terrains

2(d) Steering and motion controls
2(e) Co-simulation techniques
2(f) Modelling of contact elements
- Contact between track and terrain
- Contact between track and other turning gear elements
- Contact between tyre and terrain

**3. Introduction to Modal Analysis**
- Virtual Experimental Modal Analysis (VEMA) using.

**4. Structural analysis of hull and chassis**
- Flexi body MBD modelling

**5. Prediction of vehicle performance characteristics using vehicle dynamics model –**
- Ride evaluation
- Low speed, high speed handling
- Obstacle crossing
- Mobility evaluation

**6. Introduction to CFD softwares.**
- CFD analysis of hull/body for hydrodynamic performance of vehicles engaged in swimming, planning, steering and other manoeuvres.

**7. Armour / Ballistics**
- Introduction to softwares such as LS Dyna, Radios
- Prediction for survivability of blast load or incoming projectile; penetration, or elastic and plastic deformation.

**8. Experimental testing of vehicle and systems for validation of simulation models.**

**Text Books/References:**

1. Multibody Dynamics: Computational Methods & Applicatios, 2007, J.C.G.Orden, J.M.Goicolea & J.Cuadrado, Springer, ISBN 978-1402056833
2. Study of Vehicles Handling & Riding Characteristics by ADAMS Software, 2012, Wael-Al-Tabey, LAP Lambert Academics Publishing, ISBN 978-3848439423
3. Tyre and Vehicle Dynamics, 2$^{nd}$ edition, 2005, Hans B Pacejka, Butterworth Hienemann, ISBN 978-0750669184
4. Modal Analysis, Zhi-Fang Fu and Jimin He, 2001, Butterworth Hienemann, ISBN 978-0750650793
5. Motor Vehicle Structure: Concepts and Fundamentals, 2002, JC Brown, AJ Robertson and ST Serpento, SAE International, ISBN 978-076800909
6. Introduction to Hydrocodes, 2004, Jonas Zukas, Elsevier Science, ISBN 978-0080443485
7. LS-DYNA for Begineers, 2012, LAP Lambert Academics Publishing, ISBN 978-3846556771

Course Name- ***Armour Protection Systems***
Course Code- ***ME 613***
**Course Outcome:**
**CO1:** Understand the basics of different type of threats and structural design required for protection against these threats.
**CO2:** Understand different type of Armours, soft kill and hard kill techniques. Evaluate different Armour Testing methods, NATO targets and Ballistic testing of Armour.
**CO3:** Analyze different case studies related to Reactive protection, electric armour etc. Active protection system layout and integration to platform, Intercepting mechanism and apply the understanding to the design of future systems.
**CO4:** Understand and evaluate the requirement of different Detection signature management techniques for acoustic, thermal, EM emissions etc. and proposing solution to the existing problems persisting currently.

**Unit-I: Type of Threats:** Threats to Armoured vehicles and systems. Frontal, top, side and bottom attacks. Armoured distribution on a typist MBT, ICV, body Armour.
**Unit II: Structural Design and Protection:** Structural requirements of armoured and nonarmoured vehicles; Armour Failure modes against Kinetic Energy (KE); Chemical Energy (CE).
**Unit-III: Types of Armour:** Small Armour and Splinters; Passive Armour - Rolled Homogenous Armour Steels, Aluminium Armour, Ceramic / Composite armour, Laminated / Spaced Armour, Explosive Reactive Armour; Active Armour - Soft Kill techniques amd Hard Kill techniques.
**Unit-IV: Armour Testing:** NATO targets. Ballistic testing of Armour.
**Unit-V: Case Studies:** Reactive protection, explosive reactive Armour (ERA), Inert Reactive Armour (IRA), Electric Armour. Methods to detect ERA case studies. Active protection system, Layout and integration to platform, Sensors and control mechanism, Intercepting mechanism and case studies.
**Unit-VI: Detection signature management:** Signature Management for acoustic, Thermal, usual and EM emissions. Deceptions and decoys, Early warning systems, Camouflages and concealments.

**Text Books/References:**

1. Fighting vehicle, 1$^{st}$ edition, 1991, TW Terry, Jackson SR, Ryley CES and Wormell PJH, London: Brassey's
2. Jane's Armor and Artillery 2011-12, Christopher F Foss, IHS Janes, ISBN 0978-0710629609

3. Advances in Ceramic Armor II: Ceramic Engineering and Science Proceedings, 1st edition, 2006, Andrew Wereszczak, Edgar Lara Curzio and Lisa Prokurat Franks, Wiley, ISBN 0978-0470080573
4. Dynamic Behaviour of Materials, 1st edition, Marc Andrew Meyers, Wiley-Interscience, ISBN 0978-0471582625
5. Ballistic Impacts on Polymer Matrix Composites-Composite Armor: Personal Armor, 2011, R Zaera, Springer:Vienna, ISBN 0978-3709105221

**Course Name- *Unmanned Ground vehicles***
**Course Code- *ME 614***
Introduction to UGV, Classification of UGV, History /World Scan, Major Technologies Sub system of UGV, Mobile UGV Kinematics, Locomotion, Drive by wire technology, Planning & Navigation, Obstacle detection & warning system, Power supply system, Perception System, Payloads, Vehicle Platforms, Automatic Transmission, Controllers Tele operation, Sensors & Actuators, Allied Technology, Applications.

**Text Books/References:**
1. Autonomous Mobile Robots by Roland Siegwart, Illah R. Nour bakhsh, Davide Scaramuzza (Printice Hall )
2. Autonomous robots: From biological inspiration to implementation and control, By Bekey, G.A.
3. Intelligent unmanned ground vehicles- autonomous navigation research at carnegie mellon,By Hebert, M.H. Thorpe, C Stentz, A.
4. Robot technology fundamentals, by Keramas, J.G.
5. Principles of robot motion Theory algorithms and implementations by Choset, H. Lynch, K.M. Hutchinson, S. Kantor, G. Burgard, W. Kavraki, L.E. Thrun, S.

**Course Name- *Trials & Evaluation of Weapon Systems***
**Course Code- *ME 615***
**Unit I:** Weapon system requirements. Weapon performance characterization, firing environment and ambient conditions. Factors affecting accuracy and consistency. Statistical methods. Mean and standard deviation, Error estimation due to normal distribution, Probable Errors, test of hypothesis, Design of experiment. Acceptance testing.
**Unit II:** Static test procedures, Shock and vibration tests, Accelarated environmental tests. Closed vessel test. Conditioning chambers. Test methods for evaluation of safety. Static trials of warheads.
**Unit III:** Dynamic trials. Range and its layout, Safety distances and surface danger zones. Measurement. Instruments: Pressure, MV, Trajectory, Atmosphere data, High speed videography and motion picture analysis. Inbore pressure measurement. Telemetry and Data Acquisition. Post trial Analysis. Range and Accuracy Trial. Functioning Trial. Recovery trial and inspection.

**Text Books/References:**
1. Fighting vehicle, 1st edition, 1991, TW Terry, Jackson SR, Ryley CES and Wormell PJH, London: Brassey’s
2. Surveillance and Target Acquisition Systems: Brassey’s Land Warfare, 1997, MA Richardson, IC Luckraft and RF Powell, London:Brassey’s, ISBN 978-1857531374
3. Statistical Methods, 2nd edition, 2003, Rudolph Freund and WJ Wilson, Academic Press Inc, ISBN 978-0122676512

4. Guided Weapons: Including Light, Unguided Anti-Tank Weapons, 3rd edition, 1998, RG Lee, TK Garland Collins, CA Sparkes and E Archer, London:Brassey's, ISBN 978-1857531527
5. Dynamic Systems: Modelling and Analysis, 1996, Ramin Esfandairi and Hung V Vu, Mc Graw Hill, ISBN 978-0072966619
6. Sensors: Advancements in Modelling, Design Issus, Fabrication and Practical Applications, 2008, Yueh-Min Ray Huang, Springer, ISBN 978-3540690306

**Course Name-** ***Thermal Management of Defence Equipment***
**Course Code-** ***ME 616***
**Course Outcome:**
**CO1:** Understanding of Heat transfer fundamentals and heat generating electronic equipment
**CO2:** Understanding of methods used for thermal management of electronic equipment
**CO3:** Understanding of the basics aspects of compactness, scaling laws of heat exchanger, various types of heat exchanger. Apply thermal design concepts to Industrial compact heat exchangers using LMTD Method

| Syllabus Details | Outcome |
|---|---|
| Unit I & II | CO1 |
| Unit III | CO2 |
| Unit IV | CO3 |

**Unit I: Heat-transfer fundamentals**: conduction, convection, radiation, phase change, and heat transfer across solid interfaces.
**Unit II: Heat-generating electronic equipment:** ICs, power converters, circuit cards and electrical connectors.
**Unit III: Thermal management equipment**: heat sinks, interface materials, heat spreaders including liquid loops, and air movers. System design: system packaging architectures, facilities, system analysis. Advanced Topics: spray cooling, refrigeration
**Unit IV:** Introduction, Basic aspect of compactness, Scaling laws of heat exchangers, surface optimization, Industrial compact heat exchangers: Plate Fin heat exchangers, Tube Fin heat exchangers, Printed Circuit heat exchangers, Plate and Frame heat exchangers, Spiral heat exchangers, Plate and Shell heat exchangers. Surface comparisons, Size, shape and weight relationships, Surface types and correlations, Thermal Design-LMTD method.

**Text Books/References:**
1. Compact Heat Exchangers- Selection, Design and Operation, John E. Hesselgreaves, Gulf Professional Publishing, 2001.
2. Compact Heat Exchangers: Allan D. Kraus, R. K. Shah Hemisphere Pub. Corporation, 1990.
3. Heat Transfer -Thermal Management of Electronic Systems, Y Shabany, CRC Press.

**Course Name-** ***Kinematics and Dynamics of Machinery***
**Course Code-** ***ME 617***

**Unit I: Machine kinematics-** Overview, Degrees of freedom, Links and joints, Grashof condition, 4-bar linkage, slider-crank, and inverted slider crank.

**UNIT II: Dynamics of rigid bodies in plane motion, Dynamic force analysis of machines:** Introduction to dynamics of machines, Equations of motion for a planar body, Equations for a mechanism Joint reactions, Different types of forces, Inverse dynamics- Determination of actuating forces, Forward dynamics – determination of accelerations given the actuating forces

**UNIT III: Dynamics of rotating bodies:** Unbalance in rotating machinery; Causes and effects of unbalance; Response of a simple rotor; Types of unbalance viz., static and dynamic; Balancing technique for achieving static balance; Balancing of rigid rotors; Two-plane method for balancing.

**UNIT IV: Dynamics of Reciprocating Machines:** Approximate acceleration analysis of an IC Engine mechanism, Equivalent Link model of a connecting rod, Estimation of Inertia forces in a crank-slider mechanism; Typical arrangements of multiple cylinders State of balance of typical multi-cylinder engines; The driving torque generated in an IC Engine due to gas forces; Issues in Matching of driving and load torques; Use of flywheels to smoothen the fluctuations in speed within a cycle.

**Unit V: Programmable mechanisms-** Introduction to industrial manipulators, Kinematic chains and classifications, Coordinate transformation, Forward and inverse kinematics

**Text Books/References:**

1. R. L. Norton, Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines, McGraw-Hill, current edition.

**Course Name-** ***Composite Structures***
**Course Code-** ***ME 618***
**Course Outcome:**
**CO1:** Understand the basics of composite materials such as classification, characteristics, current and potential advantages and mechanical behavior of composites.
**CO2:** Understand the micro-mechanical behavior of lamina. Evaluate Elastic Moduli of lamina. Apply constitutive equations of composite materials and evaluate engineering constants and analyze mechanical behavior at macro level.
**CO3:** Analyze the macro-mechanical behavior of laminates and apply to the design of composite structures
**CO4:** Understand the fabrication methods, testing and characterization of composites

**Unit I: Introduction composite materials-**Classification and characteristics, mechanical behavior of composite materials, basic terminology, and manufacture of laminated fiber-reinforced composite materials, current and potential advantages of fiber –reinforced composite materials, applications of composite materials.
**Unit II: Macro-mechanical behavior of lamina-**Introduction, stress-strain relations for anisotropic materials, stiffnesses, compliances, and engineering constants for orthotropic materials, restrictions on engineering constants, stress train relation for plane stress in an orthotropic material, stress-train relations

for lamina of arbitrary orientation, invariant properties of an orthotropic lamina, strengths of an orthographic lamina, biaxial strength criteria for an orthotropic lamina.

**Unit III: Micro-mechanical behavior of lamina-**Introduction, mechanics of materials approach to stiffness, elasticity approach to stiffness, comparison of approaches to stiffness, mechanics of materials approach to strength.

**Unit IV: Macro-mechanical behavior of laminates-**Introduction, Classical Lamination Theory, Special Cases Of Laminate Stiffness, Theoretical Versus Measured Stiffness, Strength Of Laminates, Inter-Laminar Stress.

**Unit V: Introduction to design of composites structures-**Introduction to structural design, material selection, configuration selection, laminate joints design requirements and design failure criteria, optimization concepts, design analysis philosophy for composite structures.

**Unit VI: Fabrication methods of composites structures-**Introduction to Various Fabrication Methods, VARTM And RFI Methods, Process Parameters In VARTM Method, Permeability Measurements, VARTM Process Model, Process Parameters of RFI Method Film Casting And Characteristics, Concepts Of VARTM and RFI Process Optimization.

**Unit VII: Testing and characterisation of composites-**Lamina strength characterization, tensile testing, compression testing, in-plane shear testing, short beam test, double cantilever beam test. Physical properties characteristion void content evaluation, fibre Volume Fraction Evaluation, DMA, DSC FOR Tg, Wet Properties of Lamina, NDE Methods, Ultrasonic A-scan and CT-Scan Methods For Chracteristion Of Composites.

**Text books:**

Mechanics of composite materials, by Robert. M. Jones, second sedition, Taylor and Francis,1999.

**1.** Experimental characterization of advanced composites materials, third edition, Donald f Adams, Lief A. Carlsson and R. Byron pipes. CRC press.

**Reference books:**

1. Mechanics of fibrous composites by carl. T. Herakovich-john wiley and sons, 1997.55
2. Advanced composite materials, Lalit Gupta, Himalayan books. New delhi, 1998
3. Liquid moulding technologies, c d Rudd, a c long, k n Kendall and c g e Mangin, woodhead publishing limited, Cambridge England.
4. Process modeling in composites manufacturing, Suresh g advani, e. Murat sozer, Marcel Dekker, inc.

**Course Name-** ***Tribology for Design***

**Course Code-** ***ME 619***

**Course Outcome:**

**CO1:** Understand the basics of Tribology, Lubrication and its modes and additives, Bearings and its terminologies, Friction laws, classifications, theories and measurement.

**CO2:** Understand the Mechanics of Fluid Flow - Theory of hydrodynamic lubrication -Mechanism of pressure development in oil film, Two Dimensional Reynolds's Equation and its Limitations, Idealized Bearings, Infinitely Long Plane Fixed Sliders, Infinitely Long Plane Pivoted Sliders, Infinitely Long Journal Bearings, Infinitely Short Journal Bearings, Designing Journal Bearing- Sommerfeld number – Raimondi and Boyd method - Petroff's Solution - Parameters of bearing design - Unit pressure - Temperature rise - Length to diameter ratio - Radial clearance - Minimum oil-film thickness. Evaluate the load carrying capacity of the above-mentioned bearings.

**CO3:** Understanding the basic of Hydrostatic and Squeeze Film Lubrication, Load carrying capacity and flow requirements, and its applications, Elasto-Hydrodynamic Lubrication principle and applications
**CO4:** Understand Friction and Wear-Friction - Laws of friction - Friction classification - Causes of Friction, Theories of Dry Friction, Friction Measurement, Stick-Slip Motion and Friction Instabilities, Wear - Wear classification - Wear between solids – Wear between solid and liquid - Analyse the effects of various Factors affecting wear – Measurement of wear, Theories of Wear, Approaches to Friction Control and Wear Prevention

**Unit I: Introduction-**Defining Tribology, Tribology in Design - Mechanical design of oil seals and gasket
- Tribological design of oil seals and gasket, Tribology in Industry (Maintenance), Defining Lubrication, Basic Modes of Lubrication, Properties of Lubricants, Lubricant Additives, Defining Bearing, Terminology - Sliding contact bearings -Rolling contact bearings, Comparison between Sliding and Rolling Contact Bearings
**Unit II: Friction and Wear-**Friction - Laws of friction - Friction classification - Causes of Friction, Theories of Dry Friction, Friction Measurement, Stick-Slip Motion and Friction Instabilities, Wear - Wear classification - Wear between solids – Wear between solid and liquid - Factors affecting wear – Measurement of wear, Theories of Wear, Approaches to Friction Control and Wear Prevention
**Unit III: Lubrication of Bearings-**Mechanics of Fluid Flow - Theory of hydrodynamic lubrication - Mechanism of pressure development in oil film, Two Dimensional Reynolds's Equation and its Limitations, Idealized Bearings, Infinitely Long Plane Fixed Sliders, Infinitely Long Plane Pivoted Sliders, Infinitely Long Journal Bearings, Infinitely Short Journal Bearings, Designing Journal Bearing-Sommerfeld number – Raimondi and Boyd method - Petroff's Solution - Parameters of bearing design - Unit pressure - Temperature rise - Length to diameter ratio - Radial clearance - Minimum oil-film thickness.
**Unit IV: Hydrodynamic Thrust Bearing-**Introduction - Flat plate thrust bearing - Tilting pad thrust bearing, Pressure Equation - Flat plate thrust bearing - Tilting pad thrust bearing, Load - Flat plate thrust bearing - Tilting pad thrust bearing, Center of Pressure - Flat plate thrust bearing - Tilting pad thrust bearing, Friction - Flat plate thrust bearing - Tilting pad thrust bearing
**Unit V: Hydrostatic and Squeeze Film Lubrication-**Hydrostatic Lubrication - Basic concept - Advantages and limitations - Viscous flow through rectangular slot – Load carrying capacity and flow requirement - Energy losses - Optimum design, Squeeze Film Lubrication - Basic concept - Squeeze action between circular and rectangular plates - Squeeze action under variable and alternating loads, Application to journal bearings, Piston Pin Lubrications.
**Unit VI: Elasto-Hydrodynamic Lubrication-**Principles and Applications, Pressure viscosity term in Reynolds's equation, Hertz's Theory, Ertel-Grubin equation, Lubrication of spheres, Gear teeth bearings, Rolling element bearings.
**Unit VII: Gas (Air) Lubricated Bearings-**Introduction, Merits, Demerits and Applications, Tilting pad bearings, Magnetic recording, discs with flying head, Hydrostatic bearings with air lubrication, Hydrodynamic bearings with air lubrication, Thrust bearings with air lubrication.
**Unit VIII: Tribological Aspects of Rolling Motion-**The mechanics of tyre-road interactions, Road grip and rolling resistance, Tribological aspects of wheel on rail contact. Finite Bearings-Hydrostatic bearings, Hydrodynamic bearings, Thrust oil bearings, Porous Bearings, Foil bearings, Heat in bearings.
**Practice:**
1. Surface roughness test,

2. Friction & Wear test on Pin on disc Machine
3. Case studies etc.

**Text Books/References:**

1. A. Harnoy , Bearing Design in Machinery, Marcel Dekker Inc, NewYork, 2003.
2. M.M.Khonsari & E.R.Booser, Applied Tribology, John Willey &Sons,New York, 2001.
3. E.P.Bowden and Tabor.D., Friction and Lubrication, Heinemann Educational Books Ltd., 1974.
4. A.Cameron, Basic Lubrication theory, Longman, U.K.., 1981.
5. M.J.Neale (Editor),Tribology Handbook , Newnes. Butter worth, Heinemann, U.K., 1995.

**Course Name-** ***High Energy Material Technology***
**Course Code-** ***ME 620***

**Unit I: High Energy Materials:** An overview, Current trends and Furture Directions, Characterization of High Energy Materials using Modern Instrumental Techniques.
**Unit II: Solid Rocket Propellants:** Introduction classification and specification of solid rocketpropellants, Ingredients, processing and performance of each class of propellants – Double base prolellants (DBP) – Extruded, Fuel Rich Propellants (FRP), NEPE Propellants, Insulatior-inhibitor-liner, X-ray radiography, Mechanical Characterization, Ignition system,
Ballistic Prediction, Instrumentation for Static firing of Rockets, Future directions in development of solid rocket propellants.
**Unit III: Gun Propellants:** Introduction and Gun propellants developed in India, Classification, ingredients and manufacturing of gun propellants (SBP, DBP, TBP, LOVA), Combustible Cartridge Case for gun ammunition, Closed Vessel evaluation and Performance prediction of gun propellants, Future trends.
**Unit IV: High Explosives:** Introduction and uses, Classification and manufacture of high explosives, Theory of detonation and blast, Plastic Bonded explosives, explosive compositions for Low Intensity Conflict (LIC), Expliosive Reactive Armour, Fuel – Air explosive, Thermobaric explosives compositon, Measurement and instrumentation.
**Unit V: Pyrotechnics:** Introduction, Classification and manufacture, Electo-explosive devices, Pyrotechnics smoke, Pyrotechic delays, Pyrotechnic Flares, Other devices, Instrumentation for performance measurement.
DETINICS, PBX & Insensitive Explosives.

**Course Name-** ***Dynamics & Armament Mechanisms***
**Course Code-** ***ME 621***

**Unit I:** Equation of motions, Frame of reference. Newtonia, Enterian, Langrangian, Hamiltonium formulation for motion dynamics. Euler angles and transformations. Translatory and Rotary motions. Constraint and unconstraint motion.
**Unit II: Mechanisms:** Linear, Rotary, Hydraulic and Pneumatic systems.
System dynamics for first and second order systems and response in time and frequency domain.
**Unit III: Mechanisms of large Calibre Weapons:** Balancing gear, Breech and Firing Mechanisms, Recoil Mechanisms, Laying Mechanisms, Ramming Mechanisms.

**Unit IV: Small Arms Mechanisms:** Introduction, Operating Mechanisms (Blow back, recoil and Gas operated), Feeding Mechanisms, Trigger and Firing Mechanisms, Ejection and Extraction Mechanisms.
**Unit V: Fuze Mechanisms:** Safety and Arming Mechanism, Spring Mass Mechanisms, Rotary Mechanisms, Clock work Mechanisms.
Launcher Platform Leveling, Laying, Sighting, Rocket Pinaka, Control Mechanisms.

**Course Name-** ***Ballistics of Bombs & Projectiles***
**Course Code-** ***ME 622***

**Unit I: Basics** of Ballistics of any projectile, Difference between precision, accuracy and CEP.
**Unit II: Internal Ballistics (Guns)**: Burning of propellants, Vielle's mode and rate of burnings, form function, Resalls' Energy Equation. Internal ballistic solutions, Hunt hind Heydenreigh system. Lodue Method. Effect of vibrations in loading conditions, Similarity relations.
**Unit III: External Ballistics (Guns)**: Aerodynamic force system. Normal equations. Siacci form of solutions, Numerical methods of trajectory computation, Meteorological corrections. Angular motion of the Centre of mass. Drift and deflection, Dispersion of fire.
**Unit IV: External Ballistics of Rockets**: Launch dynamics, plane trajectory, boost plane trajectory models, rocket accuracy (dispersion and stability), rocket-assisted projectiles.
**Unit V: Bomb Ballistics**: Aerodynamic forces and moments acting on a bomb, Drag co-efficient, Terminal velocity and Ballistic index, Trajectory of bombs, Simulated stores (similitude) and their trajectories, Bomb stability derivatives and analysis (in roll, pitch and yaw), wind tunnel testing, Bomb trajectory calculations with point mass and Six Degrees of Freedom Equations. Calculation of Moment of Inertia and Centre of Gravity of bombs.

**Text Books/References:**

1. Text Book of Ballistic & Gunnery, 1987,Vol I & II, HMSO Publication.
2. DE Carlucci & SS Jacobson Ballistics Theory and Design of Guns & Ammunition, 2007, CRC Press.
3. Military Ballistics: A Basic Manual (Brassey's New Battlefield Weapons Systems and Technology Series into 21st Century),1999, CL Farrar, DW Leeming, GM Moss, Brassey's (UK) Ltd.

Robert L McCoy Modern Exterior Ballistics, 2001, , Schiffer Publishing.


**Course Name-** ***Design of Ordnance, Basic and Super Structure***
**Course Code-** ***ME 623***

**Unit I: Gun Barrel and Tube Launcher:** Theory of failure, Gun Barrel Design, Material and Manufacturing by VAR, ESR, etc. Proof of ordnance, Design of Combustion Chambers. Gun tube acoustics.
**Unit II: Breech Mechanism:** Principles of operation and design of Muzzle Brakes, Fume Extractors and Firing Mechanisms
**Unit III: Design of Structural Elements:** Design of gun superstructure and basic structures. Curvilinear and soft recoil systems, articulation and suspension systems.

**Text Books/References:**

1. "Engineering Design Hand Book: Recoil Systems", AMC Pamphlets, Washington, 1978
2. Thomas J. Hayes, "Elements of ordnance", John Wiley, New York, 1952

3. “Engineering Design Hand Book: Recoil; Elevating and Traversing mechanisms; Cradles; Top carriage; Bottom Carriage and Muzzle Devices”, AMC Pamphlets, Washington, 1968.

**Course Name-** ***Small Arms and Cannons***
**Course Code-** ***ME 624***

**Unit I: Introduction**: Classification, Characteristics and Operating Principles. Automatic Fire and Power Source. Principles and Factors affecting the choice and Design of Projectile and Weapon; Heating of Small Arms; Accuracy and Chance of Hit.
**Unit II: Operating Principles:** Analytical and Comparative Study of Blowback, Recoil and Gas Operation systems, and Externally Driven Weapon Systems.
**Unit III: Subsystems:** Feed Systems, Trigger and Firing Systems, Extraction and Ejection Systems, Locking and Mechanical Safety and Muzzle Attachments.
Manufacturing; Inspection; Life Estimation; Modern Trends; Typical Weapon Study: INSAS.

**Text Books/References:**
1. “Handbook of Infantry Weapons”, Part – 1, RMCS, UK, 1987
2. D Allsop, L Popelinsky et al, “Brassy’s Essential Guide to Military Small Arms: Design Principles and Operating Methods”, Brassy’s, UK, 1997
3. “Engineering Design Handbook: Automatic Weapons”, AMC Pamphlet No. 706 – 260, US Army Material Command, Washington, 1970

**Course Name-** ***Combat Vehicle Technology***
**Course Code-** ***ME 625***

**Unit I: AFV Characteristics :** Concept of Tank warfare and design philosophies of AFVs, Development of Tanks, Design parameters of combat vehicles to include configuration, overall dimensions etc.
**Unit II: Firepower** : Characteristics, components, main gun and tank ammunition including ATGMs, secondary armament, Ranging & Sighting systems including NVD, GCE & ALG, Probability of Kill, Errors & Biases, Fire Control system.
**Unit III: Mobility** : Types, performance parameters, obstacle crossing ability, navigation – GPS & GLNS.
**Unit IV: Protection** : Types, Armour Protection, Active protection systems, Protection against NBC and Fire.
Tank communication & IFF, Maintainability, Availability, Reliability and Ergonomics.
**Unit V: Critical Dimensions and Design :** Steerabilty ratio, Track Width, Pitch ratio, NGP , MMP, Angle of approach and Angle of departure, Pitch of tank, No of Road Wheels, Inter-relation between all dimensions and Design requirements.
**Unit VI: Latest Trends, FMBT, FICV, Lt Tank, AFV Variants**

**Text Books/References:**
1. Fighting vehicle, 1st edition, 1991, TW Terry, Jackson SR, Ryley CES and Wormell PJH, London: Brassey’s
2. Ballistics: Theory and Design of Gun and Ammunition,2007, Donald E Carlucci and Sidney S Jacobson, CRC Press, ISBN 978-1420066180

3. Fundamentals of Vehicle Dynamics, Thomas D Gillespie, SAE International, ISBN 978-1560911999
4. Terramechanics and Off-road Vehicle Engineering: Terrain Behaviour, Off-Road Performance and Design, 2nd edition, J.Y.Wong, Butterworth Hienemann
5. Jane's Armor and Artillery 2011-12, Christopher F Foss, IHS Janes, ISBN 0978-0710629609
6. Dynamic Behaviour of Materials, 1st edition, Marc Andrew Meyers, Wiley-Interscience, ISBN 0978-0471582625
7. Projectile Impact: Modelling Techniques and Assessment of Target Material Performance, 2014, S Syngellakis, Wit Pr, ISBN 0978-1845648794
**8.** Protection Levels for Occupants of Logistic and Light Armored Vehicles, NATOSTANAG 4569

**Course Name-** ***Vehicle Dynamics***
**Course Code-** ***ME 626***

**Unit I: Vehicle Ride :** Human response to vibration, ISO standards, Response of idealized suspension systems to stop and sinusoidal disturbance in bounce and to wheel out of balance. Combined pitch and bounce motion, application to multi wheel station vehicles. Random ground input excitation, Use of sinusoidal transmissibility function to predict mean square motion of spring mass. Vehicle performance during cornering, Dynamic Vibration Absorber.
**Unit II: Wheeled Vehicle :** Vehicle transfer function. Kinematic behaviour of vehicles with rigid wheels and with compliant tyres, neutral steer point, static margin, over and under steer. Derivation of generalized equations of motion for a vehicle, stability derivative notation. Solution with two degree of freedom in the steady in yaw. Frequency response in yaw. Extension of two degree of freedom theory to include effects of traction and braking, self aligning torque, dual wheels and bogies. Development of equations of motion to include roll of sprung mass, Effect on steady state and frequency response.
**Unit III: Tracked Vehicle Handling :** Analysis of sprocket torques and speeds, required to skid steer a tracked vehicle. Modification of theory to allow for soil conditions and lateral Weight transfer. Application of theory of steering of articulated and half – track vehicles.
**Unit IV: Terramechanics :** Nature of soil vehicle interaction, Characteristics of soil and bearing capacity, Empirical approaches for prediction of vehicle mobility.

**Text Books/References:**
1. Fundamentals of Vehicle Dynamics, Thomas D Gillespie, SAE International, ISBN 978-1560911999
2. Auotmotive Handbook, 8th edition, Robert Bosch GmbH, Wiley Blackweel, ISBN 978-0837516865
3. A Textbook of Automobile Engineering-II, P.S.Gill, Katson Books, ISBN 978-9350140420
4. Automotive Transmission-Fundamentals, Selection, Design & Application, Giesbert Lechner and Herald Naunheimer, Springer, ISBN 978-3540659037
5. Theory of Ground Vehicles, 4th edition, J.Y.Wong, John Wiley & Sons, ISBN 978-0470170387
6. Shock Absorber Handbook, John.C.Dixion, SAE International, ISBN 978-0768018431
7. Car Suspenion and Handling, 4th edition, Goeffrey Howard, Donald Bastow and John Peter Whitehead, SAE International, ISBN 978-0768008722
8. Terramechanics and Off-road Vehicle Engineering: Terrain Behaviour, Off-Road Performance and Design, 2nd edition, J.Y.Wong, Butterworth Hienemann
9. Heavy-Duty Wheeled Vehicles: Design, Theory & Calculation, Boris Nikolaevich Belousov and Sergey.D.Popov, SAE International, ISBN 978-0768077230

**Course Name-** ***Fatigue, Fracture and Failure Analysis***
**Course Code-** ***ME 627***
**Course Outcome:**
**CO1: Understand** the fatigue failure of structures, physical aspects of fatigue, phase in fatigue life, fatigue fracture surfaces, statistical aspects of fatigue behaviors.
**CO2: Understand** fatigue failure Criteria such as Goodman, Gerber and Soderberg relations and diagram, **Apply** failure criteria and **evaluate** factor of safety to predict the safety of structure under operating loads. **Apply** Miner's theory and other theories and **evaluate** life of structure under different loads for different no of cycles.
**CO3: Understand** fracture mechanics design concept**. Analyze** the fracture mechanics strength of cracked bodies. **Evaluate** stress intensity factors for typical geometries. **Analyze** effect of thickness on fracture toughness.
**CO4: Understand** the fatigue design and testing, safe life and fail-safe design philosophies, application to composite materials and structures. Evaluation of life of structures with damages.

**Unit I: Fatigue of Structures-**S.N. curves - Endurance limits - Effect of mean stress, Goodman, Gerber and Soderberg relations and diagrams - Notches and stress concentrations - Neuber's stress concentration factors - Plastic stress concentration factors - Notched S.N. curves.
**Unit II: Statistical Aspects of Fatigue Behaviour-**Low cycle and high cycle fatigue - Coffin - Manson's relation - Transition life - cyclic strain hardening and softening - Analysis of load histories - Cycle counting techniques -Cumulative damage - Miner's theory - Other theories.
**Unit III: Physical Aspects of Fatigue-**Phase in fatigue life - Crack initiation - Crack growth - Final Fracture - Dislocations - fatigue fracture surfaces.
**Unit IV: Fracture Mechanics-**Strength of cracked bodies - Potential energy and surface energy - Griffith's theory - Irwin - Orwin extension of Griffith's theory to ductile materials - stress analysis of cracked bodies - Effect of thickness on fracture toughness - stress intensity factors for typical geometries.
**Unit V: Fatigue Design and Testing-**Safe life and Fail-safe design philosophies - Importance of Fracture Mechanics in aerospace structures - Application to composite materials and structures.

**Text Books/References:**
1. Prashanth Kumar , Elements of fracture mechanics, Wheeter publication, 1999.
2. Barrois W, Ripely, E.L., Fatigue of aircraft structure, Pe/gamon press. Oxford, 1983.
3. Knott, J.F., Fundamentals of Fracture Mechanics, Buterworth & Co., Ltd., London, 1983.
4. David Broek, Elementary Engineering Fracture Mechanics, Kluwer Academic Publishers,1986.

**Course Name-** ***Design of Hydraulic and Pneumatic Systems***
**Course Code-** ***ME 628***

**Unit I: Hydraulic System & Components-**Sources of Hydraulic Power: Pumping theory – Pump classification – Gear pump, Vane Pump, piston pump, construction and working of pumps – pump performance – Variable displacement pumps. Fluid Power Actuators: Linear hydraulic actuators – Types of hydraulic cylinders – Single acting, Double acting special cylinders like tanden, Rodless, Telescopic, Cushioning mechanism, Construction of double acting cylinder, Rotary actuators – Fluid motors, Gear, Vane and Piston motors

**Unit II: Design of Hydraulic Circuits-**Construction of Control Components : Director control valve – 3/2 way valve – 4/2 way valve – Shuttle valve – check valve – pressure control valve – pressure reducing valve, sequence valve, Flow control valve – Fixed and adjustable, electrical control solenoid valves, Relays, ladder diagram. Accumulators and Intensifiers: Types of accumulators – Accumulators circuits, sizing of accumulators, intensifier – Applications of Intensifier – Intensifier circuit.
**Unit III: Pneumatic Systems and Components-**Pneumatic Components: Properties of air – Compressors – Filter, Regulator, and Lubricator Unit – Air control valves, Quick exhaust valves, and pneumatic actuators. Fluid Power Circuit Design, Speed control circuits, synchronizing circuit, Penumo hydraulic circuit, Sequential circuit design for simple applications using cascade method.
**Unit IV:Design of Pneumatic Circuits-**Servo systems – Hydro Mechanical servo systems, Electro hydraulic servo systems and proportional valves. Fluidics – Introduction to fluidic devices, simple circuits, Introduction to Electro Hydraulic Pneumatic logic circuits, ladder diagrams, PLC applications in fluid power control. Fluid power circuits; failure and troubleshooting.

**Text Books:**
1. Anthony Esposito, Fluid Power with Applications, Pearson Education 2000.
2. Majumdar S.R., Oil Hydraulics, Tata McGraw-Hill, 2000.
3. Johnson, James L., Introduction to Fluid Power, Delmar Publishers, 2003

**Reference Books:**
1. Majumdar S.R., Pneumatic systems – Principles and maintenance, Tata McGraw Hill, 1995
2. Harry L. Stevart D.B, Practical guide to fluid power, Taraoeala sons and Port Ltd. Broadey, 1976.
3. Michael J, Prinches and Ashby J. G, Power Hydraulics, Prentice Hall, 1989.
4. Dudelyt, A. Pease and John T. Pippenger, Basic Fluid Power, Prentice Hall, 1987.

**Course Name-** ***Design of Experiments***
**Course Code-** ***ME 629***

**Unit I:** Overview and Basic Principles, Simple Designs and Analysis of Variance,
**Unit II:** Block Designs, Latin Squares and Related Designs, Full Factorial Designs, 2-level Full Factorial and Fractional Factorial Designs.
**Unit III:** Response surface methods and designs, Designs with Random Factors, Nested Designs, and split-plot Designs.

**Text Books/References:**
1. Clewer, A.G. and D.H. Scarisbrick. 2001. Practical Statistics and Experimental Design for Plant and Crop Science. John Wiley and Sons, LTD. New York Morris, T.R. 1999.
2. Experimental Design and Analysis in Animal Sciences. CABI Publishing, New York

**Course Name-** ***Design of Machinery***
**Course Code-** ***ME 630***
**Course Outcome:**
**CO1:** Determine the kinematic chain and mobility, and perform the kinematic analysis of a given mechanism.

**CO2:** Identify the basic relations between distance, time, velocity, and acceleration and apply the fundamental principles of statics and dynamics to machinery
**CO3:** Understand and avoid/suppress certain common dynamical problems a machine may undergo and Apply vector mechanics as a tool for solving kinematic problems
**CO4:** Understand the fundamentals of machine design for desired kinematic or dynamic performance and use graphical and analytic methods to study the motion of a planar mechanism.

**Unit I: Introduction-** Classification of mechanisms – Basic kinematic concepts and definitions – Degree of freedom, Mobility – Kutzbach criterion, Gruebler‟s criterion – Grashof‟s Law – Kinematic inversions of four-bar chain and slider crank chains – Limit positions – Mechanical advantage – Transmission Angle – Description of some common mechanisms – Quick return mechanisms, Straight line generators, Universal Joint – rocker mechanisms.
**Unit II: Kinematics of mechanisms/machineries-** Displacement, velocity and acceleration analysis of simple mechanisms – Graphical method– Velocity and acceleration polygons – Velocity analysis using instantaneous centres – kinematic analysis of simple mechanisms – Coincident points – Coriolis component of Acceleration – Introduction to linkage synthesis problem.
**Unit III: Dynamics of mechanisms/machineries-**Dynamics Fundamentals, Dynamic Force Analysis, Balancing, Engine Dynamics, Multi cylinder Engines.
**Unit IV: Kinematic and dynamic analysis of machine components-** Classification of cams and followers – Terminology and definitions – Displacement diagrams –Uniform velocity, parabolic, simple harmonic and cycloidal motions – Derivatives of follower motions – Layout of plate cam profiles – Specified contour cams – Circular arc and tangent cams – Pressure angle and undercutting – sizing of cams.
Law of toothed gearing – Involutes and cycloidal tooth profiles –Spur Gear terminology and definitions – Gear tooth action – contact ratio – Interference and undercutting. Helical, Bevel, Worm, Rack and Pinion gears [Basics only]. Gear trains – Speed ratio, train value – Parallel axis gear trains – Epicyclic Gear Trains.

**Case Studies on design and development of models**

**Text Books/References:**
1. R L Norton, Design of Machineries, 5$^{th}$ Edition, McGraw Hill Publishers.
2. Uicker, J.J., Pennock G.R and Shigley, J.E., Theory of Machines and Mechanisms, 3rd Edition, Oxford University Press, 2009.
3. Rattan, S.S, Theory of Machines, 3rd Edition, Tata McGraw-Hill, 2009.
4. Thomas Bevan, Theory of Machines, 3rd Edition, CBS Publishers and Distributors, 2005.
5. Cleghorn. W. L, Mechanisms of Machines, Oxford University Press, 2005.
6. Allen S. Hall Jr., Kinematics and Linkage Design, Prentice Hall, 1961.
7. Ghosh. A and Mallick, A.K., Theory of Mechanisms and Machines, Affiliated East West Pvt. Ltd., New Delhi, 1988.
8. Rao.J.S. and Dukkipati.R.V. Mechanisms and Machine Theory, Wiley-Eastern Ltd., New Delhi, 1992.

**Course Name-** ***Product Design and Development***
**Course Code-** ***ME 631***
**Course Outcome:**

**CO1:** Understand the Product Design, Phases of Product Development, Design for Assembly (DFA), Design for Manufacturing (DFM).
**CO2:** Analyze the Theory of inventive problem solving (TRIZ) and Emphasis on the powerful process of innovative problem solving.
**CO3:** Understand the Manufacturing Considerations in Design systems.
**CO4:** Understand the Additive Manufacturing (AM) and Rapid Prototyping.

**Unit I: Product Design**

- Prospect identification
- Customer Requirements/Customer Experience
- Generation-Development-Evaluation" of multiple concepts enabling definition of Product Architecture, form, function, styling, design language, size, variability, durability, reliability, performance & Ergonomics.
- CAD softwares & Digital product development Simulations tools
- Environmental sustainability/"cradle to cradle" approach
- Ergonomics
- Creation of Bill of material (BoM)
- DFM/DFA overview
- Testing & Validation
- Managing Intellectual Property Rights ( IPR )

**Unit II: Product Development**

- Phases of Product Development: Product strategy definition, Product Planning, Product Design, digital & physical testing and validation, Tooling/ Fixture development, Pre-Production, Manufacturing & Sales
- Product strategy definition
- Product Planning
- Competition assessment
- Technical and commercial evaluation of concepts
- Digital & physical testing and validation
- Production readiness and Introduction to Market
- Detailed design consideration of cast, forged, machined, sheet metal, rubber parts etc.
- DFX: Design for Assembly (DFA), Design for Manufacturing (DFM), Design for Inspection (DFI), Design for Variability (DFV) & Design for Cost( DFC)
- Product costing
- Scenarios of Product design Economics

**Unit III: Theory of inventive problem solving (TRIZ)**

- Fundamentals, methods and techniques, General theory of innovation and TRIZ, Application of value engineering in Product design and development, Model based technology for generating innovative ideas.

**Unit VI : Design Thinking**

- Emphasis on the powerful process of innovative problem solving which begins with latent/ unmet customer needs with a process of innovation to converge on enhancing success rate of innovation.

**Unit V: Manufacturing Considerations in Design**

- Design for manufacture
- GD&T - Geometric Dimensioning & Tolerances including location, Runout. Profile, Orientation & form.
- Processing techniques and limitations for metals, polymers and ceramics. Influence of materials in processing and tooling on the design of components.
- Finishing, surface coatings and surface modifications of materials.
- Design for accuracy, locating pins and registers, machining in assembly, adjustment. Backlash and clearance adjustment.

**Unit VI: Introduction to Additive Manufacturing (AM) and Rapid Prototyping**

- Different AM processes & process chain
- Application level: Direct processes; Rapid Prototyping, Rapid Tooling. Rapid Manufacturing; Indirect Processes - Indirect Prototyping.
- Reverse engineering
- Impact of AM on "Time to market"

**Text Books/References:**

1 Ashby, M. F. "Materials Selection in Mechanical Design", Pergaman Press, 1992.
2 Bralla J., "Handbook of Product Design for Manufacture", McGraw Hill, 1988.
3 Levy S., and Dubois, L. H, "Plastics Production Design Engineering Handbook, Methuen Inc., 1985.
4 Dieter G E, Engineering Desing, McGraw-Hill, 1991.
5 Yotaro Hatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.
6 Ertas Atilia and Jones J C, The Engineering Design Process, John Wiley & Sons, 1996.
7 Waldron B M and Kenneth J W, Mechanical Design: Theory and Methodology, Spriinger, 1996.
8 Ian Gibson, David W. Rosen and Brent Stucker, Additive manufacturing technologies: rapid prototyping to direct digital manufacturing, Springer, 2010.

**Course Name- *Design Optimization***
**Course Code- *ME 632***

**Unit I: Introduction-**Design Characteristics of Mechanical Elements - Adequate and Optimum design - Principles of optimization - Conventional Vs Optimal design process - Design variables - Formulation of objective function – Design constraints - Variable bounds - Classification of Engineering optimization problem.

**Unit II: Single Variable Optimization Techniques-**Optimality Criteria - Bracketing Methods - Exhaustive search method - Bounding phase method – Region Elimination Methods - Interval halving method - Fibonacci search method - Golden section search method - Gradient based Methods - Newton - Raphson method - Bisection method - Secant method - Cubic search method.

**Unit III: Multi Variable and Constrained Optimization Techniques-**Optimality criteria - Direct search Method - Simplex search methods - Hooke-Jeeve's pattern search method - Powell's conjugate direction method - Gradient based method - Cauchy's method - Newton's method - Conjugate gradient method. Kuhn - Tucker conditions - Penalty Function - Concept of Lagrangian multiplier - Complex search method - Random search method

**Unit IV: Intelligent Optimization Techniques-**Introduction to Intelligent Optimization - Soft Computing - Working principles of Genetic Algorithm Types of reproduction operators, crossover & mutation, - Simulated Annealing Algorithm - Particle Swarm Optimization (PSO) - Graph Grammer Approach - Example Problems

**Unit V: Engineering Applications-**Structural applications - Design of simple truss members. Design applications - Optimum design of simple axial, transverse loaded members - Optimum design of shafts - Optimum design of springs. Dynamic applications - Optimum design of single, two degree of freedom systems and gear vibration absorbers. Mechanisms applications - Optimum design of simple linkage mechanisms

**Text Books/References:**


1. Jasbir S Arora, *Introduction to Optimum design,* Mechrawhill International, 2011.
2. S. S.Rao, *Engineering Optimisation: Theory and Practice*, Wiley- Interscience, 2008.
3. K. Deb, *Optimization for Engineering design algorithms and Examples*, Prentice Hall of India Pvt. 2005.
4. C.J. Ray, *Optimum Design of Mechanical Elements,* Wiley, John & Sons, 2007.
5. R.Saravanan, *Manufacturing optimization through intelligent techniques*, Taylor & Francis Publications.


**Course Name-** ***Mechanical Behavior of Materials***

**Course Code-** ***ME 633***

**Unit I: Introduction to deformation behaviour-** Concept of stresses and strains, engineering stresses and strains, Different types of loading and temperature encountered in applications, Tensile Test - stress – strain response for metal, ceramic and polymer, elastic region, yield point, plastic deformation, necking and fracture, Bonding and Material Behaviour, theoretical estimates of yield strength in metals and ceramics.

**Unit II: Elasticity Theory-** The State of Stress and strain, stress and strain tensor, tensor transformation, principal stress and strain, elastic stress-strain relation, anisotropy, elastic behaviour of metals, ceramics and polymers.

**Unit III: Yielding and Plastic Deformation-** Hydrostatic and Deviatoric stress, Octahedral stress, yield criteria and yield surface, texture and distortion of yield surface, Limitation of engineering strain at large deformation, true stress and true strain, effective stress, effective strain, flow rules, strain hardening, Ramberg- Osgood equation, stress - strain relation in plasticity, plastic deformation of metals and polymers.

**Unit IV: Microscopic view of plastic deformation-** crystals and defects, classification of defects, thermodynamics of defects, geometry of dislocations, slip and glide, dislocation generation - Frank Read and grain boundary sources, stress and strain field around dislocations, force on dislocation - self-stress, dislocation interactions, partial dislocations, twinning, dislocation
movement and strain rate, deformation behavior of single crystal, critical resolved shear stress (CRSS), deformation of poly-crystals - Hall-Petch and other hardening mechanisms, grain size effect - source limited plasticity, Hall- Petch breakdown, dislocations in ceramics and glasses.

**Unit V: Fracture-** Fracture in ceramics, polymers and metals, different types of fractures in metals, fracture mechanics – Linear fracture mechanics -KIC, elasto-plastic fracture mechanics - JIC, Measurement and ASTM standards, Design based on fracture mechanics, effect of environment, effect of microstructure on KIC and JIC, application of fracture mechanics in the design of metals, ceramics and polymers.

**Unit VI: Deformation under cyclic load- Fatigue-** S-N curves, Low and high cycle fatigue, Life cycle prediction, Fatigue in metals, ceramics and polymers.

**Unit VII: Deformation at High temperature-** Time dependent deformation - creep, different stages of creep, creep and stress rupture, creep mechanisms and creep mechanism maps, creep under multi-axial loading, microstructural aspects of creep and design of creep resistant alloys, high temperature deformation of ceramics and polymers.

**Text Books/References:**

1. J. Roesler, H. Harders,and M. Baeker,"Mechanical Behaviour of Engineering Materials: Metals, Ceramics, Polymers, and Composites", Springer- Verlag, 2007.

2. W.K. Liu, E.G. Karpov, H.S. Park, "Nano Mechanics and Materials", John Wiley and Sons Pvt. Ltd, 2006.

3. Thomas H. Courtney, "Mechanical Behavior of Materials", McGraw-Hill, 1990.

**Course Name- *Experimental Stress Analysis***

**Course Code- *ME 634***

**Unit I: Measurements & Extensometer-**Principles of measurements, Accuracy, Sensitivity and range of measurements. Mechanical, Optical Acoustical and Electrical extensometers and their uses, Advantages and disadvantages.

**Unit II: Electrical Resistance Strain Gauges-**Principle of operation and requirements, Types and their uses, Materials for strain gauge. Calibration and temperature compensation, cross sensitivity, Rosette analysis, Wheatstone bridge and potentiometer circuits for static and dynamic strain measurements, strain indicators.

**Unit III: Photoelasticity-**Two dimensional photo elasticity, Concept of light – photoelastic effects, stress optic law, Interpretation of fringe pattern, Compensation and separation techniques, Photo elastic materials. Introduction to three dimensional photo elasticity.

**Unit IV: Brittle Coating and Moire Methods-**Introduction to Moire techniques, brittle coating methods and holography.

**Unit V: Non–Destructive Testing-**Fundamentals of N DT, Radiography, ultrasonic, magnetic particle inspection, Fluorescent penetrant technique, Eddy current testing, Acoustic Emission Technique.

**Text Books:**

1. Srinath, L.S., Raghava, M.R., Lingaiah, K., Garagesha, G., Pant B., and Ramachandra, K., Experimental Stress Analysis, Tata McGraw-Hill, New Delhi, 1984.

**Reference Books:**

1. Dally, J.W., and Riley, W.F., Experimental Stress Analysis, McGraw-Hill Inc., New York, 2005, IV edition.

2. Hetyenyi, M., Hand book of Experimental Stress Analysis, John Wiley and Sons Inc., New York, 1972.

3. Pollock A.A., Acoustic Emission in Acoustics and Vibration Progress, Ed. Stephens R.W.B., Chapman and

Hall, 1993.

**Course Name-** ***CAD***
**Course Code-** ***ME 635***
**Unit I:** CAD Hardware and Software, Types of systems and system considerations, input and output devices, hardware integration and networking, hardware trends, Software modules,
**Unit II:** Computer Communications, Principle of networking, classification networks, network wring, methods, transmission media and interfaces, network operating systems,
**Unit III:** Computer Graphics Introduction, transformation of geometric models: translation, scaling, reflection, rotation, homogeneous representation, concatenated transformations; mappings of geometric models, translational mapping rotational mapping, general mapping, mappings as changes of coordinate system; inverse transformations and mapping;
**Unit IV :** Projections of geometric models, orthographic projections, Geometric Modeling, curve representation: Parametric representation of analytic curves, parametric representation of synthetic curves, curve manipulations. Surface representation,
**Unit V :** Fundamentals of solid modeling, boundary representation (B-rep), Constructive Solid Geometry (CSF), sweep representation, Analytic Solid Modeling (ASM), other representations; solid manipulations, solid modeling based applications: mass properties calculations, mechanical tolerancing, etc.
**Unit VI:** Finite Element Modeling and Analysis, Finite Element Analysis, finite element modeling, mesh generation mesh requirements, semiautomatic methods, fully automatic methods, design and engineering applications, System Simulation, Need of simulation, areas of applications, when simulation is appropriate tool / not appropriate, concept of a system, components of a system, discrete and continuous systems, model of a system, types of models, types of simulation approaches

**Text Books/References:**
**1.** Ibrahbim Zeid, “CAD / CAM Theory and Practice”.
2. Jim Browne, “Computer Aided Engineering and Design”.
3. P. Radhakrishnan / V. Raju / S. Subramanyam, “CAD / CAM / CIM”.
4. P.N. Rao, “CAD / CAM principles and applications”, Tata Mcraw-Hill, 2002.
5. Rogers / Adams, “Mathematical Elements for Computer Graphics”.
6. Rooney and Steadman, “Principles of Computer Aided Design”, Aug. 1993.

**Course Name-** ***MEMS - Design, Fabrication, and Characterization***
**Course Code-** ***ME 636***
**Unit I: MEMS Fabrication-**Conventional MEMS fabrication using VLSI technology: lithography, chemical etching: isotropic and anisotropic, Plasma etching, reactive ion etching (RIE), oxidation, chemical vapour deposition (CVD), LPCVD, PECVD, surface micromachining, LIGA, single layer and higher layer fabrication. Non-conventional MEMS fabrication: laser micromachining and welding, processing of metals and nonmetals with laser, Electro Discharge and Electro Chemical micromachining (EDM and ECM), Microstereolithography: scanning process, dynamic mask process. Electronic packaging.
**Unit II: MEMS: Design and Analysis-**Basic concepts of design of MEMS devices and processes, Design for fabrication, Other design considerations, Analysis of MEMS devices, FEM and Multiphysics analysis, Modeling and simulation, connection between molecular and continuum mechanics, MEM system level analysis from perspective of control theory.

**Unit III: MEMS Characterization-**Technologies for MEMS characterization, Scanning Probe Microscopy (SPM): Atomic Force, Microscopy (AFM), Scanning tunnelling microscopy (STM), Magnetic Force Microscopy, Scanning Electron Microscope, Laser Doppler vibrometer, Electronic Speckle Interference Pattern technology (ESPI). Examples and case studies: Comb actuator for nanopositioning stage by POLYMUMPS process.

**Text Books/References:**

1. Nadim Maluf, An Introduction to Microelectromechanical Systems Engineering, Artech House, Boston, 2000.
2. Stephen D. Senturia, Microsystems Design, Kluwer Academic Publishers, New York, November 2000
3. S. M. Sze, VLSI Technology, McGraw-Hill International Editions, Singapore, 1988.
4. M.Elwenspoek and H. Jansen, Silicon Micromachining, Cambridge University Press, Cambridge, UK, 1998.
5. Norio Taniguchi, editor Nanotechnology, Oxford University Press, Oxford, UK, 2003.
6. Joseph McGeough, editor Micromachining of Engineering Materials,Marcel Dekker, Inc., New York, 2002.
7. Marc Madou, "Fundamentals of Microfabrication: The science of miniaturization," CRC Press, LLC, 2002.

**Course Name-** ***Design of Pressure Vessels***
**Course Code-** ***ME 637***
**Unit I: Introduction-**Methods for determining stresses – Terminology and Ligament Efficiency – Applications.
**Unit II: Stresses in Pressure Vessels-**Introduction – Stresses in a circular ring, cylinder – Membrane stress Analysis of Vessel Shell components – Cylindrical shells, spherical Heads, conical heads – Thermal Stresses – Discontinuity stresses in pressure vessels.
**Unit III: Design of Vessels-**Design of Tall cylindrical self-supporting process columns –Supports for short, vertical and horizontal vessels – stress concentration – at a variable Thickness transition section in a cylindrical vessel, about a circular hole, elliptical openings. Theory of Reinforcement – pressure vessel Design. Introduction to ASME pressure vessel codes
**Unit III: Buckling Of Vessels-**Buckling phenomenon – Elastic Buckling of circular ring and cylinders under external pressure – collapse of thick walled cylinders or tubes under external pressure – Effect of supports on Elastic Buckling of Cylinders – Buckling under combined External pressure and axial loading.

**Text Books/References:**

1. John F. Harvey, Theory and Design of Pressure Vessels, CBS Publishers and Distributors, 1987.
2. Henry H. Bedner, Pressure Vessels, Design Hand Book, CBS publishers and Distributors, 1987.
3. Stanley, M. Wales, Chemical process equipment, selection and Design. Buterworths series in Chemical Engineering, 1988.
4. William. J., Bees, Approximate Methods in the Design and Analysis of Pressure Vessels and Piping, PreASME Pressure Vessels and Piping Conference, 1997.

**Course Name-** ***Warship Transmission and Tribology***

**Course Code-** ***ME 641***
**Course Outcome:**
**CO1:** Students will be able to **analyze and apply** basics of power transfer in Marine gear boxes, stresses, noise and modes of failure in gear drives
**CO2:** Students will be able to **explain** about Navel standards used in design of shafting in marine engines transmission system.
**CO3:** Students will be able to **analyze & apply** different types of hydrodynamic bearings starting from basic governing equations and estimate performance of rolling contact bearings
**CO4:** Student will **understand** basics of tribology, lubricants used in marine engines & modern lubrication

| **Syllabus Details** | **Outcome** |
|---|---|
| Unit I | CO1 |
| Unit II | CO2 |
| Unit IV | CO3 |
| Unit III & V | CO4 |

**Unit I: Warship Transmission Design-** Specifications, design and design checks of Marine Gearboxes (Spur and helical gears, Gear Tooth loads, Bearing loads, Reaction torque, Causes and classification of gear failures, gear noise and stress analysis).
**Unit II: Shafting-** Shafting (NES requirements, torsional and bending strength calculations), Shaft-line Bearings (NES requirements, types, numbers and load distribution), Clutches and Couplings
**Unit III: Tribology- Theory of wear, its types and reduction, Theory of hydrodynamic lubrication, properties of marine lubricants.**
**Unit IV: Bearings- Classification, selection and performance. Theories of design of Journal Bearings and Rolling element bearings with performance and life estimation**
**Unit V:** Modern Lubrication, Surface treatment.

**Text Books/References:**

1. Engineering Tribology, GW Stachowiak, AW Batchelor, Butterworth Heinman, 2001.
2. Shigley's Mechanical Engineering Design [In SI Units], Joseph Shigley, Charles Mischke, Richard Budynas, Keith Nisbett, Tata McGraw Hill, 2008.
3. Schaum's Outline of Machine Design, 3rd Ed, Tata McGraw Hill, 2010.
4. Gear Engineering, Pitman, Merritt HE, Latest edition.


**Course Name-** ***Automatic Control Systems***
**Course Code-** ***ME 642***
**Course Outcome:**
**CO1:** Students will understand basics of control systems like transfer function, closed/open systems, feedback & feed forward systems & draw block diagrams for mechanical, electrical and hydraulic systems
**CO2:** Students will understand Nyquist criterion, static & dynamic characteristics of transient, steady state, 1st/2nd order control systems using frequency response, stability analysis, root locus analysis.
**CO3:** Students will understand control system actions & components like discrete/proportional, integral & differential control actions, comparators & actuators, amplifiers, servo motors, control valves

**CO4:** Students will be able to apply control system basics to pneumatic, hydraulic & electrical systems based on microprocessor, PLC, micro-controller based distributed Marine control systems

| Syllabus Details | Outcome |
|---|---|
| Unit I | CO1 |
| Unit II | CO2 |
| Unit III | CO3 |
| Unit IV & V | CO4 |

**Unit I: Basic concepts of Automatic Control-** Transfer Functions-Modeling of systems- Mechanical, Electrical, hydraulic system block diagram, signal flow graphs, closed and open loop systems. Feedback and Feed forward control system.

**Unit II: Static and Dynamic Characteristics of Control Systems-** Transient Response and Steady state error analysis for First and second order systems. Frequency response. Experimental determination of transfer function. Stability Analysis. Root Locus Analysis. Nyquist Criteria.

**Unit III: Control Actions and Control System Components-** Discrete action, Proportional, Integral and Differential Control Action, Composite action. Characteristics, working and limitations of different types of Comparators and actuators, amplifiers, Servo motors and Control valves.

**Unit IV: Control System Implementations-** Pneumatic Systems, Hydraulic Systems, Electrical Systems, Microprocessor Based Systems, Programmable Logic Controllers, Micro Controllers and Network Based Distributed Control Systems,

**Unit V: Case Studies-** Marine Systems (for Naval Students): Integrated Platform Management System / Battle Damage Control System, Ship board digital control, architecture and implementation of control of Marine systems in the latest Indian Naval Surface Warships.

Mechanical Systems (for Non - Naval Students): Engine auto control warning system, NBC & fire fighting systems, Remote vehicles.

**Texts Books:**

1. Measurement System, Application & Design, $4^{th}$Ed, E O Doebelin, Mc Graw Hill, 2003.
2. Modern Control Engineering, 4th Ed, Katushiko Ogata, Pearson, UK, 2001.
3. Modern Control Engineering, 4th Ed, Katushiko Ogata, Pearson, UK, 2001.

**Course Name-** ***Ship Dynamics and Marine Systems***

**Course Code-** ***ME 643***

**Course Outcome:**

**CO1:** Students will be able to **explain & apply** basics of ship structure, stability and design

**CO2:** Students will be able to **analyze, explain & apply** procedures for Staff requirements and procurement of main and auxiliary machineries

**CO3:** Students will be able to **explain & apply** basics of marine systems like Distillation & Desalination Plants, Power Generation, Air conditioning & Refrigeration

**CO4:** Students will be able to **explain & apply** Damage Control, NBCD requirements, Instrumentation and controls of a ship

| Syllabus Details | Outcome |
|---|---|
| Unit I | CO1 |

| | |
|---|---|
| Unit II | CO2 |
| Unit III | CO3 |
| Unit IV & V | CO4 |

**Unit I:** **Introduction to Naval Architecture and Ship Dynamics-** Categorization of ships, ships geometry and hydrostatics, Properties of ship building materials, Strength and structure of ship's hydrostatics and initial stability. Intact and Damage Stability. Ship Powering Calculations and Propeller design.
**Unit II: Staff Requirements for new ship design-** Formulation of requirements, general role, speed, endurance, armament, logistic requirements, procedure for formulating outline, agreed and approved staff requirements, procedure for finalization of ship designs. Choice & Selection of Propulsion System and Auxiliaries
**Unit III:** General requirements of marine machinery Design for shock protection. Types of main propulsion and their evaluation. Selection of Distillation & Desalination Plants, Power Generation, Air conditioning & Refrigeration, Ships Systems,
**Unit IV:** NBCD Requirements, Marine Controls and Instrumentation.
**Unit V: Trials:** Sea trials, their requirements and procedures.

**Texts Books**
1 Introduction to Naval Architecture, TC Gilmer, Bruce Johnson, Naval Institute Press, 1982.
2 Basic Ship Theory, Vol I & II, Rawson & Tupper, Saint Louis, Butterworth Heineman, 1994.
3 Warship Propulsion System Selection, CM Plumb, The Institute of Marine Engineers, 1987.

**Course Name-** ***Marine Diesel & Steam Engines***
**Course Code-** ***ME 644***
**Course Outcome:**
**CO1:** Students will be able to **analyze** & **apply** basic reactive thermodynamics and **explain** requirements of marine diesel engine design
**CO2:** Students will be able to **analyze, apply and explain** Marine Diesel Engine rating, selection & engine-propeller matching
**CO3:** Student will be able **analyze and explain** regulations & control Mechanisms for noise and emissions control from marine diesel engines
**CO4:** Students will be able to **understand, analyze & apply** basic working characteristics, performance & basic design considerations of boilers & steam turbines using thermodynamic charts/relations

| **Syllabus Details** | **Outcome** |
|---|---|
| Unit I | CO1 |
| Unit II | CO2 |
| Unit III | CO3 |
| Unit IV & V | CO4 |

**Unit I: Basic Concepts-** Reactive Thermodynamics, complete and incomplete combustion, volumetric efficiency. Design Requirements, Materials, Types of Supercharging

**Unit II: Marine Diesel Engine rating, selection, engine-propeller matching-** Terminology, Service Rating, Corrections for ambient conditions, Diesel engine Characteristics, Principles of matching, Modifications to allow for Service conditions, Towing Loads, Auxiliary Loads, CPP.
**Unit III: Noise and Emission Reduction in marine engines-** Regulations, Constituents, Control Mechanisms for reduction of noise and exhaust emissions from marine diesel engines.
**Unit IV: Boiler Design-** Boiling process, heat transfer and fluid flow dynamics, boiler design considerations, procedure. Steam cycles analysis: Steam turbine thermodynamics, Simple Rankine cycle, Power output and efficiency calculations, measures to improve cycle performance parameters.
**Unit V: Steam turbines**-Impulse and reaction turbines, multistaging in turbines, compounding of turbines, design and part load performances, turbine losses. Steam turbine design procedure.

**Texts Books**

1. Internal Combustion Engine Fundamentals, JB Heywood, McGraw Hill , 2003.
2. Internal Combustion Engine Theory and Practices, 2nd Ed, Vol I & 2, Charles Fayette Taylor, MIT Press, 1999.
3. Steam Turbines: Theory and Design, Shlyakhin P, Foreign Languages Publishing House, Moscow, 1995.

**Course Name-** ***Marine Gas Turbines***
**Course Code-** ***ME 645***
**Course Outcome:**
**CO1:** Students will be able to **analyze, apply & explain** basic working of marine gas turbines in terms of its thermodynamic and mechanical behaviour
**CO2:** Students will be able to **analyze, apply & explain** aerodynamic & mechanical design & performance characteristics of gas turbines and compressors
**CO3:** Students will be able to **analyze, interpret & explain** mechanical design requirements of Marine gas turbine components & recommend suitable materials for its manufacturing

| Syllabus Details | Outcome |
|---|---|
| Unit I | CO1 |
| Unit II & III | CO2 |
| Unit IV & V | CO3 |

**Unit I: Gas Turbine theory and Performance:** Gas dynamics, thermodynamic and fluid mechanics concepts, Gas Turbine Types and application, Cycle Analysis & Performance. Design & off- design point performance, Transient performance of single shaft, two shaft engine with FPT. Gas Turbine Simulation. Compressor turbine Matching. Propeller matching, displacing equilibrium running line.
**Unit II: Turbo Machinery Aerodynamics Design:** Compressor design and Performance - Pressure losses separation & friction losses, Definition delta upon D, De Hallers no. Stage loading and flow parameters, degree of reaction, stall, Use of IGVs & VGVs, multi-spooling, variable temp rise distribution. Compressor design co-relations & example.
**Unit III: Mechanical Design and Performance of Turbine and Compressors:** Blade shapes, methods of design. Velocity triangles, reaction, stage loading, flow coefficient. Design for maximum power. Stage efficiency, over-tip leakage. Design correlations & example. Centrifugal, Gas, Inertia Loads acting on turbo-machinery,

**Unit IV: Creep design, Fatigue design, Requirements of naval application. Marine GT Combustors Design.**

**Unit V: Design & Materials for Marine GTs. Requirements, properties, Super-alloys, Manufacturing, Marine coatings, Types & Process. Marine GT Systems Design requirements & Integration with ships systems**.

***Texts Books/References***


1. Gas Turbine Theory, 5th Ed, Cohen, Rogers & Sarvamuttu, John Wiley & Sons, 2001.
2. Fluid Mechanics and Thermodynamics of Tubomachinery, SL Dixon, $6^{th}$ Ed, Elsevier, 2010.
3. Gas Turbine $2^{nd}$ Ed, V Ganeshan, Tata McGraaw Hill, 2010.
4. Fundamentals of Gas Turbines, 2nd Ed, Bathie WW, John Wiley, 2003.
5. The Design of Hi-efficiency Turbomachinery and Gas Turbine, DG Wilson & T Korakianitis, MIT Press, 2002.


***Course Name- Nuclear Reactor Engineering***

***Course Code- ME 646***

**Course Outcome:**

**CO1:** Students will **understand &** be able to **apply** basic knowledge of nuclear physics

**CO2:** Students will be able to demonstrate **understanding** on safety aspects related to functioning of a nuclear reactor

**CO3:** Students will be able to **analyse, apply and explain** thermal and hydraulic design aspects of nuclear reactor systems

**CO4:** Students will **understand &** be able to **explain** basics of control and instrumentation of an nuclear reactor

| **Syllabus Details** | **Outcome** |
|---|---|
| Unit I | CO1 |
| Unit II | CO3 |
| Unit III & IV | CO2 |
| Unit V | CO4 |

**Unit I: Nuclear Reactor Physics**: Introduction to nuclear physics: nuclear fission, nuclear reactions and radiations. Reactor analysis, reactor kinetics and control,

**Unit II: Nuclear Reactor Engineering**: Thermal & hydraulic aspects of reactor design, energy removal. Core and Fuel design. Reactor process system, reactor fuel design. Design aspects of major reactor components, material selection, shielding design. Overview of nuclear fuel cycle. Different reactor systems,

**Unit III: Nuclear Reactor Safety:** Overview of nuclear safety philosophy, defense in depth principle, different safety systems,

**Unit IV: Health Safety**: Effects of different types of radiation, dosage, radiation monitoring.

**Unit V: Nuclear Reactor Control & Instrumentation**: General features of reactor control, control in reactor operation. Basics of reactor instrumentation, instrumentation range and wide range of detectors used. Visit to BARC Mumbai for one day.

**Texts Books**

1. Nuclear Reactor Engineering: Reactor Design Basics, Volume – 1, Samuel Glasstone and Alexander Sesonske, CBS Publishers and Distributors, 2002.
2. Nuclear Reactor Engineering: Reactor systems engineering, Volume - 2, Samuel Glasstone and Alexander Sesonske, CBS Publishers and Distributors, 2002.
3. Introduction to Nuclear Engineering, John R. Lamarsh and Anthony J. Baratta. Prentice Hall; 3rd editions, 2001.

**Course Name-** ***Convective Heat & Mass Transfer***

**Course Code-** ***ME 654***

**Course Outcome:**

**CO1:** Students will be able to **explain, analyze & apply** basic conduction & convection principles

**CO2:** Students will be able to **analyze & apply** internal & external forced convection concepts to real life problems.

**CO3:** Students will be able to **apply** & **explain** basic concepts of radiation & mass transfer. **Understand** non-dimensional parameters affecting convective mass transfer in combined heat & mass transfer processes like boiling & condensation

| Syllabus Details | Outcome |
|---|---|
| Unit I & II | CO1 |
| Unit III & IV | CO2 |
| Unit V & VI | CO3 |

**Unit I: Basic concepts of convection**

Energy Equation, Generalized approach to energy equations, Dimensionless Groups, Velocity and thermal Boundary layer, Equation for thermal boundary layer: Scaling analysis of steady flow over flat plate, Significance of Prandtl number

**Unit II: External Laminar Forced convection**

Thermal boundary layer equation (Pohlhausen solution), Approximate solution for flat plate boundary layer problem, Flow past cylinder: Strouhal number, Average Nusselt number

**Unit III: Internal Laminar Forced convection**

Thermally fully-developed flow, Energy balance, Constant wall temperature case, constant wall heat flux case, Hydrodynamically & Thermally developed flow with constant wall heat flux, Graetz problem: Hydrodynamically developed & Thermally developing flow with constant wall heat flux

**Unit IV: Natural/Free and Mixed convection**

Free convection over vertical flat plate, Grashof number, conditions for free/forced/mixed convection, free convection for vertical cylinder, Introduction to Mixed convection: Thermal expansion number, Archimedes number, Froude number

**Unit V: Condensation and Boiling**

Introduction, film condensation on a vertical plate, average heat transfer coefficient, Laminar film condensation inside and outside of horizontal tubes, Introduction to boiling, modes of boiling

**Unit VI: Mass Transfer**

Introduction, Conservation of species for a control volume, mass diffusion equation, concentration boundary layer, Schmidt number, Sherwood number, Lewis number, Heat and mass transfer analogy, Evaporative cooling

**Practice**: Solve thermal boundary layer over flat plate using Matlab/C/python code

**Text Books:**

I. Introduction to Convective Heat Transfer Analysis by Patrick H. Oosthuizen and David Layor (McGrow-Hill)
II. Convective Heat and Mass Transfer by Kays, Crawford and Weigand (4th Edition, McGraw-Hill)
III. Convective Heat Transfer by L C Burmeister (Wiley)

**Reference Books:**

I. Convective Heat Transfer by Adrian Bejan ($4^{th}$ Edition Wiley)
II. Boundary Layer Theory by H Sctllichting (McGraw-Hill)
III. Heat and Mass transfer by Eckert ERG and Drake RM (Translated by J P Gross, McGrow-Hill)
IV. Convective Heat Transfer: Solved Problems by Michel Favre-Marinet and Sedat Tardu (Wiley)

**Course Name-** ***Performance Testing and Instrumentation***
**Course Code-** ***ME 655***
**Unit I:** Performance testing of Machinery Sea Water Cooling, Lube Oil Fill/Transfer/Purification Systems, - Main Propulsion Lube Oil System, Starting Air Compressors and System, Ship Service and Control Air Equipment, Segregated Ballast System, Steam and Condensate System, Fuel Oil Service System, Fuel Oil Quick Closing Valves, High Temperature/Low Temperature Fresh Water Cooling Systems, Stern Tube Lube Oil System,
**Unit II:** Performance testing of Ship Service Generator Operational Tests, Emergency Diesel Generator , Batteries and Chargers, Lighting System Operation, Navigation and Signal Lights, Radio Communication Equipment, Ships Whistles, Tank Level Indicators, Auxiliary Boiler and Services, Fire and Foam System, Machinery Bilge and Oily Waste Transfer System
**Unit III:** Fundamental & Importance of Instrumentation, types of instruments, selection of instruments, performance of instruments, error in measurement, calibration & standard, Calibration of Instruments: Methods & analysis, Introduction to Transducer & types, Process Instrumentation, recording instruments, indicating & recording Instruments.
**Unit IV:** Measurements of temperature, pressure, relative humidity, moisture content & velocity & flow.

**Text books/Reference:**

1. Experimental Methods, J.P. Holman McGraw Hill International, Auckland
2. Engineering Metrology, R KJain, Khanna Publishers, Delhi
3. Mechanical Measurements, Thomos G. Beckwith and I.ewis Back N. Adison Wesely Longman, Harlow
4. Industrial lnstrurnentation, John Wiley Eastern Ltd, New Delhi

**Course Name-** ***Marine Hydrodynamics***
**Course Code-** ***ME 657***
**Course Outcome:**
**CO1:** Understand and review of Ideal and viscous incompressible fluid; Kinematics of fluid; Lagrangian and Eulerian methods of description, velocity, acceleration, streamlines, pathlines, vorticity

**CO2:** Understand the basic Two dimensional motion - velocity potential, stream function, Sources, sinks, dipoles; Flow past a circular cylinder with and without circulation; Blausius Theorem
**CO3:** Understand The vortex system-circular vortex, two dimensional sources and vortex distributions, vortex sheets; Lifting Surfaces, Aerofoil theory; Velocity and pressure distribution on aerofoils; Viscous fluids- Navier-Stokes equations, Laminar flow, Poiseuille flow, Couette flow
**CO4:** Understand Gravity waves- Airy's wave; Free surface condition; Velocity potential- Dispersion relation; Surface tension effects; Orbital motion; Group velocity and its dynamical significance; Wave energy

| Syllabus Details | Outcome |
|---|---|
| Unit I | CO1 |
| Unit II | CO2 |
| Unit III | CO3 |
| Unit IV | CO4 |

**Unit I:** Ideal and viscous incompressible fluid; Kinematics of fluid; Lagrangian and Eulerian methods of description, velocity, acceleration, streamlines, pathlines, vorticity; Equation of continuity; Euler's Equations of motion; Bernoulli's equation and its application,
**Unit II**: Two dimensional motion - velocity potential, stream function, Sources, sinks, dipoles; Flow past a circular cylinder with and without circulation; Blausius Theorem; Problems on the motion of perfect fluids - steady translation of a cylinder in an infinite fluid medium, unsteady translation; Added mass of cylinders; Spheres;
**Unit III:** The vortex system-circular vortex, two dimensional sources and vortex distributions, vortex sheets; Lifting Surfaces, Aerofoil theory; Velocity and pressure distribution on aerofoils; Viscous fluids- Navier-Stokes equations, Laminar flow, Poiseuille flow, Couette flow, flow through a pipe; Boundary layer Theory-Reynolds Number; Boundary layer along a flat plate; Blasius solution; Separation, Von Karman momentum integral method;
**Unit IV**: Introduction to Turbulence; Gravity waves- Airy's wave; Free surface condition; Velocity potential- Dispersion relation; Surface tension effects; Orbital motion; Group velocity and its dynamical significance; Wave energy; Standing waves; Loops and nodes, Wave forces and Morison's equation, Long waves and waves in a canal; Tides.

**Text Books:**
1. Lamb, H. (1995) Hydrodynamics, 6th Edition, Cambridge University Press, USA
2. Newman, Nick, (1977) "Marine Hydrodynamics" MIT Press.

**References:**
1. Frank, White (2005) Viscous Fluid Flow, McGraw-Hill Education; 3$^{RD}$ edition.
2. Milne-Thomson, L. M. (1996) Theoretical Hydrodynamics, Dover Publications, Inc. New York. Introduction to Fluid Mechanics
3. Dean, R. G. & Dalrymple, R. A. (2001) "Water Wave Mechanics for Engineers and Scientists" Allied Publishers Limited, New Delhi (Reprint of World Scientific, Singapore).

**Course Name-** ***Additive Manufacturing***
**Course Code-** ***ME658***

**Unit I:** Review of solid modeling techniques with comparison. Product development. Simultaneous Engineering and Additive Manufacturing(AM). Basic Principle of AM processes.
**Unit II:** Support structure in Additive Manufacturing. Containment and critical applications. Generation of the physical layer model. Classification of AM Processes.
**Unit III:** Virtual Prototyping. Tessellation (STL format) and tessellation algorithms. Defects in STL files and repairing algorithms. Slicing and various slicing procedures.
**Unit IV:** Accuracy and Surface quality in Additive Manufacturing. Effect of part deposition orientation on accuracy, surface finish, build time, support structure, cost etc. Various Rapid tooling techniques. Introduction to Reverse Engineering. Reverse engineering and Additive Manufacturing.

**Text /References*:***
1. Ian Gibson, David W. Rosen and Brent Stucker, Additive manufacturing technologies: rapid prototyping to direct digital manufacturing, Springer, 2010.
2. C.K. Chua, K.F. Leong and C.S. Lim, Rapid prototyping: Principles and applications, 3 rd Edition, World Scientific, 2010
3. Andreas Gebhardt, Understanding additive manufacturing: rapid prototyping, rapid tooling, rapid manufacturing, Hanser Publishers, 2011.
4. L. Lu, J. Fuh and Y. S. Wong, Laser-induced materials and processes for rapid prototyping, Kluwer Academic Press, 2001.
5. Zhiqiang Fan and Frank Liou, Numerical modeling of the additive manufacturing (AM) processes of titanium alloy, lnTech, 2012.

**Course Name-** ***Rapid Prototyping***
**Course Code-** ***ME 659***
**Unit I:** Introduction- History, Development of RP systems, Applications in Product Development, Reverse Engineering, Rapid Tooling, Rapid Manufacturing- Principle, Fundamental, File format, Other translators, medical applications of RP, On demand manufacturing, Direct material deposition, Shape Deposition Manufacturing.
**Unit II:** Liquid Based and Solid Based Rapid Prototyping Systems: Classification, Liquid based system, Stereolithography Apparatus (SLA), details of SL process, products, Advantages, Limitations, Applications and Uses. Solid based system – Fused Deposition Modeling, principle, process, products, advantages, applications and uses – Laminated Object Manufacturing.
**Unit III:** Powder Based Rapid Prototyping Systems- Selective Laser Sintering – principles of SLS process, principle of sinter bonding process, Laser sintering materials, products, advantages, limitations, applications and uses. Three Dimensional Printing – process, major applications, research and development. Direct shell production casting – key strengths, process, applications and uses, case studies, research and development. Laser Sintering System, e-manufacturing using Laser sintering, customized plastic parts, customized metal parts, e-manufacturing – Laser Engineered Net Shaping (LENS).

**Text Books**
- Rafiq I. Noorani, Rapid Prototyping, “Principles and Applications”, Wiley & Sons, 2006.

- Chua C.K, Leong K.F and Lim C.S, “Rapid Prototyping: Principles and Applications”, Second Edition, World Scientific, 2003.

**References:**


- N.Hopkinson, R.J.M, Hauge, P M, Dickens, “Rapid Manufacturing – An Industrial revolution for the digital age”, Wiley, 2006
- Ian Gibson, “Advanced Manufacturing Technology for Medical applications: Reverse Engineering, Software conversion and Rapid Prototying”, Wiley, 2006
- Paul F.Jacobs, “Rapid Prototyping and Manufacturing : Fundamentals of Stereolithography”, McGraw Hill 1993.
- Pham. D.T., and Dimov. S.S., “Rapid Manufacturing”, Springer Verlog 2001.


**Course Name: *Heat Exchanger Design***

**Course Code: *ME660***

**Course Outcome:**

**CO1:** Understand the basics of Heat exchangers, its classification of different applications. Introduction to Thermal and hydraulic aspects, pressure drop and heat transfer, sizing and rating, LMTD and NTU method etc.

**CO2:** Understand role of Biot number and its significance in Fin design, lumped parameter analysis, effectiveness, efficiency and thermal resistance of fins. Understand different types of heat exchangers. Evaluate Fouling and corrosion and its effect on heat transfer and pressure drop and calculations for shell and tube heat exchanger.

**CO3:** Analyze the different components and their functions in connection Heat Pipe and Phase change heat exchangers and apply the understanding to the design of future systems.

**CO4:** Understand and evaluate the requirement of Heat Exchanger packaging and testing and proposing solution to the existing problems persisting in current inventory of combat vehicles.

**Unit I: Introduction to Heat Exchangers:** Introduction, Application of Heat exchangers, Classification of heat exchangers, Types of heat exchangers, common terminologies, Introduction to Thermal and hydraulic aspects, pressure drop and heat transfer, sizing and rating, LMTD and NTU method

**Unit II: Fin Design:** Biot number and its significance, Applicability of Lumped parameter analysis, Fins and its design, Effectiveness and efficiency, Heat transfer from fin array, Thermal resistance concept

**Unit III: Heat Exchanger Design:** Shell and Tube Heat Exchangers, Fin tube heat exchanger, Plate Fin Heat Exchangers (PFHE), Direct contact heat exchangers, Regenerators and Recuperator, types of regenerators, construction, application, Theory of Regenerator

**Unit IV: Fouling and corrosion:** Effect of fouling on heat transfer and pressure drop, Fouling mechanisms, single phase liquid side, single phase gas side, Prevention of fouling, Types of corrosion, corrosion control, advantages and disadvantages of water as a medium in heat exchangers

**Unit V: Advanced topics: Heat Pipe and Phase change heat exchanger:** Heat pipes, construction, working principle, application, and analysis. Special heat pipes, Phase change heat transfer, Phase change heat-exchangers (Evaporators and Condensers)

**Unit VI: Heat Exchanger packaging and testing:** Heat Exchanger packaging, Air elimination unit, Air blower/ fan power requirements, Safety valves, Heat Exchanger testing: Steady state and dynamic methods

**Text Books:**

1. Fundamentals of Heat Exchanger Design by Ramesh K. Shah & Dusan P. Sekulic (John Wiley & Sons)
2. Heat Exchangers: Selection, Rating, and Thermal Design by Sadik Kakaç, Hongtan Liu, Anchasa Pramuanjaroenkij (CRC Press)
3. Heat Exchanger Design by Arthur P. Fraas, Fraas (Wiley)

**Reference Books:**

1. Heat Exchanger design handbook by T. Kuppan
2. Compact Heat Exchangers by William M. Kays andA.L. London, (Krieger Publishing Company)
3. Fundamentals of heat transfer - Frank P. Incropera, David P. DeWitt

**Course Name-** ***Computational Fluid-Structure Interaction and its Applications***
**Course Code-** ***ME 661***
**Course Outcome:**

**CO1:** Understand the real-life problems of Fluid-Structure Interactions (FSI) and fundamental of governing equations and boundary conditions. Learn Fundamentals of Computational Fluid Dynamics (CFD) using Finite Volume and Finite Element techniques.

**CO2:** Understand and evaluate Fluid-structure Coupling and Interface handling: Fluid-structure coupling algorithm-Partitioned coupling schemes, Arbitrary Euler-Lagrange (ALE).

**CO3:** Analyze the different modules and their functions available in AUTODYN software for simulation of coupled Fluid-Structure Interaction problems.

**CO4:** Understand and evaluate different real-life problems through simulation using ANSYS AUTODYN software.

**Unit I: Introduction**: Fluid-Structure Interactions (FSI), Real world examples of FSI, Models of the Flow, Finite Control Volume, Infinitesimal Fluid Element, The Substantial Derivative, Physical meaning of Divergence of the Velocity, Continuity, Momentum and Energy Equations, Equations for Inviscid Flow (the Euler Equations), Comments on governing equations, Physical Boundary Conditions.

Unit II: Fundamentals of Computational Fluid Dynamics (CFD): Basic aspects of Discretization, Introduction of Taylor series, Finite Difference and Finite Volume formulation of steady/transient one-dimensional conduction equation, Consistency, Convergence and Stability, Temporal Discretisation Explicit Schemes Implicit Schemes

**Unit-III:** Fundamentals of Finite Element Method (FEM): Finite Element Formulation Starting from Governing Differential Equations, Weighted Residual Method, The General Weighted Residual (WR) Statement, Weak (Variational) Form of the Weighted Residual Statement, One-dimensional Finite Element Analysis, One-dimensional Heat Transfer

**Unit-IV: Fluid-structure Coupling and Interface handling:** Fluid-structure coupling algorithm-Partitioned coupling schemes, Arbitrary Euler-Lagrange (ALE) preliminaries, Kinematics, Fluid equations on a moving domain, Structure equations, Strong vs weak coupling

**Unit-V: Introduction to ANSYS AUTODYN**: Introduction to Autodyn, Graphical User Interface (GUI), Basic features of Autodyn, Expilict Dynamics Products, Lagrange Solvers, Euler Solvers, ALE (Arbitrary Lagrange-Euler) Solver, Coupling, Contact and Erosion, Using Autodyn in Workbench and as Standalone, Multi-material Euler Solver, Euler-Blast solver, Rigid, Fully and Weak and Polygon coupling, Introduction of material models

**Unit-VI: ANSYS AUTODYN Exercise Problems**

1. Shaped Charge Impact,

2. Effect of blast in Urban area,
3. Mine blast under a vehicle,
4. Analysis of remotely operated self actuated blast valve,
5. Underwater shock loading of a ship,
6. Penetration of 2000 lbs GP bomb in composite structure,
7. Kinetic Energy Projectile Impact on Reinforced Concrete

**Text books/References:**

1. **Computational Fluid Dynamics the Basics with Applications, Jr., John D. Anderson, ISBN-13: 9780071132107, McGraw Hill Education**
2. Textbook of Finite Element Analysis, P. Seshu, PHI Learning Pvt. Ltd, ISBN: 9788120323155, 9788120323155
3. Computational Fluid-Structure Interaction: Methods and Applications, Yuri Bazilevs, Kenji Takizawa, Tayfun E. Tezduyar, ISBN: 978-0-470-97877-1
4. Arbitrary Lagrangian Eulerian and Fluid-Structure Interaction-eBook, M'hamed Souli, ISBN-13: 9781118618684, Wiley
5. ANSYS AUTODYN User's Manual, ANSYS Inc.

***Course Name- M. Tech. Dissertation Phase– I***
***Course Code- ME 651***

***Course Name- M. Tech. Dissertation Phase– II***
***Course Code- ME 652***

***Course Name- Research Methodology and IPR***
***Course Code- PGC 01***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the fundamentals of research and its methodology |
| **CO-2** | Choose the appropriate research design and develop appropriate research hypothesis for a research project |
| **CO-3** | Knowledge of manuscript preparation, patents and Intellectual property |
| **CO-4** | Technology transfer and application of IPR in various domains |

| Unit | Syllabus Details |
|---|---|
| Unit I: | Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations |
| Unit II: | Effective literature studies approaches, analysis Plagiarism, Research ethics, |
| Unit III | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee |
| Unit IV | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of |

| | |
|---|---|
| | Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. |
| Unit V | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.<br>Patent information and databases. Geographical Indications |
| Unit VI | New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |

**References Textbooks:**

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step-by-Step Guide for beginners"
4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
5. Mayall, "Industrial Design", McGraw Hill, 1992.
6. Niebel, "Product Design", McGraw Hill, 1974.
7. Asimov, "Introduction to Design", Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.
9. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

***Course Name- Audit Course 1 & 2***
***Course Code- PGC 02***
**AUDIT 1 and 2: ENGLISH FOR RESEARCH PAPER WRITING**
**Course objectives:**
Students will be able to:
**1.** Understand that how to improve your writing skills and level of readability
**2.** Learn about what to write in each section
**3.** Understand the skills needed when writing a Title
Ensure the good quality of paper at very first-time submission

**Syllabus**

| **Units** | **CONTENTS** | **Hours** |
|---|---|---|
| **1** | Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness | **4** |
| **2** | Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction | **4** |
| **3** | Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check | **4** |
| **4** | key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, | **4** |

| | | |
|---|---|---|
| | skills needed when writing a Review of the Literature | |
| **5** | skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions | **4** |
| **6** | Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission | **4** |

**Suggested Studies:**

1. Goldbort R (2006) Writing for Science, Yale University Press (available on Google Books)
2. Day R (2006) How to Write and Publish a Scientific Paper, Cambridge University Press
3. Highman N (1998), Handbook of Writing for the Mathematical Sciences, SIAM. Highman's book.
4. Adrian Wallwork, English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011

**AUDIT 1 and 2: DISASTER MANAGEMENT**

**Course objectives:**

Students will be able to:

1. learn to demonstrate a critical understanding of key concepts in disaster risk reduction and humanitarian response.
2. critically evaluate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
3. develop an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
4. critically understand the strengths and weaknesses of disaster management approaches, planning and programming in different countries, particularly their home country or the countries they work in

**Syllabus**

| Units | CONTENTS | Hours |
|---|---|---|
| 1 | **Introduction**<br>Disaster: Definition, Factors And Significance; Difference Between Hazard And Disaster; Natural And Manmade Disasters: Difference, Nature, Types And Magnitude. | **4** |
| 2 | **Repercussions Of Disasters And Hazards**: Economic Damage, Loss Of Human And Animal Life, Destruction Of Ecosystem.<br>Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts And Famines, Landslides And Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks And Spills, Outbreaks Of Disease And Epidemics, War And Conflicts. | **4** |
| 3 | **Disaster Prone Areas In India**<br>Study Of Seismic Zones; Areas Prone To Floods And Droughts, Landslides And Avalanches; Areas Prone To Cyclonic And Coastal Hazards With Special Reference To Tsunami; Post-Disaster Diseases And Epidemics | **4** |
| 4 | **Disaster Preparedness And Management**<br>Preparedness: Monitoring Of Phenomena Triggering A Disaster Or Hazard; | **4** |

| | | |
|---|---|---|
| | Evaluation Of Risk: Application Of Remote Sensing, Data From Meteorological And Other Agencies, Media Reports: Governmental And Community Preparedness. | |
| **5** | **Risk Assessment**<br>Disaster Risk: Concept And Elements, Disaster Risk Reduction, Global And National Disaster Risk Situation. Techniques Of Risk Assessment, Global Co-Operation In Risk Assessment And Warning, People's Participation In Risk Assessment. Strategies for Survival. | **4** |
| **6** | **Disaster Mitigation**<br>Meaning, Concept And Strategies Of Disaster Mitigation, Emerging Trends In Mitigation. Structural Mitigation And Non-Structural Mitigation, Programs Of Disaster Mitigation In India. | **4** |

**Suggested Studies:**

1. R. Nishith, Singh AK, "Disaster Management in India: Perspectives, issues and strategies "'New Royal book Company.
2. Sahni, PardeepEt.Al. (Eds.)," Disaster Mitigation Experiences And Reflections", Prentice Hall Of India, New Delhi.
3. Goel S. L., Disaster Administration And Management Text And Case Studies",Deep &Deep Publication Pvt. Ltd., New Delhi.

**AUDIT 1 and 2: SANSKRIT FOR TECHNICAL KNOWLEDGE**

***Course Objectives***

1. To get a working knowledge in illustrious Sanskrit, the scientific language in the world
2. Learning of Sanskrit to improve brain functioning
3. Learning of Sanskrit to develop the logic in mathematics, science & other subjects
4. enhancing the memory power
5. The engineering scholars equipped with Sanskrit will be able to explore the
6. huge knowledge from ancient literature

***Syllabus***

| **Units** | **CONTENTS** | **Hours** |
|---|---|---|
| **1** | Alphabets in Sanskrit,<br>Past/Present/Future Tense,<br>Simple Sentences | **8** |
| **2** | Order<br>Introduction of roots<br>Technical information about Sanskrit Literature | **8** |
| **3** | Technical concepts of Engineering-Electrical, Mechanical,<br>Architecture, Mathematics | **8** |

***Suggested reading***

1. "Abhyaspustakam" – Dr.Vishwas, Samskrita-Bharti Publication, New Delhi
2. "Teach Yourself Sanskrit" Prathama Deeksha-VempatiKutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
3. "India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi.

***Course Output***

Students will be able to

1. Understanding basic Sanskrit language
2. Ancient Sanskrit literature about science & technology can be understood
3. Being a logical language will help to develop logic in students

**AUDIT 1 and 2: VALUE EDUCATION**

***Course Objectives***

Students will be able to

1. Understand value of education and self- development
2. Imbibe good values in students
3. Let the should know about the importance of character

***Syllabus***

| Units | CONTENTS | Hours |
|---|---|---|
| **1** |  Values and self-development –Social values and individual attitudes. Work ethics, Indian vision of humanism.<br> Moral and non- moral valuation. Standards and principles.<br> Value judgements | **4** |
| **2** |  Importance of cultivation of values.<br> Sense of duty. Devotion, Self-reliance. Confidence, Concentration. Truthfulness, Cleanliness.<br> Honesty, Humanity. Power of faith, National Unity.<br> Patriotism.Love for nature,Discipline | **6** |
| **3** |  Personality and Behavior Development - Soul and Scientific attitude. Positive Thinking. Integrity and discipline.<br> Punctuality, Love and Kindness.<br> Avoid fault Thinking.<br> Free from anger, Dignity of labour.<br> Universal brotherhood and religious tolerance.<br> True friendship.<br> Happiness Vs suffering, love for truth.<br> Aware of self-destructive habits.<br> Association and Cooperation.<br> Doing best for saving nature | **6** |
| **4** |  Character and Competence –Holy books vs Blind faith.<br> Self-management and Good health.<br> Science of reincarnation.<br> Equality, Nonviolence,Humility, Role of Women.<br> All religions and same message.<br> Mind your Mind, Self-control.<br> Honesty, Studying effectively | **6** |

***Suggested reading***

1. Chakroborty, S.K. “Values and Ethics for organizations Theory and practice”, Oxford University Press, New Delhi

***Course outcomes***

Students will be able to
1. Knowledge of self-development
2. Learn the importance of Human values
3. Developing the overall personality

**AUDIT 1 and 2: CONSTITUTION OF INDIA**

**Course Objectives:**

Students will be able to:
1. Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
2. To address the growth of Indian opinion regarding modern Indian intellectuals’ constitutional role and entitlement to civil and economic rights as well as the emergence of nationhood in the early years of Indian nationalism.
3. To address the role of socialism in India after the commencement of the Bolshevik Revolution in 1917 and its impact on the initial drafting of the Indian Constitution.

***Syllabus***

| Units | CONTENTS | Hours |
|---|---|---|
| **1** | **History of Making of the Indian Constitution:**<br>History<br>Drafting Committee, ( Composition & Working) | **4** |
| **2** | **Philosophy of the Indian Constitution:**<br>Preamble<br>Salient Features | **4** |
| **3** | **Contours of Constitutional Rights & Duties:**<br>Fundamental Rights<br>Right to Equality<br>Right to Freedom<br>Right against Exploitation<br>Right to Freedom of Religion<br>Cultural and Educational Rights<br>Right to Constitutional Remedies<br>Directive Principles of State Policy<br>Fundamental Duties. | **4** |
| **4** | **Organs of Governance:**<br>Parliament<br>Composition<br>Qualifications and Disqualifications<br>Powers and Functions<br>Executive | **4** |

| | | |
|---|---|---|
| | President<br>Governor<br>Council of Ministers<br>Judiciary, Appointment and Transfer of Judges, Qualifications<br>Powers and Functions | |
| **5** | **Local Administration:**<br>District's Administration head: Role and Importance,<br>Municipalities: Introduction, Mayor and role of Elected Representative, CEO of Municipal Corporation.<br>Pachayati raj: Introduction, PRI: ZilaPachayat.<br>Elected officials and their roles, CEO ZilaPachayat: Position and role.<br>Block level: Organizational Hierarchy (Different departments),<br>Village level: Role of Elected and Appointed officials,<br>Importance of grass root democracy | **4** |
| **6** | **Election Commission:**<br>Election Commission: Role and Functioning.<br>Chief Election Commissioner and Election Commissioners.<br>State Election Commission: Role and Functioning.<br>Institute and Bodies for the welfare of SC/ST/OBC and women. | **4** |

**Suggested reading**

1. The Constitution of India, 1950 (Bare Act), Government Publication.
2. Dr. S. N. Busi, Dr. B. R. Ambedkar framing of Indian Constitution, 1st Edition, 2015.
3. M. P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis, 2014.
4. D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015.

**Course Outcomes:**

**Students will be able to:**

1. Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
2. Discuss the intellectual origins of the framework of argument that informed the conceptualization of social reforms leading to revolution in India.
3. Discuss the circumstances surrounding the foundation of the Congress Socialist Party [CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
4. Discuss the passage of the Hindu Code Bill of 1956.

**AUDIT 1 and 2: PEDAGOGY STUDIES**

**Course Objectives:**

Students will be able to:

1. Review existing evidence on the review topic to inform programme design and policy making undertaken by the DfID, other agencies and researchers.
2. Identify critical evidence gaps to guide the development.

***Syllabus***

| Units | CONTENTS | Hours |
|---|---|---|
| **1** |  **Introduction and Methodology:**<br> Aims and rationale, Policy background, Conceptual framework and terminology<br> Theories of learning, Curriculum, Teacher education.<br> Conceptual framework, Research questions.<br> Overview of methodology and Searching. | **4** |
| **2** |  Thematic overview: Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries.<br> Curriculum, Teacher education. | **2** |
| **3** |  Evidence on the effectiveness of pedagogical practices<br> Methodology for the in depth stage: quality assessment of included studies.<br> How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy?<br> Theory of change.<br> Strength and nature of the body of evidence for effective pedagogical practices.<br> Pedagogic theory and pedagogical approaches.<br> Teachers' attitudes and beliefs and Pedagogic strategies. | **4** |
| **4** |  Professional development: alignment with classroom practices and follow-up support<br> Peer support<br> Support from the head teacher and the community.<br> Curriculum and assessment<br> Barriers to learning: limited resources and large class sizes | **4** |
| **5** |  **Research gaps and future directions**<br> Research design<br> Contexts<br> Pedagogy<br> Teacher education<br> Curriculum and assessment<br> Dissemination and research impact. | **2** |

**Suggested reading**

1. Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, Compare, 31 (2): 245-261.
2. Agrawal M (2004) Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies, 36 (3): 361-379.
3. Akyeampong K (2003) Teacher training in Ghana - does it count? Multi-site teacher education research project (MUSTER) country report 1. London: DFID.
4. Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count? International Journal Educational Development, 33 (3): 272–282.
5. Alexander RJ (2001) Culture and pedagogy: International comparisons in primary education.

Oxford and Boston: Blackwell.
6. Chavan M (2003) Read India: A mass scale, rapid, 'learning to read' campaign.
7. www.pratham.org/images/resource%20working%20paper%202.pdf.

**Course Outcomes**

Students will be able to understand:

1. What pedagogical practices are being used by teachers in formal and informal classrooms in developing countries?
2. What is the evidence on the effectiveness of these pedagogical practices, in what conditions, and with what population of learners?
3. How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy?

**AUDIT 1 and 2: STRESS MANAGEMENT BY YOGA**

**Course Objectives**

1. To achieve overall health of body and mind
2. To overcome stress

*Syllabus*

| Units | CONTENTS | Hours |
|---|---|---|
| **1** |  Definitions of Eight parts of yog. ( Ashtanga ) | **8** |
| **2** |  Yam and Niyam.<br>Do`s and Don't's in life.<br>i) Ahinsa, satya, astheya, bramhacharya and aparigraha<br>ii) Shaucha, santosh, tapa, swadhyay, ishwarpranidhan | **8** |
| **3** |  Asan and Pranayam<br>i) Various yog poses and their benefits for mind & body<br>ii)Regularization of breathing techniques and its effects-Types of pranayama | **8** |

***Suggested reading***

1. 'Yogic Asanas for Group Tarining-Part-I" :Janardan Swami Yogabhyasi Mandal, Nagpur
2. "Rajayoga or conquering the Internal Nature" by Swami Vivekananda, AdvaitaAshrama (Publication Department), Kolkata

**Course Outcomes:**

Students will be able to:

1. Develop healthy mind in a healthy body thus improving social health also
2. Improve efficiency

**AUDIT 1 and 2: PERSONALITY DEVELOPMENT THROUGH LIFE ENLIGHTENMENT SKILLS**

***Course Objectives***

1. To learn to achieve the highest goal happily
2. To become a person with stable mind, pleasing personality and determination
3. To awaken wisdom in students

*Syllabus*

| Units | CONTENTS | Hours |
|---|---|---|
| **1** | Neetisatakam-Holistic development of personality<br> Verses- 19,20,21,22 (wisdom)<br> Verses- 29,31,32 (pride & heroism)<br> Verses- 26,28,63,65 (virtue)<br> Verses- 52,53,59 (dont's)<br> Verses- 71,73,75,78 (do's) | **8** |
| **2** |  Approach to day to day work and duties.<br> Shrimad BhagwadGeeta : Chapter 2-Verses 41, 47,48,<br> Chapter 3-Verses 13, 21, 27, 35, Chapter 6-Verses 5,13,17, 23, 35,<br> Chapter 18-Verses 45, 46, 48. | **8** |
| **3** |  Statements of basic knowledge.<br> Shrimad BhagwadGeeta: Chapter2-Verses 56, 62, 68<br> Chapter 12 -Verses 13, 14, 15, 16,17, 18<br> Personality of Role model. Shrimad BhagwadGeeta:<br>Chapter2-Verses 17, Chapter 3-Verses 36,37,42,<br> Chapter 4-Verses 18, 38,39<br> Chapter18 – Verses 37,38,63 | **8** |

***Suggested reading***

1. "Srimad Bhagavad Gita" by Swami SwarupanandaAdvaita Ashram (Publication
2. Department), Kolkata
3. Bhartrihari's Three Satakam (Niti-sringar-vairagya) by P.Gopinath,
4. Rashtriya Sanskrit Sansthanam, New Delhi.

***Course Outcomes***

Students will be able to

1. Study of Shrimad-Bhagwad-Geeta will help the student in developing his personality and achieve the highest goal in life
2. The person who has studied Geeta will lead the nation and mankind to peace and prosperity
3. Study of Neetishatakam will help in developing versatile personality of students.

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# SCHOOL OF ROBOTICS

School of Robotics established in 2020 with the purpose of encouraging multidisciplinary advanced research on a common platform combining various cutting-edge technologies such as Robotics, Industry 4.0, Artificial intelligence & Machine Learning, etc. With the goal to develop the innovative solution based interdisciplinary research platform to achieve academic and research excellence for next generation. School of robotics seeks to combine excellence in education and research to provide students with a balance of intellectual and practical experiences that enable them to address a variety of Defence needs of India.

Experimental and computational facilities being continuously upgraded in the school to carry out significant curriculum development work in Robotics relevant fields. Apart from the regular courses the school offers, on a continual basis, a wide variety of short-term intensive programmes for personnel from DRDO laboratories, Armed Forces and industrial establishments. User-oriented M. Tech programmes on Automation and Robotics has been formulated as per the needs of the Defence sector. The Programmes offers a wide choice of specializations, electives and research areas.

**Vision of the School:**

"The School endeavours to become Centre of Excellence in interdisciplinary innovation and research in futuristic technologies in Automation and Robotics to strengthen the defence advancements and self reliance of the nation"

**Mission of the School:**

To impart advanced training, update knowledge, and develop skillset required for R&D, design, development, production, quality assurance, and inspection of efficient and economical equipment/systems of Automation and Robotics technologies for DRDO and Defence Services, other industries and society in large.

**Program Educational Objectives (PEO's):**

**PEO1**: Provide basic and advanced technical knowledge to the students in the field of Automation and Robotics.

**PEO2**: Students should be capable to undertake R&D, inspection, testing and evaluation of equipment/systems of Automation and Robotics and other industries.

**Program Outcomes (POs)**

**PO1**: An ability to independently carry out research /investigation and development work to solve practical problems

**PO2**: An ability to write and present a substantial technical report/document

**PO3**: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

**Program Specific Outcomes (PSOs)**

**PSO1:** The specific outcome of the program is to provide human resources equipped with advanced applied knowledge in the field of Industrial Automation and Robotics to fulfill the needs of DRDO, Army, Navy and Defence PSU's and other industries thereby making the country self-reliance.

**PSO2**: To be able to apply advanced engineering principles and concepts to design of equipment/systems of Industrial Automation and Robotics and other industries within realistic constraints.

**PSO3:** To be able to design and device new procedures to arrive at a solution for design or troubleshooting problems at the system/component level.

## M. Tech. in Automation and Robotics

***Brief Description*:** M.Tech. in Automation and Robotics is an interdisciplinary Masters Programme offered by School of Robotics, which is composed of various branches of Engineering such as Mechanical Engineering, Electrical/Electronics Engineering, Computer science/Information Technology Engineering, and Instrumentation Engineering. Due to increasing impact of smart systems and modernization in human life, the demand for students specialized in multidisciplinary areas such as robotics is growing day by day.

The program is designed for eligible candidates interested in designing, controlling and creating systems of robotics and automation.

***Eligibility:***

1. This programme is open under sponsorship category, for officers of Indian Armed forces (Army, Navy & Air force), Coast Guard, DRDO Scientists, Indian Ordnance Factories, various Defence PSU's (HAL, BEL, BDL, etc). This programme is also open to foreign nationals from the countries approved by GOI.
2. This programme is open under scholarship category for civilian students of any relevant graduation discipline with qualified GATE exam score in Mechanical Engg., Computer Science and Information Technology, Electronics and Communication Engg., Electrical Engg., Aerospace Engg., Instrumentation Engg., Production and Industrial Engg., Bio-medical Engg.

***Organization:*** M. Tech in Automation and Robotics is a four-semester master’s programme. There are six compulsory courses in the first semester along with four compulsory and two elective subjects in the second semester. In each semester, three tests as a part of continuous evaluation and an end semester examination will be conducted for each course. M. Tech dissertation first phase evaluation will be conducted at the end of third semester and at the end of the final semester, students submit their thesis and present their project work, which is evaluated by the Internal as well as External examiners.

***M. Tech Automation and Robotics***

**Semester I**

| S. No. | Course Code | Course | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | SR 601 | Industrial Automation | 3 | 1 | 4 |
| 2 | SR 602 | Introduction to Robotics | 3 | 1 | 4 |
| 3 | SR603 | Sensors, Actuators and Drives | 3 | 1 | 4 |
| 4 | SR 604 | Programming languages for robots | 3 | 1 | 4 |
| 5 | SR 605# Or SR 606## | Introduction to Mechanisms (SR 605) Or Introduction to Electronics Systems (SR 606) | 3 | 1 | 4 |
| 6 | AM 607 | Mathematics for Engineers | 3 | 1 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

**<u>Note:</u>** #SR 605 for (Non – Mechanical students) & ##SR 606 for (Non- Electronics students) compulsory core subject.

**Semester II**

| S. No. | Course Code | Course | Contact hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | SR 607 | Robot Dynamics and control | 3 | 1 | 4 |
| 2 | SR 609 | Industry 4.0 | 3 | 1 | 4 |
| 3 | -- | Department Elective-I | 3 | 1 | 4 |
| 4 | -- | Department Elective-II | 3 | 1 | 4 |
| 5 | -- | Elective-III | 3 | 1 | 4 |
| 6 | -- | Elective-IV | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | **Total** | **20** | **6** | **24** |

**Semester- III**

| S. No. | Course Code | Course | Credits | | Total Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | SR 651 | M.Tech. Dissertation Phase I | 14 | | 14 |
| | | **Total** | **14** | | **14** |

**Semester-IV**

| S. No. | Course Code | Course | Credits | | Total Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | SR 652 | M.Tech. Dissertation Phase II | 14 | | 14 |
| | | **Total** | **14** | | **14** |

****Contact Hours / week :-**

- 1 credit in Theory/Tutorial implies one contact hour and 1 credit in Practice/ Thesis implies two contact hours.

**List of Electives I & II**

| Sr. No. | Course Code | Course Name |
|---|---|---|
| 1 | SR 611 | Advanced Control system |
| 2 | SR 608 | Machine vision & Image Processing for Robots |
| 3 | SR 610 | Automatic Contro System |
| 4 | SR 616 | Field and service Robots |

**List of Electives (III & IV)**

| Sl. No. | Course Code | Course Name |
|---|---|---|

| | | |
|---|---|---|
| 1 | SR 613 | AI & ML for Robotics |
| 2 | SR 612 | Design aspects of automation |
| 3 | SR 614 | Swarm robotics |
| 4 | SR 615 | Introduction to Humanoid Robotics |
| 5 | SR 617 | Aerial Robotics |
| 6 | ME 628 | Design of hydraulic and pneumatic systems |
| 7 | ME 631 | Product design and development |
| 8 | ME 634 | Flexible manufacturing systems |
| 9 | ME 635 | Computer Aided Design and Manufacturing |
| 10 | ME 617 | Kinematics and Dynamics of Machinery |
| 11 | ME 632 | Design Optimization |
| 12 | ME 658 | Additive Manufacturing |
| 13 | ME 659 | Rapid Prototyping |
| 14 | -- | Open elective from other department |

**Notes:**

1. School has to decide which subjects should be offered as Elective I, II in the Semester II.
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

## ***Detailed Contents***
## ***Semester-I***

***Course Name-Industrial Automation***

***Course Code-SR 601***

**Unit I:** Introduction: Automation overview, Requirement of automation systems, Architecture of Industrial Automation system, Introduction of PLC and supervisory control and data acquisition (SCADA). Introduction to communication protocols- Profibus, Field bus, HART protocols.

**Unit II:** Material handling and identification technologies -Overview of material handling systems, Types of material handling equipment, Design of the system, Conveyor system, Automated guided vehicle system, Automated storage systems, Interfacing handling and storage with manufacturing, Overview of Automatic Identification Methods.

**Unit III:** Role of computers in measurement and control, Elements of computer aided measurement and control, man-machine interface, computer aided process control hardware, process related interfaces, Communication and networking, Industrial communication systems, Data transfer techniques, Computer aided process control software, Computer based data acquisition system, Internet of things (IoT) for plant automation.

**Unit IV**: Programmable logic controllers: Programmable controllers, Programmable logic controllers, Analog digital input and output modules, PLC programming, Ladder diagram, Sequential flow chart, PLC Communication and networking, PLC selection, PLC Installation, Advantage of using PLC for Industrial automation, Application of PLC to process control industries.

**Unit V:** Distributed Control System: Overview of DCS, DCS software configuration, DCS communication, DCS Supervisory Computer Tasks, DCS integration with PLC and Computers, Features of DCS, Advantages of DCS.

**Unit VI**: Overview of Industrial automation using robots: Basic construction and configuration of robot, Pick and place robot, Welding robot, Case studies.

**Text Books:-**

1. M.P.Groover, "Automation, Production Systems and Computer Integrated Manufacturing", $5^{th}$ Edition, Pearson Education, 2009.
2. John W. Webb and Ronald A. Reis, "Programmable Logic Controllers: Principles and Applications", 5th Edition, Prentice Hall Inc., New Jersey, 2003.
3. Krishna Kant, "Computer - Based Industrial Control", 2nd Edition, Prentice Hall, New Delhi, 2011.
4. Frank D. Petruzella, "Programmable Logic Controllers", 5th Edition, McGraw- Hill, New York, 2016.

**Reference Books:-**

1. Curtis D. Johnson, "Process Control Instrumentation Technology", 8th Edition, Pearson New International, 2013.
2. Lukas M.P, " Distributed Control Systems", Van Nostrand Reinhold Co., New York, 1986.
3. N. Viswanandham, Y. Narahari, "Performance Modeling of Automated Manufacturing Systems", 1st Edition, 2009.

***Course Name- Introduction to Robotics***

***Course Code-SR 602***

**Unit I:** Introduction to robotics**,** Evolution of Robot, Laws of Robotics, Need of industrial robot: Material transfer application, Machine loading/unloading application and part handling. Introduction to Robot assembly automation, Part joining and Mechanical part mating.

**Unit II** : Different definitions of Robot, classification based on the motion capability, classification based on the configuration, Types and components of Robot, Anatomy, Robot Terminology-Links, joints.

**Unit III** : DOF, Specification of a robot, work volume, work space, work object & MTBF, Robot geometrical configuration (PPP, RPP, RRP, RRR, etc) & Selection of Robots, Control Resolution & Spatial Resolution.

**Unit IV:** Robot work cell, Kinematic systems, spatial descriptions: Position, orientation and frames, Coordinate frames, Mapping between frames (D-H method), translations, rotations and transformations matrices and Homogeneous Transformation Matrix serial and parallel manipulators.

**Unit V:** Inverse Kinematics of Serial and parallel manipulators-geometric method, Analytical method, velocity, velocity propagation, Jacobian, acceleration, Jacobian-force relationship.

**Unit VI:** Trajectory Planning Definition, Introduction to Trajectory planning, General consideration in path description and Generation of motion. Point to point: Straight line path, Trapezoidal motion profile and S curve motion. Polynomial via point Trajectories. Application: Two axis planar mechanism Trajectory planning.

**Text Books:-**

1. S.R. Deb, *Robotics Technology and flexible automation*, Tata Mc Graw Hill publishing company Ltd.
2. John J Craig, *Introduction to Robotics-Mechanics and control*, Pearson publication,2008

3. S K Saha, *Introduction to Robotics*, McGraw Hill Education(India) Private Ltd, 2014.
4. R K Mittal, I J Nagrath, *Robotics and Control*, McGraw Hill Education(India) Private Ltd, 2003.

**References:-**

1. Francis N. Nagy, Andras Siegler, *Engineering foundation of Robotics*, Prentice Hall Inc., 1980.
2. M.P. Groover, Mitchel Weiss, *"Industrial Robotics: Technology, Programming and Applications"(2e),* McGraw Hill , 2012
3. Richard D. Klafter, Thomas. A, ChriElewski, Michael Negin, "*Robotics Engineering an Integrated Approach"*, Prentice Hall of India Pvt. Ltd., 1989
4. Carl D. Crane and Joseph Duffy, "*Kinematic Analysis of Robot manipulation"*, Cambridge University press, 1998.
5. Yoram Koren, "*Robotics",* McGraw Hill, 1992.
6. K. C. Jain and Agarwal L. N. *"Robotics Principles and Practice",* Khanna Publishers, 1997.
7. Yu Kozihev, *"Industrial Robots Handbook",* MIR Publications, 1997.

***Course Name- Sensors, Actuators and Drives***

***Course Code- SR 603***

**Unit I:** Introduction to sensors, classification, transducers - common conversion methods, Principle of operation of sensors, Classification, static characteristics, selection criteria of sensor, signals conditioning, calibration and testing of sensor. Working principle of operation of industrial sensors, displacement sensors, temperature measurement sensors, pressure measurement sensors, Flow measurement sensors.

**Unit II:** Sensors for Robots- Proximity sensors, Ultrasonic, magnetic, light sensors, speed measurement, GPS, LIDAR, IMU motion sensor, radar, gyroscope, shape memory alloy materials, smart sensing, applications.

**Unit III:** Principle of operation of actuators-Hydraulic, Pneumatic, electric, other- fundamental laws, classification, speed torque characteristics of DC motors, induction motors, synchronous motors, Speed control methods and applications.

**Unit VI:** Servo motors, switched reluctance motors, BLDC motors, stepper motor types, universal motor, torque motor, construction, torque- speed characteristics, applications, merits and demerits.

**Unit V:** Power flow control switching, power electronic devices, SCR, V- I, turn on, turn off characteristics, Switching devices triggering methods, PWM methods. Power converters static Kramer drive, static Scherbius drive, stepper motor drives, BLDC drivers, PMAC drivers, switched reluctance motors drives.

**Unit VI:** Components of electric drives, factors affecting choice of drives, fundamental torque equation, speed-torque conventions, steady state stability, multi-quadrant operation of electric drives, load torque components, load equalization, determination of motor power rating, motor duty cycles, electric braking, modes of operation, closed loop control, DC motor control, speed control, position control.

**Text books:**

1. Gopal K. Dubbey*, "Fundamentals of Electric Drives", (2e)*, Narosa Publishers, 2001.
2. M. H. Rashid, "Power electronics, circuits, devices and applications",Pearson publishers,2014.
3. J. B. Gupta, "Theory & performance of Electric Machines", S K Kataria & Sons,2013.

**References:**

1. A.K.Sawhney ,"*A course in Electrical and Electronic measurements and instrumentation*" Dhanpat Rai & Co.Publication.

2. W. Shepherd, and L. N. Hully, *"Power Electronics and Motor control", (2e)*, Cambridge University, 1995.
3. R. Krishnan, *"Electric Motor Drives Modeling, Analysis, and Control", (2e)*, Prentice Hall, 2001

***Course Name- Programming languages for Robots***
***Course Code-SR 604***

**Unit I:** Introduction to fundamentals of programming language, machine-level, assembly, high level languages, data types- declarations, constants, variables, operators and expressions, conditional expressions, programming structures, Input and Output functions, mechanics of running, testing and debugging.

**Unit II:** Robot software functions - coordinate systems, position control, control functions, subroutines, Online programming, off-line programming, advantages of off-line programming, lead through methods - powered lead through, manual lead through, teach pendant, Robot program as a path in space, defining position in space, motion interpolation, applications.

**Unit III:** Introduction to Robot operating system (ROS)- packages, launch files, understanding key concepts-services, actions and nodes, publisher, subscriber & messages, client, server, debugging of nodes, building robot environment, practice examples, sensor interfacing.

**Unit IV:** Basics of MATLAB/python programming, Introduction to Arduino, Interfacing of Arduino with MATLAB, parallel, serial, USB interfacing concepts, robot detection and movement control.

**Unit V:** Introduction to image processing, MATLAB programming - Image segmentation, Image enhancement, image arithmetic and logical operations, feature extraction, disparity map using stereo camera, optical flow based object tracking, collision avoidance using mobile robot, object recognition, pose estimation.

**Unit VI:** Real time applications using Mobile robotics.

**Text books**:-

1. Mikell P. Groover, Mitchell Weiss, Roger N. Nagel and Nicholas G. Odrey, '*Industrial Robotics Technology, Programming and Applications*', McGraw Hill Book company, 1986.
2. Bernard Hodges, *'Industrial Robotics'*, Second Edition, Jaico Publishing House, 1993.
3. R. C. Gonzalez, R. E. Woods and S. L. Eddins, *'Digital Image Processing Using MATLAB'*, Gatesmark Publishing , 2020.

**References:**

1. A.K.Gupta, S K Arora,'*Industrial Automation and Robotics*', University science press,2012

***Course Name- Introduction to Mechanisms (Non Mechanical)***
***Course Code- SR 605***

**Unit I Physical Principles:** Force and Torque, Motion, Newton's Law of Motion, Momentum and Conservation of Momentum, Work, Power and Energy.

**Unit II Simple Machines:** The Inclined Plane, Screw Jack, Gears, Belts and Pulleys, Lever, Wedge, Efficiency of Machines .

**Unit III Machines and Mechanisms**: Planar and Spatial Mechanisms, Kinematics and Dynamics of Mechanisms, Links, Frames and Kinematic Chains, Skeleton Outline, Pairs, Higher Pairs, Lower Pairs and Linkages, Kinematic Analysis and Synthesis.

**Unit IV Kinematics:** Basic Kinematics of Constrained Rigid Bodies, Degrees of Freedom of a Rigid Body, Kinematic Constraints, Constrained Rigid Bodies, Degrees of Freedom of Planar Mechanisms

**Unit V Planar Linkages:** Introduction, Four Link Mechanisms, Cams, Gears: Gear Classification, Gear-Tooth Action, Involute Curve, Terminology for Spur Gears, Condition for Correct Meshing, Ordinary Gear Trains, Planetary gear trains.

**Unit VI Basic Mechanisms:** Straight line mechanisms, Ratchet Mechanism, Overrunning Clutch, Intermittent Gearing, Geneva Wheel mechanism, Universal Joint.

**Practice :**

1. MSC Adams tutorials
2. Basic mechanics/mechanisms tutorials in Python/Matlab
3. Mechanisms Design in Solid works

**Text Books:**

1. Irving H. Shames& GK Mohana Rao, *Engineering Mechanics: Statics and Dynamics*, PEARSON Education, 2006
2. Shingley.J.E. *Theory of Machines and Mechanisms*, 2nd Edition, McGraw Hills Inc, 1995.
3. J.E. Shigley, *Mechanical Engineering Design*, McGraw Hill International,2001.

**Reference books:**

1. P. Beer& Johnson, *Vector Mechanics for Engineers: Statics and Dynamics*, Tata McGraw Hill, New Delhi,2001.
2. Thomas Bevan, *Theory of machines*

***Course Name- Introduction to Electronics Systems (Non Electronics)***
***Course Code- SR606***

**Unit-I: REVIEW SEMICONDUCTOR DEVICES**

Two terminal devices, three terminal devices: BJT, JFET, MOSFET, four terminal devices: SCR, DIAC, TRIAC, photo devices: photo diode, LED, LCD. Half wave rectifier, full wave rectifiers, filter circuits, regulated power supplies: introduction, characteristics, stabilization.

**Unit-II: AMPLIFIERS AND OSCILLATORS**

Transistor as an amplifier, single stage amplifier, multistage amplifier, Class A, B, and C amplifiers. Introduction to operational amplifier, specification and characteristics, application: constant gain, voltage summing, voltage buffer, instrumentation circuits, active filters. Oscillators.

**Unit-III: INTRODUCTION TO COMPUTING**

Number system and code conversion, logic gates, Boolean algebra, combinational circuit design, sequential circuit, flip flops, counters, shift registers, decoder, encoder, MUX, DEMUX, memories, I/O, programmable logic devices, microprocessors and microcontrollers.

**Unit-IV: MEASUREMENTS AND INSTRUMENTS**
Introduction, Analog to Digital converters and Digital to Analog converters, digital multimeter, frequency counters. Sensors: temperature sensor, force and pressure sensor, magnetic field sensor, optical sensor, microwave sensor, acoustic sensor, and image sensor.

**Unit-V: INTRODUCTION TO OTHER ELECTRONIC SYSTEMS**
Analog communication system, digital communication system, wireless communication system, embedded system, real time system, VLSI, RF.

**Text/References:**

1. Robert L Boylestad, Electronic Devices & Circuit Theory, Pearson Education, 11$^{th}$ Edition, 2013.
2. Thomas L. Floyd, Digital Fundamentals, Pearson Education, 11$^{th}$ Edition, 2015.
3. Thomas L. Floyd, Electronic Devices, Pearson Education, 9$^{th}$ Edition, 2012.
4. Jacob Fraden, Handbook of Modern Sensors, Springer, 4$^{th}$ Edition, 2010.


***Course Name-Mathematics for Engineer***
***Course Code-AM 607***

**Unit-I Elements of Probability and Statistics:** Basic concepts of Probability, Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, etc.,).
**Unit-II Components of Operations Research:**
Introduction to Operations Research, Linear programming (Simplex Method, Revised Simplex Method, Dual simplex, Duality theory), Transportation Models.
**Unit-III Linear Algebra:**
General (real) vector spaces, Subspaces, Linear Independence of Vectors, Basis and Dimension, Linear Transformations, Span, Norms, Orthogonal basis and Gram-Schmidt Orthogonalization.
**Unit-IV Ordinary Differential Equations :**
Review of solution methods for first order as well as second order equations, Power Series methods.
Higher Order Linear Equations, Boundary Value Problems for Second Order Equations.
**Unit-V Transform Techniques :**
Overview of Laplace transforms, Fourier Transforms, Z transform.
**Unit-VI Numerical Methods for ODE and P.D.E.:**
Taylor series method – Euler and Modified Euler methods – Runge-Kutta method.
Parabolic, Hyperbolic and Elliptic Equations using finite difference method

**Text/References:**

1. Advanced Engineering Mathematics, 11th Ed, 2010, Erwin Kreyszig, Wiley Eastern.
2. Linear Algebra and its Applications, 4th Ed., 2008, Gilbert Strang, Academic Press.
3. Numerical Methods for Scientists and Engineers, Joe D. Hoffman, Marcel Dekker Inc.
4. Numerical Methods for Engineers, Sixth Edition, Steven Chapra and Raymond Canale, McGraw-Hill Education
5. Elements of Numerical Analysis, 2nd Edition, Radhey S. Gupta**,** Cambridge University Press
6. Numerical Solutions of Partial Differential Equations: An Introduction, 2nd Ed., 2005, K. W. Morton, D. F. Mayers, Cambridge University Press.
7. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.

8. Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
9. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
10. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
11. Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko, 3rd Ed., Vol. 7, 2006, Springer Verlag, New York.
12. .S. Gupta.. Calculus of Variation, Prentice Hall of India Pvt. Ltd.

## Semester II

***Course Name- Robot Dynamics and control***
***Course Code- SR 607***

**Unit I:** Review of Robot Kinematics- Transformations: Joint/Task space, Forward Kinematics, Inverse Kinematics, Jacobians, Trajectory Generation, Serial and Parallel Kinematics.

**Unit II:** Robot Dynamics- Lagrange-Euler Dynamics, Force, Inertia, and Energy, Lagrange's Equations of Motion, Newton's equations of motion, Formulation of robot dynamics, State-Variable Representations, Dynamics of robots with actuators.

**Unit III:** Robot control problems – Regulator problem, tracking problem, controllers. Set point Tracking, Actuator Saturation, Integrator Anti-windup Compensation, Quadratic Optimal control problem.

**Unit IV:** Nonlinear dynamics and control - Lyapunov stability theorem, Robust control, Feedback Linearization Controllers, Lyapunov Designs, Variable-Structure Controllers, Saturation-Type Controllers.

**Unit V:** Inverse dynamics controllers, Force control, Stiffness control, Impedance control, Hybrid Position/Force Control, Reduced state modeling and control, Impedance Control, Stiffness and Compliance, Under-actuated System.

**Unit VI**: Case Studies.

**Text Books:**

1. Francis N-Nagy Andras Siegler, Engineering foundation of Robotics, Prentice HallInc., 1987
2. John J. Craig, Introduction to Robotics Mechanics and Control, Second Edition, Addison Wesly Longman Inc. International Student edition,1999
3. M.P. Groover , Mitchel Weiss, “Industrial Robotics: Technology, Programming and Applications”(2e), McGraw Hill ,2012

**References:**

1. Robert J. Schilling, Fundamentals of Robotics Analysis and Control, Prentice Hall of India Pvt. Ltd.,2000
2. Richard D. Klafter, Thomas. A, Chmielewski, Michael Negin, Robotics Engineering an Integrated Approach, Prentice Hall of India Pvt. Ltd.,1989.
3. M. W. Spong and M. Vidyasagar, Robot Dynamics and Control, John Wiley & Sons, NY, USA, 2004 11
4. P.A. Janaki Raman, Robotics and Image Processing an Introduction, Tata Mc Graw Hill Publishing company Ltd.,1995
5. Bernard Hodges, Industrial Robotics, Jaico Publishing house, 2nd Edition,1993.
6. Tsuneo Yohikwa, Foundations of Robotics Analysis and Control, Prentice Hall of India Pvt. Ltd.,2001.
7. Bijay K.Ghosh, NingXi,T.J.Tarn, Control in Robtics and Automation Sensor-Based integration, Academic Press,1999

***Course name: Industry 4.0***
***Course code: SR 609***

**Unit I:** Introduction to Industry 4.0, Sensing & actuation, Communication, Networking Industry 4.0 Globalization and Emerging Issues, evolution of industrial revolutions, Introduction to Internet-of-Things (IoT), Industrial-Internet-of-Things (IIoT), Internet-of-Services (IoS) and the Internet-of-Everything (IoE).
**Unit II:** LEAN Production Systems, Smart and Connected Business Perspective, Smart Factories Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management.
**Unit III** : Cyber security in Industry 4.0, Basics of Industrial IoT: Industrial Processes, Industrial Sensing & Actuation, Industrial Internet Systems. Industrial IoT Layers: Sensing, Processing, Communication. Communication, Networking. Big Data Analytics and Software Defined Networks. Machine Learning and Data Science.
**Unit IV**: Cyber Physical Systems (CPS)', Advanced Robotics, Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL).Augmented Reality and Virtual Reality, Artifical Intelligence, Big Data and Advanced Analysis
**Unit V**: Industrial IoT for Factories and Assembly Line, Food Industry, Healthcare, Power Plants, Inventory Management & Quality Control, Plant Safety and Security (Including AR and VR safety applications), Facility Management, Manufacturing industry, autonomous vehicles, Applications of UAVs in Industries.
**Unit VI:** Case studies.

**Text/References:**

1. "Industry 4.0: The Industrial Internet of Things", by Alasdair Gilchrist (Apress)
   "Industrial Internet of Things: Cyber manufacturing Systems" by Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat (Springer).

## <u>Elective subjects</u>

***Course Name-Machine Vision and Image Processing***
***Course Code-SR 608***
**Unit I:** Architecture of Robotic vision system, Image acquisition, representation, processing Data Acquisition, Conversion, Transmission and Processing: Inertial sensors, Laser Scanners 2D and 3D, Robot Vision, 3D cameras, filters for removal of noise and, INS, gyroscopes,2D,3D Scanner platforms.
**Unit II:** Image acquisition and analysis, Vision and image sensors, digitization, preprocessing, vision system components, basic optics, basic radiometry, image formats, image noise, image representation, color space, conversion of color spaces.
**Unit III:** Image enhancement, operations on images, noise removal, segmentation, thresholding, edge detection algorithms, morphological operations, image analysis coding and representation of regions, dimensional analysis, feature extraction Fourier transformations, spatial domain techniques, discrete cosine transform to images, image scaling, standard video formats.
**Unit IV:** 3D vision: Perspective projection geometry, pinhole camera model, lens distortion, affine and metric geometry, 2d and 3d geometrical transformations, intrinsic and extrinsic camera parameters,

calibration methods, stereovision, epipolar geometry, triangulation, rotational matrix, fundamental matrix, stereo correspondence algorithms – feature based and correlation based, 3d reconstruction.

**Unit V:** Motion estimation and tracking: Optical flow estimation, the concept of sensor fusion - Kalman filter, Localization and Mapping techniques, object tracking with Kalman filtering, feature extraction & object recognition

**Unit VI:** Case studies/application: Industrial application of vision controlled Robotics systems, industrial robot guidance, demonstration of applications using computer vision toolbox and image processing toolbox.

**Text/References:**


1. Milan Sonka, Vaclav Hlavac, Roger Boyle, *Image Processing, Analysis and Machine Vision", (2/e)*, 1998.
2. Rafael C. Gonzalez, Richard E. Woods, *Digital Image Processing, (2/e),* Pearson education, 2003.
3. Boguslaw Cyganek& J. Paul Siebert, *An Introduction to 3D Computer Vision Techniques and Algorithms*, Wiley, 2009.
4. E.R. Davies, Royal Holloway, *Machine Vision: Theory, Algorithms and Practicalities, (3/e),* University of London, December 2004.
5. R. Jain, R. Kasturi, B. G. Schunck, *Machine Vision*, McGraw-Hill, New York, 1995.
6. P.A. Janaki Raman, Robotics and Image Processing an Introduction, Tata Mc Graw Hill Publishing company Ltd., 1995.


***Course Name-Automatic control system-***

***Course Code- SR 610***

**Unit I:** Automatic Control System: definition and types, performance specifications, Design process, Block diagrams, Laplace transform and transient analysis, closed and open loop systems. Feedback and Feed forward control system.

**Unit II:** Modeling of systems Mechanical, Electrical, hydraulic system block diagram representations, Transfer functions of motors. Block diagram reduction techniques, signal flow graphs.

**Unit III**: Time response analysis, Standard test signals, Static and Dynamic Characteristics of Control Systems- Transient Response for First and second order systems. Time domain specifications, Stability and Steady State Error, Routh  Hurvitz criterion.

**Unit III**: Frequency response analysis, Frequency domain specifications, Polar Plots, Nyquist Criteria systems, stability analysis using Nyquest plots, Gain margin, Phase margin. Experimental determination of transfer function.  Stability Analysis. Root Locus Technique

**Unit IV:** Control Actions and Control System Components- Discrete action, Proportional, Integral and Differential Control Action, Composite action. Characteristics, working and limitations of different types of Comparators and actuators, amplifiers, Servo motors and Control valves.

**Unit V:** Control System Implementations- Pneumatic Systems, Hydraulic Systems, Electrical Systems, Microprocessor Based Systems, Programmable Logic Controllers, Micro Controllers and Network Based Distributed Control Systems.

**Unit VI:** Case Studies.

**Text/References:**


1. Nise, N.S., Control Systems Engineering, 5th Ed., Willey, 2008.
2. Ogata, K., " Modern Control Engineering", 5th Ed., Prentice Hall of India, 2013.

3. Kuo, B.C., “Automatic Control System”, 5th Ed., Prentice Hall of India, 1995.
4. Raven, F.H., “Automatic Control Theory”, 5th Ed., McGraw Hill, 1995

***Course Name: Advanced Control system***

***Course code: SR 611***

**Unit I:** Model Based Controller Design, Control structures and performance measures, Time and frequency domain performance measures, Design of controller, Design of controller for SISO system, Controller design for TITO processes, Limitations of PID controllers, PI-PD controller for SISO system, PID-P controller for Two Input Two Output system, Effects of measurement noise and load

**Unit II:** Frequency Domain Based Identification: Identification of dynamic models of plants, Relay control system for identification, Off-line identification of process dynamics, On-line identification of plant dynamics.

**Unit III:** Time Domain Based Identification: State space based identification, State space analysis of systems, State space based identification of systems -1, State space based identification of systems -2, Identification of simple systems, Identification of FOPDT model, Identification of second order plus dead time model, Identification of SOPDT model,

**Unit IV**: Steady state gain from asymmetrical relay test, Identification of SOPDT model with pole multiplicity, Existence of limit cycle for unstable system, Identification procedures, Identification of under damped systems, Off-line identification of TITO systems, On-line identification of TITO systems,

**Unit V:** Review of time domain based identification, DF based analytical expressions for on-line identification, Model parameter accuracy and sensitivity, Improved identification using Fourier series and wavelet transform, Reviews of DF based identification,

**Unit VI:** Design of Controllers: Advanced Smith predictor controller, Design of controllers for the advanced Smith predictor, Model-free controller design, Model based PID controller design, Model based PI-PD controller design, Tuning of reconfigurable PID controllers

**Text/Reference:**

1. S. Majhi, Advanced Control Theory-Relay Feedback Approach, Cengage Asia/IndiaPvt.Ltd, 2009.2.
2. A. Johnson and H. Moradi, New Identifications and Design Methods, Springer -Verlag, 2005.3.
3. Norman S. Nise, Control Systems Engineering, John Wiley & Sons, 2008.

***Course Name: Design aspect of Automation***

***Course code: SR 612***

**Unit I:** Introduction, Basic concepts, Mechatronics, Design of automated systems, Mechatronics based systems, Automated systems and equipment used in manufacturing, selection and fabrication, selection of electrical and electronics components for Mechatronics based systems,

**Unit II**: terms related to performance of electro mechanical systems, computer aided design of components, fabrication processes, Measurement system and potentiometer sensors, Displacement position and proximity sensor, fluid flow pressure and temperature measurement.

**Unit III:** Signal conditioning and microprocessor technology, signal conditioning, amplification, filtering, pulse modulation, protection devices and wheastone bridge, signal conversion, microprocessor technology, introduction to microprocessor programming,

**Unit IV**: Electrical drives, application of electric drives in automation, DC and AC motors, stepper motor and servo motor, Mechanisms: types of industrial automation mechanisms, Ball screw based linear motion drives,

**Unit V**: Application of camsin automation, Application of indexing mechanisms in automation, Application of tool magazine in automation, material handling systems, Hydraulic systems, fundamental concepts, hydraulic pumps, Control valves and graphical representation, direction control valves, flow control and pressure relief valves, graphical representation of hydraulic system elements,

**Unit VI**: Pneumatic systems, basic concepts and air compressors, air treatment and pressure regulation, graphical representation and pneumatic circuits, computer aided manufacturing and process planning, CNC machine and interpolation.

**Text books**


1. Bishop, R. H. (Ed.). (2017). "*Mechatronics: an introduction*", CRC Press.
2. Ogata, K. (2004). *System dynamics* (Vol. 13). Upper Saddle River, NJ: Pearson/Prentice Hall.


**Reference**


1. Bernard Hodges, "*Industrial Robotics*", Jaico Publishing house, 2nd Edition,1993.
2. Richard D. Klafter, Thomas. A, Chmielewski, Michael Negin, "*Robotics Engineering an Integrated Approach*", Prentice Hall of India Pvt. Ltd.,1989.


***Course Name: AI & Machine Learning in Robotics***

***Course Code: SR613***

**Unit I:** Introduction to AI: Knowledge-based intelligent systems, rule based expert systems-search methods-uncertainty management in rule-based expert systems, Introduction to uncertainty, basic probability theory, Bayesian reasoning, certainty factor.

**Unit II:** Foundation of machine learning, applications of machine learning, model of neuron in artificial neural networks, activation function, back propagation to train neural network.

**Unit III:** Overview of machine learning approaches: unsupervised, supervised, semi-supervised, reinforcement, Linear regression and classification: gradient descent, support vector machine, k nearest neighbor, and other classifiers.

**Unit IV:** Introduction of deep neural network, convolution neural network (CNN): convolution operations, pooling, flattening, building a CNN.

**Unit V:** Clustering: k-mean, self-organizing maps, other clustering algorithms.

**Unit VI:** Reinforcement learning, case studies in the area of robotics.

**Text/ Reference Books:**


1. Artificial Intelligence: a modern approach, Stuart Russell & Peter Norvig, Prentice Hall, 3rd Edition, 2009.
2. Artificial Intelligence, E. Rich and K. Knight, 2nd ed., McGraw-Hill, New York, 1991.
3. An Introduction to Neural Network, J. A. Anderson, MIT Press, 1995.
4. Self-Organizing Maps, T. Kohonen, Springer.
5. Introduction to AI Robotics, Robin R. Murphy, MIT Press, 2000.
6. Artificial intelligence: a modern approach, Stuart Russell and Peter Norvig, 2002.

***Course name- Swarm Robotics***
***Course code-SR 614***

**Unit I:** Swarm Intelligence - from computational to physical intelligence, Introduction, Definition, Ant Colony Optimization, Biological Inspiration Computationally Hard Path Planning problems, The Ant Colony Optimization Meta-heuristic, Ant System (AS), Ant Colony System (ACS) and Max-Min Ant System.

**Unit II:** Particle Swarm Optimization, Biological inspiration, Convergence Evolutionary Algorithms, Genetic representation of a problem.

**Unit III:** Neural network: Biological background, A single layer perception, Multilayer perception, Recurrent neural network, Training of neural networks. Self-organization in physical system, Swarm intelligence in robotics systems, Robotic material

**Unit IV:** Designing algorithm for embodied swarm intelligence, topology and algorithm specification, PSO tuning,

**Unit V:** Task allocation, Optimal task allocation, Response threshold task allocation, Market based algorithms

**Unit VI:** Synchronization of computational systems with communication delays, case studies

**Text/Reference:**


1. Swarm Intelligence: From natural to artificial systems. E. Bonabeau, G. Theraulaz, and M. Dorigo, 1999.
2. Self-Organization in Biological Systems, Camazine, Deneubourg, Franks, Sneyd, Theraulaz, Bonabeau, 2003.
3. Floreano, Dario, and Claudio Mattiussi. Bio-inspired artificial intelligence: theories, methods, and technologies. MIT press, 2008.
4. Decentralized Spatial Computing, M. Duckham, Springer, 2013


***Course Name- Introduction to Humanoid Robotics***
***Course Code- SR 615***

**Unit I:** Introduction to Humanoid Robotics, Understanding of specific properties of humanoid robots, and state-of-the-art, Kinamatic equation for basic robot systems- Coordinate transforms, Homogeneous transforms Characteristics of Rotational Motion. Velocity in Three Dimensional Space. Robot Data Structure and Programming, Kinematics of a Humanoid Robot.

**Unit II:** Biped locomotion fundamentals- Configuration of legged Robots, Terminologies of locomotion- Single support phase, double support phase, support polygon, Gait pattern, Gait stability criteria, Static and dynamic stability of humanoid robot systems, ZMP and Ground Reaction Forces, Measurement of ZMP Dynamics of Humanoid Robots Humanoid Robot Motion. Angular Momentum and Inertia Tensor of Rigid Body.

**Unit III:** Two Dimensional Walking Pattern Generation, Two Dimensional Inverted Pendulum, Planning a Simple Biped Gait, Extension to a Walk on Uneven Terrain, ZMP Based Walking Pattern Generation, Stabilizer-Principles of Stabilizing Control, reconfiguration of legged robots.

**Unit IV:** Hardware for humanoid Robots, Robot vision, behavior based robotics, Human robot interaction and social Robotics, learning for intelligent robotic manipulator, cognitive intelligence for Human-robot teaming

**Unit V:** Humanoid applications in healthcare, teaching, military, space, agriculture.

**Unit VI:** Real life Case studies.

**Text Books:-**

1. Shuuji Kajita·Hirohisa Hirukawa Kensuke Harada·Kazuhito Yokoi, “*Introduction to Humanoid Robotics*”, springer,2014.

**References:**

1. Ambarish Goswami Prahlad Vadakkepat, “*Humaniod Robotics*”,Springer reference,2019

***Course Name- Field and service Robots***

***Course Code-SR 616***

**Unit I Introduction to Field and service robots**: History of service robotics – Present status and future trends – Need for service robots – applications examples and Specifications of service and field Robots. Non conventional Industrial robots. Classification, applications, sensing and perception, social and ethical implications of robotics

**Unit II Autonomous Mobile robots:** Kinematics, locomotion, perception, motion planning and control, localization and mapping. Road map path planning, intelligent unmanned vehicles. Wheeled and legged, Legged locomotion and balance, Arm movement, Gaze and auditory orientation control, Facial expression, Hands and manipulation, Sound and speech generation, Motion capture/Learning from demonstration, Human activity recognition using vision, touch, sound, Vision, Tactile Sensing, Models of emotion and motivation. Performance, Interaction, Safety and robustness

**Unit III: Field Robots:** Collision Avoidance-Robots for agriculture, mining, exploration, underwater, civilian and military applications, nuclear applications, Space applications. Industrial applications like cleaning robots, wall painting robots, wall plastering robots, vehicle equipment and building robots, etc. Load carrying robots. IDE detection and diffusion robots

**Unit IV: Underwater robots**: Kinematics and dynamics, modeling and simulation, navigation, guidance and control. Marine data collection (Temperature, other environment parameters)

**Unit V: Aerial robots**: Basics of aerial robots, sensors and actuators, modelling and control of small Unmanned Aerial vehicles, guidance and navigation of small range aerial robots, Autonomous indoor flight control Air defence robots.

**Text Books:**

1. Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza, Introductionto Autonomous Mobile Robots, Bradford Company Scituate, USA, 2004
2. Riadh Siaer, The future of Humanoid Robots- Research and applications, Intech Publications,20

**Reference books:**

1. Richard D Klafter, Thomas A Chmielewski, Michael Negin, "*Robotics Engineering AnIntegrated Approach*", Eastern Economy Edition, Prentice Hall of India PLtd. ,2006.
2. Kelly, Alonzo; Iagnemma, Karl; Howard, Andrew, *Field and Service Robotics*, Springer,2011.

***Course Name- Aerial Robotics***

***Course Code- SR 617***

**Unit I:** Introduction of unmanned aerial robotics, different type of multi-rotor UAV configurations.

**Unit II:** Reference frames, Rotational matrices, UAV-kinematics.

**Unit III :**UAV-forces and moments, UAV dynamics, Six-degree-of-freedom equations of motion, stability derivatives, trim conditions, linearization, longitudinal dynamics, lateral dynamics.

**Unit IV:**UAV sensors and actuators, longitudinal autopilot (pitch-rate damping, pitch hold, altitude hold, velocity hold), lateral autopilot (yaw-rate damping, roll hold, heading hold, coordinated turn, turn compensation)

**Unit V :** State-space model of LTI system, eigen value-eigenvectors, modalde composition, transfer function models, first and second-order systems, time response, frequency response, root locus, bode plot

**Unit VI :** Vision-based navigation, waypoint following.

**Text Books:**

1. Small Unmanned Aircraft: Theory and Practice, R. W. Beard and T. M. Mclain, first edition.
2. Automatic control of aircraft and missiles, John H. Blakelock, second edition.
3. Linear control systems: Analysis and Design, J. J. D'Azzo, C. H. Houpis and S.N. Sheldon, fifth edition.

**Reference Book:**

1. Modern Control Engineering, K. Ogata, fifth edition.

***Course Name -Design of Hydraulic and Pneumatic Systems***

***Course Code-ME628***

**Unit I:** Hydraulic System & Components-Sources of Hydraulic Power: Pumping theory – Pump classification – Gear pump, Vane Pump, piston pump, construction and working of pumps – pump performance – Variable displacement pumps.

**Unit II:** Fluid Power Actuators: Linear hydraulic actuators – Types of hydraulic cylinders – Single acting, Double acting special cylinders like tanden, Rodless, Telescopic, Cushioning mechanism, Construction of double acting cylinder, Rotary actuators – Fluid motors, Gear, Vane and Piston motors

**Unit III:** Design of Hydraulic Circuits-Construction of Control Components : Director control valve – 3/2 way valve – 4/2 way valve – Shuttle valve – check valve – pressure control valve – pressure reducing valve, sequence valve, Flow control valve – Fixed and adjustable, electrical control solenoid valves, Relays, ladder diagram.

**Unit IV:** Accumulators and Intensifiers: Types of 89 accumulators – Accumulators circuits, sizing of accumulators, intensifier – Applications of Intensifier – Intensifier circuit.

**Unit V:** Pneumatic Systems and Components-Pneumatic Components: Properties of air – Compressors – Filter, Regulator, and Lubricator Unit – Air control valves, Quick exhaust valves, and pneumatic actuators. Fluid Power Circuit Design, Speed control circuits, synchronizing circuit, Penumo hydraulic circuit, Sequential circuit design for simple applications using cascade method.

**Unit V:** Design of Pneumatic Circuits-Servo systems – Hydro Mechanical servo systems, Electro hydraulic servo systems and proportional valves. Fluidics – Introduction to fluidic devices, simple circuits, Introduction to Electro Hydraulic Pneumatic logic circuits, ladder diagrams, PLC applications in fluid power control. Fluid power circuits; failure and troubleshooting.

**Text Books:**

1. Anthony Esposito, Fluid Power with Applications, Pearson Education 2000.
2. Majumdar S.R., Oil Hydraulics, Tata McGraw-Hill, 2000.
3. Johnson, James L., Introduction to Fluid Power, Delmar Publishers, 2003 Reference Books:
4. Majumdar S.R., Pneumatic systems – Principles and maintenance, Tata McGraw Hill, 1995

5. Harry L. Stevart D.B, Practical guide to fluid power, Taraoeala sons and Port Ltd. Broadey, 1976.
6. Michael J, Prinches and Ashby J. G, Power Hydraulics, Prentice Hall, 1989.
7. Dudelyt, A. Pease and John T. Pippenger, Basic Fluid Power, Prentice Hall, 1987.

***Course Name- Product Design and Development.***
***Course Code- ME 631***

**Unit I: Introduction-** Significance of product design, product design and development process, sequential engineering design method, the challenges of product development,

**Unit II: Product Planning and Project Selection-** Identifying opportunities, evaluate and prioritize projects, allocation of resources Identifying Customer Needs: Interpret raw data in terms of customers need, organize needs in hierarchy and establish the relative importance of needs.

**Unit III: Product Specifications-** Establish target specifications, setting final specifications, Concept Generation: Activities of concept generation, clarifying problem, search both internally and externally, explore the output.

**Unit IV: Industrial Design-**Assessing need for industrial design, industrial design process, management, assessing quality of industrial design, Concept Selection:Overview, concept screening and concept scoring, methods of selection.

**Unit V: Theory of inventive problem solving (TRIZ)-**Fundamentals, methods and techniques,
General Theory of Innovation and TRIZ, Value engineering Applications in Product development and design, Model-based technology for generating innovative ideas

**Unit VI: Concept Testing-** Elements of testing: qualitative and quantitative methods including survey, measurement of customers' response. Intellectual Property- Elements and outline, patenting procedures, claim procedure, Design for Environment-Impact, regulations from government, ISO system.

**Text/Reference books:-**

1. Ulrich K. T, and Eppinger S.D, *Product Design and Development*, Tata McGraw-Hill Education, 2003
2. Otto K, and Wood K, *Product Design*, Pearson, 2001.
3. By Semyon D. Savransky, *Engineering of creativity: Introduction to TRIZ methodology of inventive Problem Solving*, CRC Press, Aug 29, 2000.
4. Michael A. Orloff, *Inventive thinking through TRIZ: a practical guide*, Springer Verlag, 2003.
5. John Terninko, AllaZusman, *Systematic innovation: an introduction to TRIZ; (theory of inventive Problem Solving)*, CRC Press., Apr 15, 1998.

***Course Name- Flexible Manufacturing Systems***
***Course Code- ME634***

**Unit I:** Definition of an FMS-need for FMS, types and configuration, types of flexibilities and performance measures. Economic justification of FMS. Development and implementation of FMS-planning phases, integration, system configuration, FMS layouts, simulation

**Unit II:** Functions, types, analysis of material handling systems, primary and secondary material handling systems-conveyors, Automated Guided Vehicles-working principle, types, traffic control of AGVs. Role of robots in material handling.

**Unit III:** Automated storage systems- storage system performance - AS/RS-carousel storage system, WIP storage systems, interfacing handling and storage with manufacturing - Planning, scheduling and computer control of FMS, Hierarchy of computer control, supervisory computer.

**Unit IV:** DNC system- communication between DNC computer and machine control unit, features of DNC systems - System issues, types of software - specification and selection- trends-application of simulation and its software, Manufacturing Data systems- planning FMS data base.

**Unit V :** Modelling of FMS- analytical, heuristics, queuing, simulation and petrinets modeling techniques - Scheduling of operations on a single machine- two machine flow shop scheduling, two machine job shop scheduling - three machine flow shop scheduling- scheduling 'n' operations on 'n' machines, knowledge based scheduling, scheduling rules, tool management of FMS, material handling system schedule.

**Texts /References:**

1. N K Jha, *Handbook of Flexible Manufacturing Systems*, Academic Press,2012.
2. Raouf, M. Ben-Daya, *Flexible Manufacturing Systems: Recent Developments*, Elsevier,09-Feb-1995.

***Course Name- Computer aided design and manufacturing***
***Course Code-ME 635***

**Unit I:** Criteria for selection of CAD workstations, Shigle Design Process, Design criteria, Geometric modeling, entities, 2D & 3D Primitives. 2D & 3D Geometric Transformations: Translation, Scaling, Rotation, Reflection and Shearing, concatenation.

**Unit II:** Graphics standards: GKS IGES, PDES. Wire frame modeling: Curves: Curve representation. Analytic curves – lines, Circles, Ellipse,Conis.Syntheticcurves–Cubic,Bezier,B-Spline,NURBS-Surfaceentities,Surface Representation.

**Unit III:** Analytic Surface – Plane Surface, Ruled Surface, Surface of Revolution, Tabulated Cyliner. Synthetic Surface-Cubic, Bezier, Bspline, Coons - Graph Based Model, Boolean Models, Instances, Cell Decomposition & Spatial – Occupancy Enumeration, Boundary Representation (B-rep) & Constructive Solid Geometry (CSG)

**Unit IV:** Feature Based Modeling, Assembling Modeling, Behavioral Modeling, Conceptual Design & Top Down Design.

**Unit V:** Capabilities of Modeling & Analysis Packages such as solid works, Unigraphics, Ansys, Hypermesh. Computer Aided Design of mechanical parts and Interference Detection by Motion analysis.

**Text/Reference:**

1. M Groover and E. Zimmers, CAD/CAM: *Computer-Aided Design and Manufacturing*, Pearson Education,1983.
2. A J Medland, *CAD/CAM in Practice*, Springer science and media,2012

| | |
|---|---|
| Course Code | **PGC-601** |
| Course Name | **Research Methodology and IPR** |
| L – T – P - C | **2 – 0- 0 – 2** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **PGC/All Departments DIAT** |

| |
|---|
| Course Outcomes: After completing this course, the students will be able to:<br>CO1: Understanding the fundamentals of research and its methodology<br>CO2: Choose the appropriate research design and develop appropriate research hypothesis for a research project<br>CO3: Knowledge of manuscript preparation, patents and Intellectual property<br>CO4: Technology transfer and application of IPR in various domains. |
| **Course Contents** |
| Unit I: Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations<br>Unit II: Effective literature studies approaches, analysis Plagiarism, Research ethics,<br>Unit III Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and<br>assessment by a review committee<br>Unit IV Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.<br>Unit V Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.<br>Patent information and databases. Geographical Indications<br>Unit VI New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |
| **Texts / References** |
| Stuart Melville and Wayne Goddard, “Research methodology: an introduction for<br>science & engineering students’”<br>Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”<br>Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for<br>beginners”<br>Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd,2007.<br>Mayall, “Industrial Design”, McGraw Hill, 1992.<br>Niebel, “Product Design”, McGraw Hill, 1974.<br>Asimov, “Introduction to Design”, Prentice Hall, 1962.<br>Robert P. Merges, Peter S. Menell, Mark A. Lemley, “ Intellectual Property in New Technological Age”, 2016.<br>T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008 |

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|---|---|
| Course Code | **PGC-602** |
| Course Name | **Audit Course** |
| L – T – P - C | **2 – 0- 0 – 0** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |

| Offered by (Name of Department/ Centre ) | **PGC/All Departments DIAT** |
|---|---|
| Unit I: English for Research Paper Writing<br>Unit II: Disaster Management<br>Unit II: Sanskrit for Technical Knowledge<br>Unit IV: Value Education<br>Unit V: Constitution of India<br>Unit VI: Pedagogy Studies<br>Unit VII: Stress Management by Yoga<br>Unit VIII: Personality Development through Life Enlightenment Skills | |

# SCHOOL OF COMPUTER ENGINEERING AND MATHEMATICAL SCIENCES

In the vibrant landscape of technological digital advancement, the **School of Computer Engineering and Mathematical Sciences** (SoCE&MS) emerged in 2022 as a beacon of innovation and progress. Born with the fusion of the **Department of Computer Science and Engineering (CSE),** the **Department of Applied Mathematics (AM)** and **Data Centre**, the mission is to pioneer breakthroughs in the realm of Computing and Mathematical Sciences. The CSE, our trailblazing department was founded in 1987, with first MTech course offered in 2009; while AM has been integral part of our institute's history since its inception. We stand on the shoulders of this rich legacy as to strengthen and apply modern-digitization, as a step into a future defined by innovation, critical thinking and scientific excellence.

As SoCE&MS, we offer a tapestry of **FIVE Post-Graduation academic programs** and research ventures, a testament of our commitment to diversity and multi-disciplinarity. From M.Tech., MS by Research, M.Sc., to Ph.D programs are tailored for scientists of R&D organizations, officers of Tri-Services, GATE-Qualified candidates, & self-financed scholars, our offerings are diverse as the ever-evolving world of technology. Among our flagship **M.Tech. programs** are **Modelling & Simulations, CSE (Artificial Intelligence), Data Sciences,** and **Cyber Security.** The School has extended its arms to science graduates with the introduction of M.Sc. in Data Science in 2023.

Our dynamic community comprises approximately 160 post-graduate students per year; fueled by the boundless curiosity of successful 21 Ph.D. completions. They thrive an ecosystem that fosters creativity and explorations, where the cutting-edge laboratories, state-of-art equipment, and a stellar faculty beacon them into the world of tomorrow's technological needs. Our 13 faculty members luminaries in fields ranging from Cyber Security, Artificial Intelligence, and Data Sciences to Ethical hacking, Cryptography, Computational Fluid Dynamics, Image Processing, and the rigorous mathematics.

Research in SoCE&MS isn't just a buzzword; its our heartbeat. We are on the forefronts of cutting-edge research, impart trainings, actively managing funded projects and ahead in revenue generations. The School has received accolades for recognitions via patents & publications; in various national level hackathons; national & international conferences & seminars, Sports & Cultural events. The SoCE&MS is the driving force behind the Data Centre activities, facilitating internet access, email service, and web hosting for DIAT.

The SoCE&MS's dedication extends beyond the walls of DIAT. We are championing ATMA-NIRBHAR BHARAT INDIA@75 with PAN-INDIA Certification Courses in Artificial Intelligence & Cyber Security. The customized programs for Tri-Services and other national organizations underscore our commitment to empowerment and growth to build self-reliant nation. With resounding emphasis on research, interdisciplinary collaborations, and a global outlook, SoCE&MS stands tall as the vanguard of education, charting the course for a brighter future, to build self-reliant and sustainable nation. The aspiring candidates are welcome to the SoCE&MS where innovation know no bounds!

**Institute Vision**

To be a Center of Excellence of international repute for Education, Training and research in Advanced Technologies with a view to strengthen national security and self reliance.

**Institute Mission**

To evolve as an Innovative Unique Research University to develop indigenous contemporary Defence related technologies in Navigation Systems, Wireless Sensors, Efficient Propulsion Systems, Weapon Systems for DRDO and Defence Services, provide technological solutions to the Services to optimize combat battlefield effectiveness and above all produce qualified quality manpower which can truly become an instrument for building a strong indigenous technology base in the context of creating a performing Defence Industrial Base in India.

**Our Vision**
To be a Center of Excellence of International repute to provide high-quality education, research, and training in the area of Modelling & Simulation (M&S), Data Science (DS), Cyber Security (CS) and Artificial Intelligence (AI) to promote innovation and entrepreneurship skills among the students with a view to strengthen national security and self-reliance.

**Our Mission**

| | |
|---|---|
| M1 | To build strong education, teaching and research environment in the field of Modelling & Simulation (M&S), Data Science (DS), Cyber Security (CS) and Artificial Intelligence (AI) to meet requirements from Defence, specially related to national security. |
| M2 | To strive for continuous learning, innovation, entrepreneurship and quality research culture amongst the student community through effective government, industry & academia collaboration. |
| M3 | To encourage ethics, team work and technological leadership skills among students to solve complex engineering problems collaboratively by imparting strong theoretical foundation complemented with extensive practical training. |
| M4 | Engage with industry, government, DRDO, Tri-services and PSUs to transfer knowledge and technology, and to contribute to the social and economic development of our region and beyond. |

## M.Tech. in Cyber Security

**Introduction**:
Communication networks and information systems have become an essential factor in economic, social development and almost in every facet of our daily lives. Information systems are vulnerable to one or more types of cyber attacks. The security of communication networks and information systems and their availability in particular, is therefore of increasing concern. In general, cyber security threats are increasing rapidly, the incidents range from defaced websites to theft of large volumes of intellectual property and money, to even Internet crimes. Cyber security is now a prominent field of study. Professionals who are trained in this field are highly regarded and contribute to strengthening the social, political and financial fabric of modern society.
The domain of cyber security refers to the collection of tools, policies, security concepts, guidelines, risk management approaches, actions, training, best practices, assurance and technologies that can be used to protect the cyber environment, organization and user’s assets. To survive in an Information Centric Warfare scenario, the tools and techniques of cyber security will provide mechanisms to safeguard the critical systems against related threats & attacks.

**Eligibility**: Full-time B.E./B.Tech. in Computer science/Electronics/Electrical/Electronics and Communications/Telecommunications/Information Technology/or equivalent discipline or Full-time M.Sc. in Computer Science/Maths or equivalent discipline with valid GATE score in CS/ECE.

**Organization:** The programme curriculum has been designed considering the Cyber Security requirements of Industry and Defence Research and Development. It is designed and reviewed by panel of experts chosen from various DRDO labs and leading academic institutions. The course work includes subjects (Core and Elective) such as Data Security and Privacy, Advanced System Security, Applied Cryptography, Security Standards and Penetration Testing, Digital Forensics, Reverse Engineering and Malware Analysis, Network and Cloud Security, Cyber Physical Systems, and others related subjects to Cyber Security.

Each subject of 4 credits is delivered by subject experts through the duration of 16 weeks approximately. It consists of 3 Hrs of class room interaction and 2 Hrs of lab sessions per week. The evaluations follow continuous assessment process that includes – 3 monthly evaluation exams (10 Marks each), internal assessment (20 Marks) and final examination (50 Marks). The lab focuses on practical exposure to the Cyber Security tools and techniques in form of mini projects and lab assignments. The 3rdand 4th semesters have a major component of M.Tech. project dissertation, where the students work under close supervision and guidance of their project guide. The students present their work at the end of 3rd and 4th semester. The M.Tech. thesis is submitted and evaluated by the panel of expert examiners at the end of 4th semester.

**Program Educational Objectives (PEOs)**

**PEO1** The M.Tech. Computer Science and Engineering aims at developing skilled Human Resources in the field of Cyber Security and Artificial Intelligence by providing two different specializations, catering the emerging multidisciplinary problem solving needs of defense, civil and DRDO sectors.

**PEO2** The M.Tech. in Cyber Security(CS) programme aims at developing skilled Human Resources in the field of Cyber Security with a thrust on solving defence and society related problems. The present programme is conceived to understand, assimilate & use the advanced technologies such as Network security, Cryptography, Ethical Hacking, Digital Forensic, Malware Analysis, Information Security Management and Trusted Computing techniques. After completing this course, students are expected to understand and practice the essential CS concepts along with developing secure systems.

**PEO3** The M.Tech. Computer Science and Engineering with specialization in Artificial Intelligence programme aims at developing skilled Human Resources in the field of AI with a thrust on solving defence and society related problems. The present programme is conceived to understand, assimilate & apply the advanced technologies such as deep learning, robotics, machine learning, computer vision, video surveillance, text analytics, speech analytics etc. After completing this course, students are expected to understand and practice the essential AI concepts along with developing AI based systems to solve society/defence related problems, carry out research and innovation.

**Program Outcomes (PO)**

**PO1** The M.Tech. Computer Science and Engineering aims at developing an ability in students to independently carry out research /investigation and development work to solve practical problems

**PO2** The M.Tech. Computer Science and Engineering aims at developing an ability in students to write and present a substantial technical report/document

**PO3** The M.Tech. Computer Science and Engineering students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

**Program Specific Outcomes (PSO)**

**PSO1** The M.Tech. Computer Science and Engineering aims at developing skilled knowledgeable Human task force in the field of Cyber Security, catering the needs of defence, social and DRDO requirements

**PSO2** The M.Tech. Computer Science and Engineering aims at developing skilled knowledgeable Human task force in the field of Artificial Intelligence, catering the needs of defence, social and DRDO requirements.

**SEMESTER I**

| Sl. No. | Course Code | Course | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | **L** | **T/P** | |
| 1 | CE-694A | Data Security & Privacy | 3 | 1 | 4 |
| 2 | CE-665A | Security Standards & Penetration Testing | 3 | 1 | 4 |
| 3 | CE-663 | Applied Cryptography | 3 | 1 | 4 |
| 4 | CE-662A | Advanced System Security | 3 | 1 | 4 |
| 5 | CE-684 | Digital Forensic | 3 | 1 | 4 |
| 6 | AM-607 | Mathematics for Engineers | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

**SEMESTER II**

| Sl. No. | Course Code | Course | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | **L** | **T/P** | |
| 1 | CE-664A | Network and Cloud security | 3 | 1 | 4 |
| 2 | CE-694 | Cyber Physical Systems | 3 | 1 | 4 |
| 3 | | Elective – I (From CSE) | 3 | 1 | 4 |
| 4 | | Elective – II (From CSE) | 3 | 1 | 4 |
| 5 | | Elective – III | 3 | 1 | 4 |
| 6 | | Elective – IV | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | - | - | - |
| | | **Total** | **18** | **6** | **24** |

**SEMESTER III**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | **L** | **T/P** | |
| 1 | CE-651 | M.Tech. Dissertation Phase I | 28 | | 14 |
| | | **Total** | **28** | | **14** |

**SEMESTER IV**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | **L** | **T/P** | |
| 1 | CE-652 | M.Tech. Dissertation Phase II | 28 | | 14 |
| | | **Total** | **28** | | **14** |

**List of Audit Subjects (Applicable for Sem - II):**

| Sr.No. | Course Code | Course |
|---|---|---|
| 1. | **PGC-602** | English for Research Paper Writing |
| 2. | | Disaster Management |
| 3. | | Sanskrit for Technical Knowledge |
| 4. | | Value Education |
| 5. | | Constitution of India |
| 6. | | Pedagogy Studies |
| 7. | | Stress Management by Yoga |
| 8. | | Personality Development through Life Enlightenment Skills |

**List of Open Electives:**

| Sr.No. | Course Code | Course |
|---|---|---|
| 1. | CE 669 | Reverse Engineering & Malware Analysis |
| 2. | CE 681 | Mobile Computing |
| 3. | CE 683 | Information Warfare |
| 4. | CE 689 | Fault Tolerant Computing Systems |
| 5. | CE 690 | Parallel & Distributed Systems |
| 6. | CE 691 | Secure Wireless Sensor Networks |
| 7. | CE 667 | Trustworthy Computing |
| 8. | CE 688 | Game Theory |
| 9. | CE 692 | Computational Geometry & Applications |
| 10. | CE 694 | Big data Analysis & Algorithms |
| 11. | CE 695 | Cyber-Physical & Self-Organising Systems |
| 12. | CE 69F | Theory of Computation |
| 13. | CE 697 | Biometric Security |
| 14. | CE 698 | Multimedia Security |
| 15. | CE 699 | Internet of Things |
| 16. | CE 69B | Network Forensics |
| 17. | CE 604 | Computational Intelligence |
| 18. | CE 632 | Computer Vision |
| 19. | CE 70A | Formal Specification and Verification of Programs |
| 20. | CE 70B | Advanced Algorithms |
| 21. | CE 700 | Quantum Computing |
| 22. | CE 70D | Computer Network Audit & Forensics |
| 23. | CE 70E | Machine Learning in Python |
| 24. | CE 70F | Cloud Computing |
| 25. | CE 70G | Blockchain Technology |
| 26. | CE 70H | Cyber Security and Cryptography for Embedded Systems |
| 27. | CE 682 | Secure Software Engineering |
| 28. | CE 63A | Practical Machine Learning |
| 29. | CE 66A | Algorithmic Cryptanalysis |
| 30. | *AM 625* | *Image and Video Analytics* |
| 31. | *AM 628* | *Computational Number Theory and Cryptography* |
| 32. | *EE 612* | *Advanced Wireless Communication* |
| 33. | *EE 613* | *Electronic Warfare* |
| 34. | *EE 618* | *DSP System Design* |
| 35. | *TM 609* | *System Engineering* |
| 36. | *TM 611* | *Software Projects Management* |

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|---|---|
| **SubjectCode** | **CE694A** |
| **Subject Title** | **Data Security & Privacy** |
| **Credit** | **04** |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/weekTotal Contact hours 05 per week. |
| Evaluation Pattern | Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>One Final Evaluation at the End of the Term **50 Marks**<br>Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** |
| Total Marks | 100 Marks |
| Prerequisite | None.<br>First 10 hours will be devoted for Prerequisite learnings related to basics of Databases (04 hours), Computer Networks (02 Hours), Operating System (02 Hours),Trends in evolutions of Compute-Devices (02 Hours) |
| About the Course | As data collection and information networks expand (and stories of security breaches and the misuse of personal information abound), data security and privacy issues are increasingly central parts of the information policy landscape.<br>Legislators, regulators, businesses, and other institutions of all kinds are under increasing pressure to draft and implement effective laws, regulations, and security and privacy programs under rapidly changing technological, business, and legal conditions.<br>A strong need is arising for individuals with the training and skills to work in this unsettled and evolving environment.<br>This course will examine: 1) security issues related to the safeguarding of sensitive personal and corporate information against inadvertent disclosure; 2) policy and societal questions concerning the value of security and privacy regulations, the real world effects of data breaches on individuals and businesses, and the balancing of interests among individuals, government, and enterprises; 3) current and proposed laws and regulations that govern information security and privacy; 4) private sector regulatory efforts and self-help & system design measures; 5) emerging technologies that may affect security and privacy concerns; and 6) issues related to the development of enterprise data security programs, policies, and procedures that take into account the requirements of all relevant constituencies; e.g., technical, business, and legal.<br>This course is intended for students and professionals in information policy, public policy, business, and information science who have an interest in work or research in security and privacy fields, or in support of those fields.<br>Along with traditional responsibilities individuals may have new security considerations, e.g., programming. The course will include individual reading and writing assignments, class discussion, case studies, and a group assignment. Students will have some latitude to tailor the assignments to their skills and interests. |
| Course Objectives | VII. The growth of importance of information security and privacy matters in the government and enterprise arenas has significantly broadened the scope of |

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| | individuals who must be aware of relevant issues as part of their work. Security is becoming more of an element of existing roles such as records management, and new security roles such as Chief Information Security Officer are appearing in the enterprise.<br>Security considerations may become new elements of traditional responsibilities (e.g., programmers historically have been expected to document code, but now should be aware that failure to document may be a factor in a law enforcement investigation of whether a data breach was foreseeable).<br>This course will help students to examine policy, and enterprise issues and problems related to security and privacy.<br>Electronic data will be the focus. Discussions will take general approaches and also focus on specific technologies. | | |
| **Course Outcomes** | **Bloom's Taxonomy:**<br>**Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create** | | |
| | **CO Title** | **Level** | **Descriptor** |
| | **CO1:** Student will be able to examine and identify Data Models for various applications + A general background in concepts of privacy at National & International Scenarios | L1, L2 | Remember, Learn |
| | **CO2:** Student will be able to apply data abstraction & normalization techniques to handle volume and veracity + An understanding of how automation is changing the concepts and expectations concerning privacy and the increasingly interconnected issue of security; | L3, L4 | Apply, Analyse |
| | **CO3:** Student will be able to analyze & apply multi-dimensional data models for complex scenarios + Knowledge of technologies and regulations concerning information security from both data protection and law enforcement perspectives. | L4, L5 | Analyse, Evaluate |
| | CO4: Student will be able to propose solutions using v arious data models to cater special application requirements & to form a base to apply Data Mining & AIML techniques. + Use Case Study and apply Knowledge of the role of private regulatory and self-help efforts. | L5, L6 | Evaluate, Create |
| Summary of the Course OutCome | At the end of the course, a student will have an understanding of the concepts of data models, inherent security mechanisms using data models and issues necessary to address emerging areas of data security and privacy in their potential or current careers. Broadly defined roles include, but certainly are not limited to, systems managers, developers, and engineers; librarians, records managers and other archivists; business managers whose areas of responsibility include systems; data analysts; public and private sector policy professionals; and privacy and security professionals. | | |
| **Syllabus Description** | | | |

| | | | | |
|---|---|---|---|---|
| **Basics & Preliminaries** | Types of Data Models, Role of Basic and Advanced Data Structures in Data Models, Basic Dictionary Data Types; Algorithms and basics of analysis,<br><br>OS & Algorithms in Parallel Environments; Protocols of Computer Networks preliminaries, Concerns for Data Security and Privacy | Cormen et al, Horowitz Sahani, Bipin Desai, Korth et al. Kurose Ross | 10 Hours | CO1 |
| Unit-1 | Security Architectures<br>Information Systems; Database management Systems; Information Security CIA; Information Security Architecture; Database Security levels' Menances to Databases; Asset Types & their values | Text Book-1, Ch-1<br><br>Text Book-2, Ch-1 | 08 Hours | CO1 |
| Unit-2 | Database Security Methods<br>Environments: Parallel DBs, Distributed DBs, Database security Methodology; Database Security Definition | Text Book-1, Ch-1<br>Text Book-2, Ch-2,3 | 04 Hours | CO1 |
| Unit-3 | Profiles, Password Policies, Privileges, and Roles<br>Defining and using Profiles: Creating Profiles in SQLServers & end users;<br>Password Policies, Privileges, Tables and Database Objects Privileges, Column-Level Privileges;<br>Creating, Assigning and Revoking User Roles | Text Book-1, Ch-4<br><br>Text Book--2, Ch-4 | 06 Hours | CO1<br>CO2 |
| Unit-4 | Database Application Security Models:<br><br>Security Models: Access Matrix Model, Access Modes Models; Application Types: Client/Server Application; Web Application, Data Warehouse, Data Stream Applications | Text Book-1, Ch-5<br><br>Text Book-2 Ch-5,6,7,8 | 06 Hours | CO3 |
| Unit-5 | Virtual Private Databases:<br>VPD, Implementation, VPD Row Col Security | Text Book-1, Ch 6 | 06 Hours | CO3 |
| Unit-6 | Database Auditing Models<br>Technical Audit Environment, Process, Objectives, Classification Types, Incidence Reports, Level ofescalations.<br><br>Application Data Audit:<br>DML Action Audit; Triggers; Fine-Grained Auditing FGA; Application Errors; PL-SQL Environments, Audit DB Activities | Text Book-1 Ch 7, 8, 9<br><br>Text Book-2, Ch-12,13 | 06 Hours | C04 |
| Unit-7 | Evolving Models & Security: Big Data; Data Streams; Structured, Unstructured, SQL and NOSQL, BlockChains, NFTs; Database Trojans, SQL Attachments in e-mails; Anatomy of vulnerability SELECT Encrypt data-at-rest & data-at-transit, Dataand AIML Models.<br><br>Project Cases data Security and Privacy: Online Databases; CSV files to Structured Environments, SCADA, IoTs, | Text Book-1, Ch-10<br><br>Text Book-2 Ch.9,10,11 | 06 Hours | CO1, CO4 |

| | | | | |
|---|---|---|---|---|
| **Text Books (MUST Know)** | Text Book 1<br>Hassan A. Afyouni,―Database Security and Auditing‖, Third Edition, CengageLearning,2009. | | | |
| **Reference Books (SHOULD Know)** | Reference Book-1<br>Charu C. Aggarwal, Philip S Yu ―Privacy Preserving Data Mining ‖: Models and Algorithms, Kluwer Academic Publishers, 2008 | | | |
| **Consortium, e-books and Web Link references (SHOULD/ Could Know)** | W3.org<br>Meity.gov.in<br>SIGSAC SIGSEC acm.org<br>Isca-speech.org<br>Issa.org<br>Oracle.com/database/security<br>Thelawreviews.co.uk<br>Data Security Council of India (DSCI)<br>prsindia.org<br>10. iso.org ISO/IEC 27000/27001/27002 | | | |
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| **LAB Assignments** | *Each student will work on unique case study. Will require approval of the same at thebeginning. Report submission is essential for each Lab Assignment. | | | |
| | | | | |
| 1 | Describe the Use Case*. Model the case study. Abstract. Apply & implement DDL. | Unit-1, | 02 hours | CO1 |
| 2 | Using the case-study, Apply and implement Security Model. Analyse Threats. Wrt Roles, Access Rights. | Unit-2 | 02 hours | CO2 |
| 3 | Apply, analyse and evaluate ACID Properties. Identify Threats and implement a Mitigation-technique to secure the data-tuples. | Unit-3 & 4 | 02 hours | C03 |
| 4 | Implement and apply Multi-dimensional DBs. Implement three basic operations: Perform Diagnostic Analysis | Unit 4 & 5 | 02 hours | CO3 |
| 5 | Implement and apply Multi-dimensional DBs. Implement operations to observe 'what-if' analysis:Perform Predictive Analysis | Unit 4 & 5 | 02 hours | CO4 |
| 6 | Create use case environment, Implement & Perform Audit wrt Application/Domain Control | Unit 6 | 02 hours | CO4 |
| 7 | Create use case environment, implement & performaudit wrt Technology | Unit 6 | 02 hours | CO4 |
| 8 | Create model and implement a security feature to demonstrate data security. | Unit-7 | 02 hours | CO4 |
| 9 | Assigned ISO module's Study, Audit and Presentation. | Unit 1 to 7 | Sem | CO4 |
| 10 | Mini-project. Implementation and Demonstration. Report Submission is essential | Unit 1 to 7 | Sem | CO4 |

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|---|---|
| **Subject Code** | **CE665A** |
| **Subject Title** | **Security Standards & Penetration Testing** |
| **Credit** | **04** |
| Type of Subject | -Core (MTech in CSE)<br>-Professional Open Elective for All Engineering and Science disciplines |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. |
| Evaluation Pattern | Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>One Final Evaluation at the End of the Term **50 Marks**<br>Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** |
| Total Marks | 100 Marks |
| Prerequisite | Basic computer networking, operating systems and computer programming knowledge is required. |
| Dept | CSE |
| Course Objectives | This course examines the methods for securing information existing in different forms. This course will provide an introduction to the different technical and administrative aspects of Information Security and Assurance. Also, one cannot protect his information assets if he doesn't know how attackers think and what techniques attackers use to exploit systems. Hence, learning offensive security techniques like Ethical Hacking and penetration testing is becoming a need of future cyber security world. Objectives are: 1. To facilitate individual in gaining knowledge on information security management systems,.2. To facilitate individual in gaining knowledge on security standards like ISO-27001 standards, TCSEC, ITSEC, Secure coding etc. 3. To train individual to become competent information security professional by learning both theoretical as well as practical ethical hacking and penetration testing knowledge base |
| **Course Outcomes** | Bloom's Taxonomy:<br><br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze<br>Level-5 Evaluate; Level-6 Create |

| | **CO Title** | **Level** | **Descriptor** |
|---|---|---|---|
| | CO1: Students will able to identify and apply basic concepts, terminology, theories, models and methods in the field of information security management field. (PO1, PO3, PSO1) | L1, L2 | Remember, Understand |
| | CO2: Student will able to design policies for managing information security effectively adhering to ISO- 27001 standards, TCSEC, ITSEC, Secure coding practices etc. (PO1,PO2, PO3, PSO1) | L3 | Remember, Understand Analyse |
| | CO3: Student will learn to design, implement, integrate and manage various security countermeasures/tools/mechanisms/best practices and penetration testing through hands-on activities. (PO1, PO3, PSO1) attacks like Network Intrusion, DDOS, Malware attacks are carried out successfully by attackers. (PO1, PO2, PO3, PSO1, PSO2) | L3 | Remember, Understand Analyse |

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|---|---|---|---|---|
| | CO1, 03: End semester Exam | L4 | Apply, Analyse | |
| **Syllabus Description** | | | | |
| **Basics & Preliminaries** | **Details** | **Books & References** | **Duration** | **COs** |
| Unit-1 | Introduction to Information security, Concepts, Threats, Attacks, and Assets, Security Functional Requirements, Countermeasures , Access Control Principles, Access Rights , Discretionary Access Control, Role - Based Access Control, Mandatory Access Control , Trusted Computing and Multilevel Security, Security Design Principles, Cryptographic Tools, Common Criteria for Information Technology Security Evaluation, Information security management systems (ISMS), ISO27000 and other security standards, Management responsibility, Responsibilities of Chief Information Security Officer (CISO) | Textbooks - 1,2 | 16L | CO1 |
| Unit-2 | Security audits and assurance, Information Security Policy, Standards, and Practices, Asset Management, Human Resource Security, Security awareness training, Physical Security, Risk Management, Business continuity planning, Disaster Recovery planning, Penetration Testing Methodologies Security Assessments, Penetration Testing Methodologies, Penetration Testing Steps, Setting up own virtual ethical hacking lab for experimentation, Ethical Hacking and penetration Basics - Hacking terminology & attacks, Ethics, Legality. | Textbooks - 2,3 | 13L | CO3 |
| Unit-3 | Phases - Reconnaissance, Scanning,Gaining access, Maintaining access, Covering tracks; Reconnaissance - Information gathering,Vulnerability research, Foot -printing, whois, DNS enumeration, Social Engineering, E - Mail Tracking,Web Spiders; Scanning & Enumeration - Sniffing techniques & tools, arp/icmp/tcp/ip host discovery, types of Scanning , Ping Sweep Techniques, Nmap, Command Switches, SYN, Stealth, XMAS, NULL, IDLE, and FIN Scansdetecting OS fingerprinting, banner grabbing, Null Sessions, SNMP/DHCP/DNS enumeration, Proxy Servers, Anonymizers, HTTP Tunneling Techniques, IP Spoofing Techniques; Cryptographic Techniques | Textbooks - 2,3,4,5,6 References -1-7 | 9L | CO2 |
| Unit-4 | Attacking System and Maintaining Access– Password/hashcracking, NetBIOS DoS Attacks, PasswordCracking Countermeasures; escalating privileges - exploiting vulnerabilities, Buffer Overflows,Rootkits, Hiding FilesNTFS Stream | Textbooks - 4-6, / References -1-7 | 10L | CO2 |

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|---|---|---|---|---|
| | Countermeasures, Steganography Technologies, Cover tracks and Erase Evidence, Disabling Auditing, Clearing the event Log, Malware attacks-Trojan, Backdoor, Viruses, Worms, DoS/DDoS; Attacks, Windows Hacking; Linux Hacking; Web and Database Hacking; Google Hacking; Wireless Hacking; Mobile Hacking; Penetration Testing Tools like Kali Linux, Metasploit ,Pen-Test Deliverables | | | |
| | LAB/ Assignments/Student Presentations [2T/P per week | | 02L/ Week | CO4 |
| Text Books (MUST Know) | Michael E Whitman, Herbert J Mattord, “Principles of Information Security”, Course Technology, 3rd Edition, 2008.<br>William Stallings and Lawrie Brown, “Computer Security: Principles and Practice”, 2nd edition, Pearson, 2012.<br>Krutz, R. L. & Vines, R. D., “The CISSP and CAP Prep Guide”, Platinum Edition, New York, Wiley Publishing., 2006.<br>Nina Godbole, “Information Systems Security: Security Management, Metrics, Frameworks and Best Practices”, Wiley India Pvt Ltd, 2012.<br>Dhavale, S. V. (2019). Constructing an Ethical Hacking Knowledge Base for Threat Awareness and Prevention (pp. 1-305). Hershey, PA: IGI Global.<br>Stuart McClure, Joel Scambray, George Kurtz, “Hacking Exposed:n/w sec secrets and solutions”, Mcgraw Hill, 2012 | | | |
| Reference Books (SHOULD Know) | Various Security Standards - ISO 27000 series published by ISO.<br>Department of Defense Standard, Department of Defense, “Trusted Computer System Evaluation Criteria”, Orange Book.<br>Dieter Gollmann, “Computer Security”, John Wiley and Sons, Inc., 3rd edition, 2011<br>David Kennedy, Jim O’Gorman, Devon Kearns, and MatiAharoni, ”Metasploitpentest guide”,No starch Press, san Francisco, 2011<br>Bastian ballman, “Understanding n/w hacks:attack and defense with python”, Springer,2012<br>Rich Annings, HimanshuDwivedi, Zane Lackey, ”Hacking Exponsed Web 2.0”, Tata Mcgraw hill Edition<br>Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/IBM/EC-Council sources | | | |
| **Laboratory Assignments/ Demonstrations** | | | | |
| 1 | Study Windows Essential Tools-Part 1 | Unit - 1 | 02 hours | CO1, CO2,CO3, & CO4 |
| 2 | Study Windows Essential Tools-Part 2 | Unit - 1 | 02 hours | CO1, CO3, & CO4 |
| 3 | Study Sysinternals utilities to manage, diagnose, troubleshoot, and monitor a Microsoft Windows environment | Unit - 2 | 02 hours | CO2, CO3, & CO4 |
| 4 | Study passive information gathering tools. | Unit - 3 | 02 hours | CO1, CO3, & CO4 |
| 5 | Write Security Policy Document | Unit - 3 | 04 hours | CO1, & CO4 |
| 6 | Case study: LDRA and Parasoft tools | Unit - | 02 | CO2, & CO3 |

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|---|---|---|---|---|
| | | 3 | hours | |
| 7 | Kali Linux Attacks – Part1 | Unit - 3 | 02 hours | CO3, & CO4 |
| 8 | Kali Linux Attacks – Part2 | Unit - 4 | 04 hours | CO2, & CO3 |
| 9 | SSPT Practice Test -1Quiz | Unit - 4 | 04 hours | CO2, & CO4 |
| 10 | Apply data mining tools for cyber security related data analysis | Unit - 4 | 02 hours | CO1,CO2, CO3, & CO4 |

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|---|---|---|---|---|
| **Subject Code** | **CE663** | | | |
| **Subject Title** | **Applied Cryptography** | | | |
| **Credit** | **04** | | | |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. | | | |
| Evaluation Pattern | 03 – monthly test + 01 Final Evaluation<br>1. Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>2. One Final Evaluation at the End of the Term **50 Marks**<br>3. Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** | | | |
| Total Marks | 100 | | | |
| Prerequisite | Basic understanding of mathematics concept like Prime numbers, Group, Ring and Fields Theory | | | |
| Objective | Understanding of basic encryption and authentication schemes and issue related to cryptanalysis and be able to determine the strength and weakness of the encryption/authentication schemes. | | | |
| **Course Outcome** | CO1: Students are able to understand and analyse Private keys encryption schemes<br>CO2: Public keys encryption schemes and able to perform the cryptanalysis<br>CO3: Students are able to understand and design new schemes for information security<br>CO4: Students are able to understand and design new schemes for end user's authentication & secure Communication | | | |
| **Syllabus Details** | | **Book** | **Hours** | **Outcome** |
| **Unit – I**:. | Classical Encryption Techniques and their Cryptanalysis: Symmetric cipher model, Substitution techniques, Transposition techniques, Steganography, One-Time Pad (Vernam's Cipher), Limitations of Perfect Secrecy, Shannon's Theorem | Text Book-1 | 6 | CO3, & CO4 |
| **Unit – II**: | Private-Key Encryption Schemes and Block Ciphers: Pseudorandom Functions and Permutations, Private-Key Encryption Schemes from Pseudorandom Functions, DES – The Data Encryption Standard, Attacks on DES, Single-Round DES, Two-Round DES, Three-Round DES, Brute Force Search, Best | Text Book-1 | 8 | CO1, & CO3 |

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|---|---|---|---|---|
| | Known Attacks on Full DES, AES, Stream cipher A5 | | | |
| **Unit – III** :. | Number Theory: Prime numbers and factoring, modular arithmetic, computations in finite fields, Discrete logarithms | Text Book-1 | 6 | CO1, & CO3 |
| **Unit – IV**: | Public-Key (Asymmetric) Cryptography: Public-Key Problems and Mathematical Background, Diffie-Hellman Key Agreement, El-Gamal Encryption Scheme, RSA Encryption, Security of RSA, Hybrid Encryption , Attacks on RSA, Private and Public-Key Reversal, Common Modulus Attack, Simplified Broadcast Attack,Timing Attacks, Elliptic Curve Cryptography. | Text Book-1 | 6 | CO2, & CO3 |
| **Unit – V**: | Hash Functions: Definition and Properties, Constructions of Collision-Resistant Hash Functions, Random Oracle Model.Hashalgorithms:MD5,SHA-256.Message Authentication, Digital Signatures and Applications, Definitions, Constructions, Certificates and Public- Key Infrastructure, Combining Encryption and Signatures – SignCryption. | Text Book-1 | 6 | CO3, & CO4 |
| **Unit – VI**: | Secure key distribution using Quantum techniques, Hash based Cryptography | Text Book-3 | 6 | CO3 |

**Textbooks:**

“Cryptography & Network Security” by William Stallings 4th Edition, 2006, Pearson Education Asia.
Kahate A, “Cryptography & Network Security”, Tata McGraw Hill, 2004.
Post-Quantum Cryptography by Daniel J. Bernstein, Johannes, Buchmann, Erik Dahmen, Springer. ISBN: 978-3-540-88701-0.

**References**:

“Applied Cryptology” by Schiner Bruce, John Wiley & Sons, 2001.
“Introduction to Cryptography with Coding Theory” by Wade Trappe & Lawrence C Washington, New Jersey, Pearson Education, 2006.
CharlieKaufman, Radia Perlman and Mike Speciner, “Network Security: Private Communication in a Public World”, Prentice Hall of India Private Limited.
Behrouz A. Forouzan, “Cryptography and Network Security”, McGraw Hill
Jonathan Katz and Lindell, “Introduction to Modern Cryptography: Principles and Protocols”,Chapman and Hall/CRC

**Lab Assignments**

| | | | | |
|---|---|---|---|---|
| Lab 1 | To encrypt the text containing numbers using Playfair Cipher | Unit-1 | 02 hours | CO3, & CO4 |
| Lab 2 | To encrypt the image containing RGB values in the pixel using playfair | Unit-1 | 02 hours | CO3, & CO4 |
| Lab 3 | Programme to find the multiplicative inverse of an integer | Unit-3 | 02 hours | CO1, & CO3 |
| Lab 4 | Programme to find the polynomial inverse | Unit-3 | 02 hours | CO1, & CO3 |
| Lab 5 | Programme to implement the Key expansion of Data Encryption Standard | Unit-2 | 02 hours | CO1, & CO3 |

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|---|---|---|---|---|
| Lab 6 | To encrypt the text file using the using A5 Stream cipher | Unit-2 | 02 hours | CO1, & CO3 |
| Lab 7 | Programme for Fair Coin Toss | Unit-4 | 02 hours | CO2, & CO3 |
| Lab 8 | Develop a system to Securely Info Exchange between 2 Ends ( Mini Project) | Unit-2,3,4, 5 | 02 hours | CO1, & CO3 |
| Lab 9 | Develop code for symmetric key encryption. | Unit-2, 6 | 02 hours | CO1, & CO3 |
| Lab 10 | Light weight symmetric key encryption applications. | Unit-2 | 02 hours | CO1, & CO3 |

| **Subject Code** | **CE-662A** |
|---|---|
| **Subject Title** | **Advanced System Security** |
| **Credit** | **04** |
| TeachingScheme | Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week. |
| Evaluation Pattern | 03 monthly tests + 01 final evaluation + assignments for internal assessment |
| Total Marks | 100 |
| Prerequisite | Basic Operating System concepts; Programming language-preferably C |

**Objective**:
To learn designing and building a secure operating system, ensuring the enforcement of system security goals and evaluating the OS w.r.t necessary and sufficient conditions.
This includes learning and understanding-
The security architectures of current operating systems
Distinct approaches to building secure operating systems and Challenges in implementation
Concept of virtualization
Explore a range of existing problems and tensions in modern systems' security

**Course Outcome:**

CO1- Understand the System Security concept. Learn the security terminology and models. Identify the components in building a secure OS.
CO2- Analyse and Assess the security mechanisms in in earlier implemented secure OS and the contemporary commercial OS. Assess the vulnerabilities and challenges.
CO3- Learn the Security policy models. Apply the policy and mechanism to building secure operating systems based on the security goals. Analyse and evaluate the distinct approaches for Secure OS design using VM.
CO4- Practically realize the exploits of security mechanism and prevention mechanism to appreciate a Systems' security level.

| **Syllabus Details:** | **Text Book** | **Hours** | **Outcome** |
|---|---|---|---|
| **Unit – I**<br>**Security Principles:** CIA triad; Operating System Security goals, Trust model, Threat model; Protection system; Reference monitor concept. Distributed System | Textbook 1, Reference 1 | 08 | CO1, CO4 |

| | | | |
|---|---|---|---|
| Security Goals. **Access Control:** Discretionary protection system, Mandatory protection system, Authentication and Role Based Access Control, Authorization and Attribute Based Access Control, Rule-based access control. | | | |
| **Unit – II**<br>**Multics:** Multics security fundamentals, protection system models, vulnerability analysis. **Security in Commercial Operating Systems:** protection system, authorization, security analysis for Unix-like and Windows OS. Security in Distributed Systems. | Textbook 1, Textbook 2 | 10 | CO2, CO4 |
| **Unit – III**<br>**Verifiable Security Goals:** Information flow models, secrecy models, integrity models. **Secure Capability Systems:** Capability system fundamentals, Secure capability systems mechanisms. **Secure Virtual Machine Systems:** Separation kernels, sandboxing, Multiple Independent Levels of Security. | Textbook 1, Reference 2 | 12 | CO3, CO4 |
| **Unit – IV**<br>**Attack vectors:** Memory exploits, code based attacks; Return-to-libc Attacks, Spectre and Meltdown; shared library, buffer overflow attacks.<br>**Case Studies** (Security enhanced OS): STUDENT PRESENTATION & INTERACTIVE SESSIONs | Textbook 1, Textbook 2, Reference 1 | 12 | CO2, CO4 |

**Textbooks**

Jaeger, T., “Operating System Security”, Morgan & Claypool (online), 2008.
Wenliang Du, “Computer & Internet Security: A Hands-on Approach”, 1 May 2022

**References**

Matt Bishop, “Computer Security”, Addison Wesley, 2002
Morrie Gasser: "Building a Secure Computer System"
Silberschatz and Galvin: "Operating System Concepts", Addison Wesley, 2006
Virgil Gligor‘s Lectures on Security Policies.

**Lab Assignments**

| | | | | |
|---|---|---|---|---|
| Lab 1 | Introduction to basic UNIX commands | Unit 1 | 02 Hrs | CO1 & CO4 |
| Lab 2 | Managing Users and Groups | Unit 1 | 02 Hrs | CO1 & CO4 |
| Lab 3 | Environment Variables and SetUID | Unit 2 | 02 Hrs | CO2 & CO4 |
| Lab 4 | Exploring limitations of DAC in conventional Linux / Windows | Units 1 & 2 | 02 Hrs | CO1, CO2 & CO4 |
| Lab 5 | Buffer Overflow; Return-oriented Programming | Unit 4 | 02 Hrs | CO2 & CO4 |
| Lab 6 | Jailing in Linux using “chroot” | Unit 2 | 02 Hrs | CO2 & CO4 |
| Lab 7 | VM Install and Kernel Compile | Unit 3 | 02 Hrs | CO3 & CO4 |
| Lab 8 – Lab 10 | Mini Project: Implementing Linux Security Module in form of SafeOpen || Code Injection || Binary Exploitation || Kernel Backdoors and Rootkits || Realization of (any of the) Attack Vectors | Units 1, 2, 3, 4 | 02 Hrs | CO1, CO2, CO3 & CO4 |

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|---|---|---|---|---|
| **SubjectCode** | **CE684** | | | |
| **Subject Title** | **Digital Forensics** | | | |
| **Credit** | **04** | | | |
| TeachingScheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/weekTotal Contact hours 05 per week. | | | |
| Evaluation Pattern | Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>One Final Evaluation at the End of the Term **50 Marks**<br>Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** | | | |
| Total Marks | 100 Marks | | | |
| Prerequisite | Knowledge of OS, Assembly Languages like Python, Number System and their Conversions, Internal Structure of CD/DVD. | | | |
| **Course Outcomes** | CO1: Students will be able to understand the standard procedures of Digital Forensics required for Cyber Crime Investigation.<br>CO2 : Students will be able to apply proper commands and procedures required for digital investigation.<br>CO3: Students can practically demonstrate or articulate the suspicious activity/artifacts extraction w.r.t. from the digital evidence.<br>CO4: Students will be able to solve the real-time case-studies available on benchmarked repositories | | | |
| **Syllabus Details** | **Details** | **Text books/Refer nce books** | **No. of Hrs** | **COs** |
| Unit I | Introduction to digital forensics<br>Stages of Forensic: acquisition or imaging of exhibits, analysis and reporting standards<br>Introduction to Computer Forensics: Digital Devices with rudimentary computing power<br>Acquisition or imaging of Onboard Memory and Static Memory<br>Introduction to legal issues, Analysis and Reporting Standards,Online and Live Forensics | Text Book1, R3 | 12 | CO1, CO4 |
| Unit 2 | Forensic study of database and their metadata, database contents, log-files for creating timeline or recover relevant information | Text Book3 | 12 | CO3, CO4 |
| Unit III | MFT & Registry Hives Extraction from Windows OS through Tools and Scripts<br>Data Carving Using Open Source Tools,Data Recovery and Secure deletion on Storage media. Evidence or Intrusion detection from internet logs, monitoring and analysis of network traffic.Internet of Things | Text Book2, R1 | 12 | CO2, CO4 |
| Unit IV | Recovery and Analysis of artifacts from Mobile Devices<br>Information gathering and analysis using Social Network<br>Analysis of artifacts from mobile devices,Social Network Artifacts Extraction and Analysis | Text Book2, R2 | 12 | CO2, CO4 |

| **Text Book:** |
|---|
| 1. Kanellis, Panagiotis, “Digital Crime and Forensic Science in Cyberspace”, IGI Publishing”, ISBN 1591408733.<br>2. Marshell, Angus M. (2008), “Digital Forensics: Digital Evidence in Criminal Investigation”, Wiley- Blackwell, ISBN 0470517751.<br>3 Brain Carrier, “File System Forensics Analysis”, Addison-Wesley Professional, 1st Edition, 2005 |
| **Reference Books:**<br>1. Chris Prosise, Kevin Mandia “ Incident Response & Computer Forensics", McGraw-Hill, 2nd Edition, 2003.<br>2. Rick Ayers, Sam Brothers, Wayne Jansen, “Guidelines on Mobile Device Forensics”, NIST, US Dept. of Commerce, Revision 1, 2014<br>3. Pavan Duggal, “Cyberlaw–The Indian Perspective”, 2009 Edition |

**Lab Assignments**

| Name of Experiments | Units | Duration (Hrs) | Co’s |
|---|---|---|---|
| Perform Imaging and Analysis of Non-Volatile Memory using Open Source Tools in the absence of Write-Blockers. | I | 02 | CO1, CO4 |
| Perform Imaging and Analysis of Non-Volatile Memory using EnCase/Other Open Source Tools With and Without Write Blockers. | I | 02 | CO1, CO4 |
| Explore the Phases of Ethical Hacking in terms of implementing some attack. | I | 02 | CO1, CO4 |
| Perform Imaging and Analysis of Volatile Memory using EnCase/Other Open Source Tools | I | 02 | CO1, CO4 |
| MFT & Registry Hives Extraction from Windows OS through Tools and Scripts. | II | 02 | CO3, CO4 |
| Recovering Deleted File from the File System | II | 02 | CO3, CO4 |
| SystemHiding Data into Slack Space. | II | 02 | CO3, CO4 |
| Data Recovery and Secure deletion on Storage media. | III | 02 | CO2, CO4 |
| Data Carving Using Open Source Tools | III | 02 | CO2, CO4 |
| Information gathering and network traffic analysis using TCP DUMP and WIN DUMP | III | 02 | CO2, CO4 |
| Attacks and Forensics using IoT devices | IV | 02 | CO3, CO4 |
| Social Network Artifacts Extraction and Analysis. | IV | 02 | CO3, CO4 |

| **Subject Code** | **CE-664A** |
|---|---|
| **Subject Title** | **Network and Cloud Security** |
| **Credit** | **04** |
| Teaching Scheme | Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week. |
| Evaluation Pattern | 03 monthly tests + 01 final evaluation + assignments for internal assessment |
| Total Marks | 100 |

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|---|---|
| Prerequisite | Basic computer networking, operating systems and computer programming knowledge is required. |

**Objective:**
Understanding basic issues, concepts, principles and mechanisms in Network and Cloud Security.
Basic Security concepts
Authentication
Access Control
IPSec and Internet Key Management
SSL/TLS Protocol
Firewall/UTM
Malicious Software
Intruder Detection Systems
Cloud Computing and Security
Be able to determine appropriate mechanisms for protecting networked systems. Network and Cloud Security Laboratory.
To facilitate individual in gaining knowledge on Network and Cloud Security Protocols, Appliances and systems.
To facilitate individual in gaining hands on experience on various attacks and countermeasures

**Course Outcomes:**
CO1: Students will be able to understand and apply Network and Cloud security Concepts along with various countermeasures. (PO1, PO3, PSO1)
CO2: Students will be able to understand and apply Network and Cloud Security concepts, hardware, software, standards and policies required for an organization. (PO1, PO2, PO3, PSO1)
CO3: Students will be able to understand the importance of implementation of Network and Cloud Security protocols, Devices, policies. (PO1, PO3, PSO1)
CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in Network and Cloud Security. (PO1, PO2, PO3, PSO1, PSO2)

**Syllabus:**

| **Syllabus Details** | | **Text Book** | **Hours** | **Outcome** |
|---|---|---|---|---|
| Unit 1 | Introduction, OSI security Architecture, Security Principles, Attacks and Threats, Model of Network Security<br>Security at Application Layer: Email Architecture, PGP, S/MIME | Text book 1 Chap 1, & 8 | 6 | CO1 |
| Unit 2 | Security at Transport Layer: SSL Architecture, TLS, SET, HTTPS protocols<br>Security at Network Layer, IPSec, VPN, ISKMP | Text Book1, Chap 6 & 9 | 7 | CO1 |
| Unit 3 | Firewall: Types of Firewalls, Firewall configuration, DMZ, UTMs | Text book 1 Chap 12 | 5 | CO1 |
| Unit 4 | Intrusion Detection and Intrusion Prevention Systems, Honeypots, Distributed IDS, Password Management<br>Authentication: kerberos, X509, Authentication, PKI | Text Book 1 Chap 11 & 4 | 7 | CO2 |
| Unit 5 | Wireless Security: Wireless LAN, 802.11 Standards, Security of WLAN | Text Book 1 Chap 7 | 4 | CO2 |

| | | | | |
|---|---|---|---|---|
| Unit 6 | Cloud Security: Cloud Computing, Security Issues and Challenges, Applications | Text Book 1 Chap 5 | 5 | CO2 |
| Unit 7 | DDoS : Direct, Reflector and Amplifier Attacks, TCP Syn Flooding, Countermeasures, Digital Attack Maps | Text Book 1 Chap 10 Text Book 2 | 3 | CO3 |
| Unit 8 | Malicious Software: Viruses, Worms, Ransomware etc, Anti-virus Architecture, Generation of Anti-Virus, Types of Viruses Network Reconnaissance, Traceroute, Port Scanning, ICMP Scanning, Sniffing, Probing Routers | Text Book 1 Chap 10 Text Book 3 | 6 | CO3 |
| Unit 9 | Game Theory applications in Network Security | Research Papers | 4 | CO3 |
| Unit 10 | Miscellaneous topics and current developments, Dark Web Network Security Observatory: Monitoring Networks | Research Papers | 7 | |

**Text Book:**

1. William Stallings, “Network Security Essentials”, 6th Edition, Pearson Education, 2019.
2. B. Menezes, “Network Security and Cryptography”, Cengage, 2013.
3. W. Du, “Computer and Internet Security: A Hands On Approach”, 3rd Edition, 2022.

**Reference Books:**

1. A Fadia, “Network Security: A Hacker’s Perspective”, Second Edition, Macmilan, 2013.
2. Bragg et al. “Network Security: The complete Reference”, McGraw Hill, 2004
3. Seedlabs: https://seedsecuritylabs.org/ ( last accessed on 12th June 2022).

**Lab Assignments**

| **Sl No** | **Lab Experiment** | **Unit** | **Hours** | **Outcome** |
|---|---|---|---|---|
| 1 | Packet Sniffing and Spoofing Lab | 1 | 2 hrs | CO1, CO4 |
| 2 | TCP attacks Lab | 2 | 2 hrs | CO1, CO4 |
| 3 | Firewall Exploration Lab | 3 | 2 hrs | CO1, CO4 |
| 4 | VPN Lab | 2 | 2 hrs | CO1, CO4 |
| 5 | Wireshark Lab | 8 | 2 hrs | CO3, CO4 |
| 6 | Snort: Intrusion Detection Lab | 4 | 2 hrs | CO2, CO4 |
| 7 | CyberCiege Lab | 1 | 2 hrs | CO1, CO4 |
| 8 | OpenSSL Exploration Lab | 2 | 2 hrs | CO1, CO4 |
| 9 | Digital Attack Maps DOS lab | 7 | 2 hrs | CO3, CO 4 |
| 10 | Cloud Computing Lab | 6 | 2 hrs | CO2, CO4 |

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|---|---|
| **Subject Code** | **CE694** |
| **Subject Title** | **Cyber Physical Systems** |
| **Credit** | **04** |
| Type of Sub | - Open Elective for All Engineering and Science disciplines |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. |
| Evaluation Pattern | Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>One Final Evaluation at the End of the Term **50 Marks**<br>Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** |
| Total Marks | 100 Marks |
| Prerequisite | None.<br><br>First 10 hours will be devoted for Prerequisite learnings related to basics of Databases (04 hours), Computer Networks (02 Hours), Operating System (02 Hours), Trends in evolutions of Compute-Devices (02 Hours) |
| Dept | CSE |
| Experts | Contribution from Academia/ R&D Org: Dr. Rituraj, ScG, CAIR<br>Contribution from Industry: Dr Prashant Pansare, CEO & Founder, Rubiscape, |
| About the Course | This course examines a new class of computational systems called Cyber-Physical Systems CPS. Such systems have the potential to provide far-reaching benefits in addressing some of the toughest problems we face as a society, such as: reducing healthcare costs, minimizing traffic congestion, and constructing zero-net energy buildings. Four important features characterize CPS: their ability monitors the underlying physical environment, reason about the monitored data, control the physical environment through actuation, in a coordinated manner using a communication medium. It can be seen in CPS, the computational element (cyber) and the environment (physical) are tightly coupled, with one influencing the other.<br>CPS sits at the confluence of several traditional disciplines, such as: embedded systems, real-time systems, sensor networks, control and hybrid systems, and security. It presents many challenging problems and opportunities for research. With guidance from the professor, students will survey recent CPS publications, develop an aptitude.<br>Readings will include papers on CPS applications (e.g., Body Area Networks, smart automobiles, and energy-efficient buildings), issues involved in designing CPS (e.g., monitoring, communication, and control), and how to ensure that the designed systems satisfy certain essential properties (e.g., safety and security).<br>CPS combine cyber capabilities (computation and/or communication) with physical capabilities (motion or other physical processes). Cars, aircraft, and robots are prime examples, because they move physically in space in a way that is determined by discrete computerized control algorithms. Designing these algorithms to control CPSs is challenging due to their tight coupling with physical behavior. At the same time, it is vital that these algorithms be correct, since we rely on CPSs for safety-critical tasks like keeping aircraft |

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| | from colliding, its role in Command & Control environments. |
| Course Objective | To meet end-user, Administrator & System Designer perspectives, develop skill sets to be resourceful in knowledge & information systems. Enhance analytical capabilities to evaluate a domain specific and technical area. Multi-Disciplinary Course useful to any engineering discipline who are keen to contribute in digitizations, like be it smart cities, smart telemedicine systems, automated and autonomous systems. |
| Course Outcomes | Bloom’s Taxonomy:<br><br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create |

| | **CO Title** | **Level** | **Descriptor** | **Out come** |
|---|---|---|---|---|
| | CO1: Students will be able to understand the scope of applications of CPS. | L1, L2 | Remember, Learn, Understand | 20% |
| | CO2: Students will be able to analyse the various components of CPS | L3, L4 | Apply, Analyse | 20% |
| | CO3: Students will apply mechanisms to enable autonomous and self-organising techniques | L4, L5 | Analyse, Evaluate | 20% |
| | CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in cyber and information security domain along with scope to apply AIML and build secure digitized systems. (PO1, PO2, PO3, PSO1, PSO2) | L5, L6 | Evaluate, Create | 40% |

CO-PO : Course Outcome and Program Outcome Evaluation Metrics

| | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|---|---|---|---|---|---|
| CO1 | Y | | | Y | Y |
| CO2 | Y | | | Y | Y |
| CO3 | | Y | Y | Y | Y |
| CO4 | | Y | Y | Y | Y |
| | | | | | |

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| Summary of the Course Out Come | At the end of the course, a student will understand the concepts of CPS. Develop skills to relate a CPS as a feedback system along with its designing, modelling and implementation challenges. Evaluate the requirements to address emerging areas of digitization, AIML, and Secure environments. |

**Syllabus Description**

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|---|---|---|---|---|
| **Basics & Preliminaries** | Role of Basic and Advanced Data Structures in Data Models, Types of Data Models, Basic Dictionary Data Types; Algorithms and basics | Cormen et al, Horowitz | 10 Hours | CO1, PO1 |

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| | of analysis,<br><br>OS & Algorithms in Parallel Environments. Protocols of Computer Networks preliminaries, Concerns for Data Security and Privacy | Sahani, Bipin Desai, Korth et al. Kurose Ross | | |
| Unit-1 | CPS**:** Introduction Main Concepts, Challenges; Background role of Computer Networks, Data, Algorithms | Text Book-1, Ch-1 | 08 Hours | CO1, CO2, PO1 |
| Unit-2 | Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software, | Text Book-1, Ch-2, 3 | 04 Hours | CO1, PO1 |
| Unit-3 | Agents and Multi-Agent Systems Computing trends, Data device proliferation, Confluence of trends | Text Book-1, Ch-4 | 06 Hours | CO1 CO2, PO1 |
| Unit-4 | Technological and economic drivers Self-organisation Mechanisms, Stigmergy, Gossip, Trust and Reputation for Successful Software Self-organisation, Cooperation , Immune Systems, Holonic Multi-Agent Systems Engineering Artificial Self-organising Systems | Text Book-1, Ch-4, 5 | 06 Hours | CO3, PO2 |
| Unit-5 | Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems | Text Book-1, Ch 5,6,7,8 | 06 Hours | CO3, PO2 |
| Unit-6 | CPS design Standards, Time Models, CPS Special Interest Groups and Mitre Commendations in Design and developments | Weblink References | 06 Hours | C04, PO4 |
| Unit-7 | Applications of Self-organising Software, Self-organisation in Constraint Problem Solving, Adaptive Trust Management, Security in Artificial Systems<br><br>Project Cases: SCADA, Industry 4.0 applications, Telemedicine, Environment Monitoring, IoTs, etc. | Text book-1, Ch-8,9 | 06 Hours | CO1, CO4, PO1, PO3 |
| Text Books (MUST Know) | Text Books<br>Self Organising Software from Natural to artificial Adaptation, Di- MarzoSerugendo, ;Gleizer, M-p; Karageorgos, A (Eds), 2011, XVIII,462P; Hardcover ISBN:978-3642-17347-9 | | | |
| Reference Books | Reference Book-1 | | | |

| | | | | |
|---|---|---|---|---|
| (SHOULD Know) | "Principles of Cyber-Physical Systems" - Rajeev Alur, MIT Press, 2015<br><br>Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006<br><br>Kurose and Ross, Top Down Approach of Computer Networks, Prentice Hall, 8th Edition 2021. | | | |
| Consortium, e-books and Web Link references (SHOULD/ Could Know) | https://www.cdsaonline.org/cps-standard/<br><br>https://pages.nist.gov/cpspwg/<br><br>International Association for Automation<br><br>Research Papers shared by the subject incharge | | | |
| Laboratory Assignments/ Demonstrations- | | | | |
| LAB Assignments | *Each student will work on unique case study. Will require approval of the same at the beginning. Report submission is essential for each Lab Assignment. | | | |
| | | | | |
| 1 | Describe the Use Case*. Model the case study. Abstract. | Unit-1 | 02 hours | CO1 |
| 2 | Modelling Tools exploration and implementation of the subsystems/ systems of the case study. | Unit-2 | 02 hours | CO2 |
| 3 | Depiction of Agents in the designed model, and modelling their state, transitions and parameters status. Any one scenario for automous execution using algorithms. | Unit-3 & 4 | 02 hours | C03 |
| 4 | Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations. | Unit 4 & 5 | 02 hours | CO3 |
| 5 | Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations.<br>Develop the methods to audit and parameters of importance.<br>Generate the incidence response reports. | Unit 4 & 5 | 02 hours | CO4 |
| 6 | Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations.<br>Specify the security concern and mitigation technique. Generate the incidence response reports. | Unit 6 | 02 hours | CO4 |
| 7 | Create use case environment, implement & perform intra and Inter-system mappings. | Unit 6 | 02 hours | CO4 |
| 8 | Create model and implement any one security | Unit-7 | 02 hours | CO4 |

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| | feature to demonstrate cyber security concern, intra and inter and mitigation. | | | |
| 9 | Study of Research paper on the assigned topic and its presentation. | Unit 1 to 7 | Sem | CO4 |
| 10 | Mini-project. Implementation and Demonstration. Report Submission is essential | Unit 1 to 7 | Sem | CO4 |

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| **Subject Code** | **CE 66A** |
| **Subject Title** | **Algorithmic Cryptanalysis** |
| **Credit** | **04** |
| **Course Objectives** | This course discusses cryptanalysis from basics to advanced application from algorithmic point of view. After completion of the course, the students should be able to identify and apply the suitable algorithm for more sophisticated cryptographic applications, including LFSR-based stream ciphers and index calculus methods. The students should be able to observe the advancements in current computer architectures and its impact on implementation aspects of cryptanalysis methods. |
| *Syllabus Description* | |
| *UNIT-I* | Preliminaries, Defining security in cryptography, Elementary Number Theory and Algebra, Evolution in Computing Devices, Evolution in Communication Media, Evolving Programming Environments, Three Generic Forms of Cryptanalysis: Cipher text only, Known cipher text/plain text pairs, and Chosen plain text or chosen cipher text. |
| *UNIT-II* | General Approaches to Cryptanalysis – (i) based on properties on encryption algorithms & (ii) bruteforce, Linear Algebra, Sieve Algorithms, Brute Force Cryptanalysis, The Birthday Paradox: Sorting or Not? Birthday-Based Algorithms for Functions, Algorithmic complexities & computational costs. |
| *UNIT-III* | Birthday Attacks through Quadrisection, Fourier and Hadamard–Walsh Transforms, Lattice Reduction, Polynomial Systems and Gröbner Bases Computations; Study of protocols for cryptanalysis**.** |
| *UNIT-IV* | Attacks on Stream Ciphers, Lattice-Based Cryptanalysis, Elliptic Curves and Pairings, Index Calculus Algorithms |
| **Text Book** | Algorithmic Cryptanalysis, by Antoine Joux, 2010 |
| **Reference Books** | 1. Cryptanalysis: A Study of Ciphers and Their Solution (Dover Brain Games), by Helen F. Gaines , 1956<br>2. Cryptanalysis of Number Theoretic Ciphers, By Samuel S. Wagstaff, Jr., 2002. |

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|---|---|
| **Subject Code** | **AM 607** |

| Subject Title | **Mathematics for Engineers** |
|---|---|
| **Credit** | **04** |
| TeachingScheme | Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week. |
| Evaluation Pattern | 03 monthly tests + 01 final evaluation + assignments for internal assessment |
| Total Marks | 100 |
| Prerequisite | |
| Course offered from Mathematics Department, DIAT | |

**Syllabus:**

**Elements of Probability and Statistics:** Basic concepts of Probability, Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, etc.,).

**Components of Operations Research:**

Introduction to Operations Research, Linear programming (Simplex Method, Revised Simplex Method, Dual simplex, Duality theory),Transportation Models.

**Linear Algebra:**

General (real) vector spaces, Subspaces, Linear Independence of Vectors, Basis and Dimension, Linear Transformations, Span, Norms, Orthogonal basis and Gram-Schmidt Orthogonalization.

**Ordinary Differential Equations :**

Review of solution methods for first order as well as second order equations, Power Series methods. Higher Order Linear Equations, Boundary Value Problems for Second Order Equations.

**Transform Techniques :**

Overview of Laplace transforms, Fourier Transforms, Z transform.

**Numerical Methods for ODE and P.D.E.:**

Taylor series method – Euler and Modified Euler methods – Runge-Kutta method. Parabolic, Hyperbolic and Elliptic Equations using finite difference method

**Text/References:**


Advanced Engineering Mathematics, 11th Ed, 2010, Erwin Kreyszig, Wiley Eastern.

Linear Algebra and its Applications, 4th Ed., 2008, Gilbert Strang, Academic Press.

Numerical Methods for Scientists and Engineers, Joe D. Hoffman, Marcel Dekker Inc.

Numerical Methods for Engineers, Sixth Edition, Steven Chapra and Raymond Canale, McGraw-Hill Education

Elements of Numerical Analysis, 2nd Edition, Radhey S. Gupta**,** Cambridge University Press

Numerical Solutions of Partial Differential Equations: An Introduction, 2nd Ed., 2005, K. W. Morton, D. F. Mayers, CambridgeUniversity Press.

Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.

Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.

Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.

An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.

Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko, 3rd Ed., Vol. 7, 2006, Springer Verlag,New York.

.S. Gupta.. Calculus of Variation, Prentice Hall of India Pvt. Ltd.

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|---|---|
| **Subject Code** | **PGC-601** |
| **Subject Title** | **Research Methodology and IPR** |
| **Credit** | **02** |
| TeachingScheme | Lectures: 02 hours/week |
| Evaluation Pattern | 03 monthly tests + 01 final evaluation + assignments for internal assessment |
| Total Marks | |
| Prerequisite | |
| Course Instructor | |

**Syllabus Contents:**

**Unit 1:**
Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem Scop and objectives of research problem.Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

**Unit 2:**Effective literature studies approaches,Analysis Plagiarism,Research ethics,

**Unit 3:** Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

**Unit 4:** Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

**Unit 5:** Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

**Unit 6:** New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

**References:**

Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"

Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"

Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for

Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.

Mayall, "Industrial Design", McGraw Hill, 1992.

Niebel, "Product Design", McGraw Hill, 1974.

Asimov, "Introduction to Design", Prentice Hall, 1962.

Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.

T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

## M.Tech Computer Science & Engineering (Artificial Intelligence)

### Brief Description

Artificial Intelligence (AI) based systems have become an essential factor in economic, social development and almost in every facet of our daily lives. AI, deep learning and machine learning are becoming thrust areas and prominent field of study. Professionals who are trained in this field are highly regarded and contribute to strengthening the social, political and financial fabric of modern society.

**Program Objectives** The MTech (AI) programme aims at developing Human Resources in the field of AI with athrust on defence related problems. The present programme is conceived to understand, assimilate & use the advanced technologies to design and develop AI based systems to solve society/ defence problems. Advanced technologies in the areas of deep learning, robotics, machine learning, computer vision, video surveillance, text analytics, speech analytics are the topics/components of this curriculum.

**Pre-requisites/Eligibility**

Scholarship Students Category: Minimum CPI of 6.5 or 60% of marks or first class in qualifying degree. Bachelor degree in Engineering/Technology or Equivalent in CS/IT/ECE/ETC/EE or in relevant Disciplines and a valid GATEScore.

Sponsored Students Category: Minimum CPI of 6.5 or 60% of marks or first class in qualifying degree. Bachelor degree in Engineering/Technology or Equivalent in any Discipline.

**Program Outcome** To generate highly skilled manpower, to research, design, develop and test reliable AI based systems to solve critical problems in various sectors. After completing this course, students are expected to understand and practice the essential concepts related to AI.

**Organization** The Programme curriculum has been designed considering the cyber security requirements of Industry and Defence research and development. It is designed and reviewed by panel of experts chosen from various DRDO labs and leading academic institutions. Each Course of 4 credits is delivered by Course experts through the duration of 16 weeks approximately. It consists of 3 hrs of class room interaction and 2 hrs of lab sessions per week. The evaluations follow continuous assessment process that includes – 3 monthly evaluation exams (10 Marks each), internal assessment (20 Marks) and final examination (50 Marks). The lab focuses on practical exposure to the cyber security tools and techniques in form of mini projects and lab assignments. The 3rdand 4th semesters have a major component of MTech project dissertation, where the students work under close supervision and guidance of their project guide. The students present their work at the end of 3rd and 4th semester. The MTech thesis is submitted and evaluated by the panel of expert examiners at the end of 4th semester.

**Program Educational Objectives (PEOs)**

**PEO1** The M.Tech. Computer Science and Engineering aims at developing skilled Human Resources in the field of Cyber Security and Artificial Intelligence by providing two different specializations, catering the emerging multidisciplinary problem solving needs of defense, civil and DRDO sectors.

**PEO2** The M.Tech. in Cyber Security(CS) programme aims at developing skilled Human Resources in the field of Cyber Security with a thrust on solving defence and society related problems. The present programme is conceived to understand, assimilate & use the advanced technologies such as Network security, Cryptography, Ethical Hacking, Digital Forensic, Malware Analysis, Information Security Management and Trusted Computing techniques. After completing this course, students are expected to understand and practice the essential CS concepts along with developing secure systems.

**PEO3** The M.Tech. Computer Science and Engineering with specialization in Artificial Intelligence programme aims at developing skilled Human Resources in the field of AI with a thrust on solving defence and society related problems. The present programme is conceived to understand, assimilate & apply the advanced technologies such as deep learning, robotics, machine learning, computer vision, video surveillance, text analytics, speech analytics etc. After completing this course, students are expected to understand and practice the essential AI concepts along with developing AI based systems to solve society/defence related problems, carry out research and innovation.

**Program Outcomes (PO)**

**PO1** The M.Tech. Computer Science and Engineering aims at developing an ability in students to independently carry out research /investigation and development work to solve practical problems

**PO2** The M.Tech. Computer Science and Engineering aims at developing an ability in students to write and present a substantial technical report/document

**PO3** The M.Tech. Computer Science and Engineering students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

**Program Specific Outcomes (PSO)**

**PSO1** The M.Tech. Computer Science and Engineering aims at developing skilled knowledgeable Human task force in the field of Cyber Security, catering the needs of defence, social and DRDO requirements

**PSO2** The M.Tech. Computer Science and Engineering aims at developing skilled knowledgeable Human task force in the field of Artificial Intelligence, catering the needs of defence, social and DRDO requirements.

**Semester I**

| Sr. No. | CourseCode | Course | Contact Hours / Week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | CE694 | Big Data Analysis and Algorithms | 3 | 1 | 4 |
| 2 | CE606A | Software Engineering & System Modelling | 3 | 1 | 4 |
| 3 | CE638 | Foundations of AI | 3 | 1 | 4 |
| 4 | CE639 | Practical Machine Learning | 3 | 1 | 4 |
| 5 | CE634 | Natural Language Processing | 3 | 1 | 4 |
| 6 | AM 607 | Mathematics for Engineers | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

**Semester II**

| Sr. No. | CourseCode | Course | Contact Hours / Week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | CE631 | Deep Learning | 3 | 1 | 4 |
| 2 | CE632 | Computer Vision | 3 | 1 | 4 |
| 3 | | **Elective I** | 3 | 1 | 4 |
| 4 | | **Elective II** | 3 | 1 | 4 |
| 5 | | **Elective III** | 3 | 1 | 4 |
| 6 | | **Elective IV** | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | **Total** | **20** | **6** | **24** |

**List of Audit Courses (Applicable for Sem - II):**

| Sr.No. | Course Code | Course |
|---|---|---|
| **1.** | **PGC-602** | English for Research Paper Writing |
| **2.** | | Disaster Management |
| **3.** | | Sanskrit for Technical Knowledge |
| **4.** | | Value Education |
| **5.** | | Constitution of India |
| **6.** | | Pedagogy Studies |
| **7.** | | Stress Management by Yoga |
| **8.** | | Personality Development through Life Enlightenment Skills |

**List of Open Electives Semester-II**

| Sr. No. | Course Code | Course |
|---|---|---|
| 1. | CE-695A | Cyber Physical Systems |
| 2. | CE664A | Network and Cloud security |
| 3. | CE630 | Virtual Reality |
| 4. | CE665A | Security Audit and Penetration Testing |
| 5. | CE633 | Pattern Recognition |
| 6. | CE691 | Secure Wireless Sensor Networks |
| 7. | CE699 | Internet of Things |
| 8. | Open Electives | |
| The electives and other Core Courses offered in the $2^{nd}$ semester by the other departments may be opted by the students on consultation with the course OIC. | | |

**COURSE CURRICULUM**
**SEMESTER I CORE COURSES**

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|---|---|
| **Subject Code** | **CE694** |
| **Subject Title** | **Big Data Analysis & Algorithms** |
| **Credit** | **04** |
| Type of Subject | -Core (MTech in CSE)<br>-Open Elective for All Engineering and Science disciplines |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. |
| Evaluation Pattern | Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>One Final Evaluation at the End of the Term **50 Marks**<br>Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** |
| Total Marks | 100 Marks |
| Prerequisite | None.<br><br>First 10 hours will be devoted for Prerequisite learnings related to basics of Databases (04 hours), Computer Networks (02 Hours), Operating System (02 Hours), Trends in evolutions of Compute-Devices (02 Hours) |
| About the Course | The use of Big Data is becoming a crucial way for leading companies to outperform their peers. In most industries, established competitors and new entrants alike will leverage data-driven strategies to innovate, compete, and capture value. Early adopters of Big Data are using data from sensors embedded in products from children's toys to industrial goods to determine how these products are actually used in the real world. Such knowledge then informs the creation of new service offerings and the design of future products. Big Data will help to create new growth opportunities and entirely new categories of companies. With everything going digital, data is pouring in from all kinds of sources imaginable. Organisations are getting inundated with terabytes and petabytes of data in different formats from sources like operational and transactional systems, customer service points, and mobile and web media. The problem of such huge data is storage and with no proper utilisation of the data, collecting and storing is a waste of resource. Earlier it had been difficult to process such data without relevant technology. Big data analytics is becoming an integral part of organisations who want to grow in this age of innovation and is being done by most of the big companies. There is huge scope of big data analytics professionals as this is going to be an essential part of companies in the future.<br>**The Need:** (a) Cyber-Security Perspective: As the complexity of IT networks has grown, the inventiveness and sophistication of cyber security threats and attacks has grown just as quickly. As malware attacks increase in volume and complexity, it's becoming more difficult for traditional analytic tooling and infrastructure to keep up thanks to the Data volume, For example, every day at |

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| | Sophos Labs, over 300,000 new potentially malicious files that require analysis are reported. Scalability: SQL-based tooling and infrastructure doesn't scale well and is costly to maintain. Big Data Analytics is a Path Forward to Cyber Security. (b) AI / Intelligent Systems Perspective: Centre for Big Data Analytics and Intelligent Systems focuses on the theory development, novel techniques and smart solutions of big data analytics in broad domains, along with theories and techniques of building computer systems, which capture the intelligent behaviours in complex environments. AI dwells on Big Data. (c) Multi-Disciplinary Course useful to any engineering discipline who use a computer. |
| Course Outcomes & Objective | To meet end-user, administrator & system designer perspectives, develop skill sets to be resourceful in building and handling knowledge & information systems. Enhance analytical capabilities to evaluate a domain specific and technical area. Multi-Disciplinary Course useful to any engineering discipline who use computer.<br>To educate the stakeholders on the growth of importance of information security. Along with personal utilization of systems, the privacy matters in the government, enterprise arenas. The study will significantly broaden the scope of individuals who must be aware of relevant issues as part of their work. |
| OBE Course Outcomes | Bloom's Taxonomy:<br><br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze<br>Level-5 Evaluate; Level-6 Create |

| | **CO Title** | **Level** | **Descriptor** | **Expected Outcome** |
|---|---|---|---|---|
| | CO1: Student will be able to examine and identify Data Models for various applications | L1, L2 | Remember, Understand<br>Learn, | 20% |
| | CO2: Student will be able to apply data abstraction & normalisation techniques to handle volume and veracity | L3, L4 | Apply, Analyse | 20% |
| | CO3: Student will be able to analyze & apply multi-dimensional data models for complex scenarios | L4, L5 | Analyse, Evaluate | 20% |
| | CO4: Student will be able to evaluate the system requirements and propose solutions using various data models to cater special application requirements & to form a base to apply Data Mining & AIML techniques. | L5, L6 | Evaluate, Create | 40% |

CO-PO : Course Outcome and Program Outcome Evaluation Metrics

| | PO1 | PO2 | PO3 | PSO1 | PSO2 |
|---|---|---|---|---|---|
| CO1 | Y | | | Y | Y |
| CO2 | Y | Y | | Y | Y |
| CO3 | | Y | Y | | Y |
| CO4 | | | Y | | Y |
| | | | | | |

| | |
|---|---|
| Summary of the Course OutCome | At the end of the course, a student will understand the concepts of data models. Use data models. Evaluate requirements to address emerging areas of data handling with the growing needs. Broadly defined roles. Knowledge of enabling systems. Conducive environment building for data analysts. Data engineering to handle the data at public and private sectors while complying with the data policies to be professionals who understand structured and unstructured data and the challenges to handle them. |

**Syllabus Description**

| | | | | |
|---|---|---|---|---|
| **Basics & Preliminaries** | Types of Data Models, Role of Basic and Advanced Data Structures in Data Models, Basic Dictionary Data Types; Algorithms and basics of analysis,<br><br>OS & Algorithms in Parallel Environments. Protocols of Computer Networks preliminaries, Concerns for Data Security and Privacy | Cormen et al, Horowitz & Sahani, Bipin Desai, Korth et al. Kurose Ross | 10 Hours | CO, PO1 |
| Unit-1 | Introduction to big data analysis: Evolution of data, data streams, database models, graph data, normalizations, structured & unstructured data, | Text Book-1, Ch-1 | 08 Hours | CO1, CO2, PO1 |
| Unit-2 | Architectures, Adoption, Frameworks that enable big data analytics, Multi-Dimensional Data Models, Data cube Computations | Text Book-1, Ch-2, 3 | 04 Hours | CO1, PO1 |
| Unit-3 | Data Preprocessing, Data Warehousing OLTPS, OLAPS, Data Warehouse Architectures, Big Data Mining Frequent Patterns, Big Data Associations & Correlations, Classifications & Predictions, Clustering Techniques & Analysis, Mining | Text Book-1, Ch-4 | 06 Hours | CO1 CO2, PO1 |

| | | | | |
|---|---|---|---|---|
| | Data Streams, Graph Mining, Mining Spatial & Temporal Objects, Predictive Analysis, Ad Hoc Queries, Web Analytics | | | |
| Unit-4 | Algorithms for SISD, SIMD environments, Linked Big Data Analysis – Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications, Large-Scale Machine Learning, Big Data Analytics on Specific Processors, Hardware and Cluster Platforms for Big Data Analytics, Big Data Next Challenges – IoT, Cognition, and Beyond | Text Book-1, Ch-4, 5 | 06 Hours | CO3, PO2 |
| Unit-5 | Big Data Storage & Processing Concepts<br>Relational database technology, Parallel and Distributed Processing capabilities, Clouds, MapReduce Framework | Text Book-1, Ch 5,6,7,8 | 06 Hours | CO3, PO2, PO3 |
| Unit-6 | Database Auditing Models<br>Technical Audit Environment, Process, Objectives, Classification Types, Incidence Reports, Level of escalations.<br><br>Application Data Audit:<br>DML Action Audit; Triggers; Fine-Grained Auditing FGA; Application Errors; PL-SQL Environments, Audit DB Activities | Weblink References | 06 Hours | CO4, PO2, PO3 |
| Unit-7 | Big data analytics tools, HDFS, NOSQL, SQL environments<br><br>Project Cases Big data, Big Data Security: Online Databases; CSV files to Structured Environments, SCADA, IoTs, | Text Book-1, Ch-8 | 06 Hours | CO1, CO4, PO1, PO3 |
| Text Books (MUST Know) | Text Book 1<br>Big Data Fundamentals: Concepts, Drivers & Techniques (Prentice Hall Service Technology) Paperback – Import, 5 Jan 2016 by Thomas Erl (Author), Wajid Khattak (Author), Paul Buhler (Author), Publisher: Prentice Hall (5 January 2016), 240 pages , ISBN-10: 0134291077 , ISBN-13: 978-0134291079<br>Text Book-2:<br>Big Data: Concepts, Technology, and Architecture, | | Must Know. | |

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| | Balamurugan Balusamy, Nandhini Abirami R, Seifedine Kadry, Amir H. Gandomi, Wiley Publications, ISBN: 978-1-119-70185- 9 March 2021 | | |
| Reference Books (SHOULD Know) | Reference Book-1<br>Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006 | Should Know. | |
| Consortium, e-books and Web Link references (SHOULD/ Could Know) | https://iveybusinessjournal.com/publication/why-big-data-is-the-new-competitive-advantage/<br><br>https://www.datameer.com/company/datameer-blog/challenges-to-cyber-security-and-how-big-data-analytics-can-help/<br><br>https://www.iss.nus.edu.sg/executive-education/discipline/detail/analytics-and-intelligent-systems<br>W3.org<br>Meity.gov.in<br>SIGSAC SIGSEC acm.org<br>Isca-speech.org<br>Issa.org<br>Oracle.com/database/<br>Thelawreviews.co.uk<br>Data Security Council of India (DSCI)<br>prsindia.org<br>iso.org ISO/IEC 27000/27001/27002 | Should and Could Know. | |

| Laboratory Assignments/ Demonstrations | | | | |
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| LAB Assignments | *Each student will work on unique case study. Will require approval of the same at the beginning. Report submission is essential for each Lab Assignment. | | | |
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| 1 | Describe the Use Case*. Model the case study. Abstract. Apply & implement DDL. | Unit-1 | 02 hours | CO1 |
| 2 | Data Manipulation Language (DML) and Data Control Language (DCL) | Unit-2 | 02 hours | CO2 |
| 3 | Apply, analyse and evaluate ACID Properties. High level language extensions with cursors. High level language extension with Triggers. | Unit-3 & 4 | 02 hours | C03 |
| 4 | Implement and apply Multi-dimensional DBs. Implement three basic operations: Perform Diagnostic Analysis | Unit 4 & 5 | 02 hours | CO3 |
| 5 | Implement and apply Multi-dimensional | Unit 4 | 02 hours | CO4 |

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| | DBs. Implement operations to observe 'what-if' analysis: Perform Predictive Analysis | & 5 | | |
| 6 | Create use case environment, Implement & Perform Data Flow wrt Application/Domain Control | Unit 6 | 02 hours | CO4 |
| 7 | Create use case environment, implement & perform Inter-environment mappings and data pre-processing to apply to AIML model. | Unit 6 | 02 hours | CO4 |
| 8 | Create model and implement any one security feature to demonstrate data security concern & mitigation. | Unit 7 | 02 hours | CO4 |
| 9 | Assigned NOSQL Environment Study and Presentation. | Unit 1 to 7 | Sem | CO4 |
| 10 | Mini-project. Implementation and Demonstration. Report Submission is essential | Unit 1 to 7 | Sem | CO4 |

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| **Course Code: CE606A** | | |
| **Course Title: Software Engineering & System Modelling** | | |
| Credit: 4 | | |
| Evaluation Pattern - 03 – monthly test + 01 Final Evaluation | | |
| Prerequisite: C programming and debugging concepts, basic concepts of operating systems. | | |
| Objective: Major objective is to learn basic principles of Software Engineering and Design, which can facilitate the resource efficient model of the Software Systems. | | |
| Course Outcome-<br>CO1: Students are able to understand Basic Principles of Software Engineering and Design<br>CO2: Students are able to create Use Cases and develop Use Case Models of the Systems.<br>CO3: Students are able to apply UML design notations to develop the software systems<br>CO4: Able to recognize and apply appropriate software design patterns for software efficiency | | |
| Unit | Syllabus Details | Outcome |
| Unit – I | Software Development Process, Planning software project, Cost, Scheduling and Risk Management. Metrices, Design Principles, Introduction to Object Oriented Design. | CO1, & CO4 |

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| Unit – II | Introduction to OOAD –What is OOAD? –What is UML? What are the Unified process(UP) phases, Case study –the NextGen POS system, Inception-Use case Modeling, Relating Use cases– include, extend and generalization. . Elaboration - Domain Models, Finding conceptual classes and description classes, Associations, Attributes, Domain model refinement – Finding conceptual class hierarchies, relationships, UML activity diagrams and modeling | CO2, & CO3 |
| Unit – III | System sequence diagrams (SSD) -Relationship between sequence diagrams and use cases Logical architecture and UML package diagram, Logical architecture refinement, UML class diagrams, UML interaction diagrams | CO3, & CO4 |
| Unit – IV | GRASP: Designing objects with responsibilities –Creator, Information expert, Low Coupling, Controller, High Cohesion, Designing for visibility, Applying GoF design patterns – adapter, singleton, factory and observer patterns. | CO1, & CO4 |
| Unit – V | UML state diagrams and modeling -Operation contracts, Mapping design to code, UML deployment and component diagrams. | CO2, & CO4 |

Textbooks:
Software Engineering- Pankaj Jalote, TMH
Software Engineering- Ian Sommerville , Pearson
Craig Larman, "Applying UML and Patterns: An Introduction to object-oriented Analysis and Design and iterative development", Third Edition, Pearson Education
References:
Mike O'Docherty, "Object-Oriented Analysis & Design: Understanding System Development with UML 2.0", John Wiley & Sons, 2005.
2. James W-Cooper, Addison-Wesley, "Java Design Patterns –A Tutorial", 2000.
4. Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides, "Design patterns: Elements of Reusable object-oriented software", Addison-Wesley, 1995.

Lab Assignments

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| Lab 1 | UML Modelling UML modelling through Case study: Generation of Use-case diagram, class diagram, sequence diagram. |
| Lab 2 | Use Case Modelling |
| Lab 3 | Security Use Cases Modelling |
| Lab 4 | Identification of objects from Use Cases |
| Lab 5 | Object Modelling |
| Lab 6 | Activity Diagrams |
| Lab 7 | Sequence Diagrams |

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| Lab 8 | Mapping of operations in Class and Sequence Diagrams |
| Lab 9 | Implementations of Design Patterns |

| **Course Code** | **CE638** | | |
|---|---|---|---|
| **Course Title** | **Foundations of AI** | | |
| **Credit** | **04** | | |
| Type of Course | -Core (MTech in CSE)<br>-Professional Open Elective for All Engineering and Science disciplines | | |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. | | |
| Evaluation Pattern | Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>One Final Evaluation at the End of the Term **50 Marks**<br>Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** | | |
| Total Marks | 100 Marks | | |
| Prerequisite | Knowledge of Statistical Techniques, Probability Theory, Data Structures and Algorithms, Programming Language such as Python, Matlab. | | |
| Course Objectives | The main objective of the course is to introduce concepts of Artificial Intelligence. The general objectives are to learn about computer systems that exhibit intelligent behaviour, design intelligent agents, identify AI problems and solve the problems, design knowledge representation and expert systems, design neural networks for solving problems, identify different machine learning paradigms and identify their practical applications. | | |
| Course Outcomes | Bloom's Taxonomy:<br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze<br>Level-5 Evaluate; Level-6 Create | | |
| | **CO Title** | **Level** | **Descriptor** |
| | CO1: Student will be able to understand the concepts and basics of AI | L1, L2 | Remember, Learn, Understand |
| | CO2: Student will be able to apply the algorithms for Problem Solving and Knowledge Representation | L3, L4 | Apply, Analyse |
| | CO3: Student will be able to analyze & apply the concepts of Machine Learning for structured and unstructured data | L4, L5 | Analyse, Evaluate |

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| | CO4: Student will be able to evaluate the AI based system and propose solutions using various AI models for multi-disciplinary application requirements | L5, L6 | Evaluate, Create | |
| **Syllabus Description** | | | | |
| **Basics & Preliminaries** | Details | Books & References | Duration | COs |
| Unit-1 | **Introduction:** Artificial Intelligence (AI), AI Perspectives: acting and thinking humanly, acting and thinking rationally, History of AI, Foundations of AI, Applications of AI | T1, R1 | 8 | CO1 |
| Unit-2 | **Intelligent Agents:** Introduction of agents, Structure of Intelligent agent, Properties of Intelligent Agents, Configuration of Agents, PEAS description of Agents, Types of Agents: Simple Reflexive, Model Based, Goal Based, Utility Based, Environment Types: Deterministic, Stochastic, Static, Dynamic, Observable, Semi-observable, Single Agent, Multi Agent | T1,R1 | 8 | CO1 |
| Unit-3 | **Problem Solving by Searching:** Definition, Problem as a state space search, Problem formulation, Well-defined problems, Solving Problems by Searching, Search Strategies, Performance evaluation of search techniques, Uninformed Search: Depth First Search, Breadth First Search, Depth Limited Search, Iterative Deepening Search, Bidirectional Search, Informed Search: Greedy Best first search, A* search, Hill Climbing, Simulated Annealing, Game playing, Adversarial search techniques, Mini-max Search, Alpha-Beta Pruning, Constraint Satisfaction Problems | T1,R2 | 8 | CO2 |
| Unit-4 | **Knowledge Representation:** Definition and importance of Knowledge, Issues in Knowledge Representation, Knowledge Representation Systems, Properties of | T2, R2, R3 | 8 | CO2 |

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| | Knowledge Representation Systems. Types of Knowledge Representation Systems: Semantic Nets, Frames, Conceptual Dependencies, Scripts, Rule Based Systems, Propositional Logic, Predicate Logic Propositional Logic(PL): Syntax, Semantics, Formal logic-connectives, truth tables, tautology, validity, well-formed-formula, Inference using Resolution, Backward-Chaining and Forward Chaining, Predicate Logic: FOPL, Syntax, Semantics, Quantification, Inference with FOPL: By converting into PL (Existential and universal instantiation), Unification and lifting, Inference using resolution, Handling Uncertain Knowledge, Radom Variables, Prior and Posterior Probability, Inference using Full Joint Distribution, Bayes' Rule and its use, Bayesian Networks, Reasoning in Belief Network, Fuzzy Logic | | | |
| Unit-5 | **Machine Learning:** Introduction to Machine Learning, Concepts of Learning, Supervised, Unsupervised and Reinforcement Learning, Statistical-based Learning: Naive Bayes Model | T2,R1,R2 | 16 | CO3 |
| Text Books (MUST Know) | Stuart Russell & Peter Norvig, Artificial Intelligence: A Modern Approach, Prentice-Hall, Third Edition (2009)<br>Micheal Negnivitsky, Artificial Intelligence: A Guide to Intelligent Systems, Addison-Wesley, 3nd Edition, 2011 | | | |
| Reference Books (SHOULD Know) | E. Rich and K. Knight, Artificial Intelligence, 2nd ed., McGraw-Hill, New York, 1991.<br>M. Ginsberg, Essentials of Artificial Intelligence, Morgan Kaufmann, San Mateo, Ca., 1993.<br>D. Poole and A. Mackworth, Artificial Intelligence: Foundations of Computational Agents, Cambridge University Press, Cambridge, UK, 2010 | | | |
| Laboratory Assignments/ Demonstrations | | | | |
| Lab 1 | Design and Implement Uninformed Search like DFS, BFS, Greedy Best | UNIT III | 02 hours | CO1,CO4 |

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| | First, A*, Game Search Like Min Max Search | | | |
| Lab 2 | Design and Implement constraint satisfaction problems like water jug, n-queen problem, crypto-arithmatic problem. | UNIT III | 02 hours | CO1,CO4 |
| Lab 3 | Write programs for illustrating the concepts knowledge representation systems like rule based (If -then Else format) and predicate logic (using predicates) | UNIT IV | 02 hours | C02,CO4 |
| Lab 4 | Write programs for illustrating the concepts knowledge representation systems like frames (using concepts of class) and semantic nets (using concepts of graph | UNIT IV | 02 hours | CO2,CO4 |
| Lab 5 | Implementing Naive Bayes algorithm | UNIT V | 02 hours | CO3,CO4 |
| Lab 6 | Implementing Neural Networks for realization of AND, OR gates | UNIT V | 02 hours | CO3,CO4 |
| Lab 7 | Mini-project. Implementation and Demonstration. Report Submission is essential | UNIT I - V | 04 hours | CO4 |

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| **Subject Code** | **CE639** |
| **Subject Title** | **Practical Machine Learning** |
| **Credit** | **04** |
| Type of Subject | -Core (MTech in CSE)<br>-Professional Open Elective for All Engineering and Science disciplines |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. |
| Evaluation Pattern | Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>One Final Evaluation at the End of the Term **50 Marks**<br>Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** |
| Total Marks | 100 Marks |
| Prerequisite | Knowledge of Statistical techniques, Linear algebra and computer programming knowledge is required. |
| Dept | CSE |

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| Course Objectives | To provide the knowledge of Python programming language as it applies to data analytics. Skills will be developed for Data Analysis with Python and develop product in python. Student will learn various ML techniques including Supervised, unsupervised classification and regression analysis, Artificial Neural Networks, etc. Student will learn Python Programming for implementing these algorithms on standard datasets |
| Course Outcomes | Bloom's Taxonomy:<br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze<br>Level-5 Evaluate; Level-6 Create |

| | **CO Title** | **Level** | **Descriptor** |
|---|---|---|---|
| | CO 1 - Students will be able to understand ML paradigms and various Supervised, unsupervised classification and regression analysis methods. (PO1,PO2, PO3, PSO2) | L1, L2 | Remember, Learn, Understand |
| | CO2: Students will be able to understand various ML algorithms like and analyse their applications in real world (PO1,PO2, PO3, PSO2) | L2 | Remember, Learn, Understand |
| | CO3: Students will be able to understand advanced ML algorithms and techniques etc. (PO1,PO2, PO3, PSO2) | L3 | Remembering, Understanding, Analysing |
| | CO4: Students will be capable of applying their ML knowledge and skills to solve engineering problems in various domains using ML programming languages( PO1, PO2, PO3, PSO1, PSO2) | L4 | Applying, Analysing |

**Syllabus Description**

| **Basics & Preliminaries** | Details | Books & References | Duration | Cos |
|---|---|---|---|---|
| Unit-1 | Data Analytics Foundations: R programming, Python Basics -Expressions and Variables, String Operations, Lists and Tuples, Sets, Dictionaries Conditions and Branching, Loops, Functions, Objects and Classes, Reading/Writing files, Hand ling data with Pandas, Scikit Library, Numpy Library, Matplotlib, scikit programming for data analysis, setting up lab environment, study of standard datasets. Introduction to Machine Learning- Applications of Machine Learning, Supervised, unsupervised classification and | Textbooks - 1,2 | 12 Hrs | CO1 |

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| | regression analysis | | | |
| Unit-2 | Python libraries suitable for Machine Learning Feature Extraction. Data pre-processing, feature analysis etc., Dimensionality Reduction & Feature Selection Methods, Linear Discriminant Analysis and Principal Component Analysis, tackle data class imbalance problem | Textbooks - 2,3 | 12 Hrs | CO2 |
| Unit-3 | Supervised and regression analysis, Regression, Linear Regression, Non-linear Regression, Model evaluation methods, Classification, K-Nearest Neighbor, Naïve Bayes, Decision Trees, Logistic Regression, Support Vector Machines, Artificial Neural Networks, Model Evaluation. | Textbooks - 2,3,4 | 12 Hrs | CO2 |
| Unit-4 | Unsupervised classification K-Means Clustering, Hierarchical Clustering, Density-Based Clustering, Recommender Systems-Content-based recommender systems, Collaborative Filtering, machine learning techniques for standard dataset, ML applications, Case Study: Image spam detection | Textbooks - 4-5, / References - 1-4 | 12 Hrs | CO3 |
| | LAB/ Assignments/Student Presentations [2T/P per week] | Textbooks - 4-5, / References - 1-4 | 02 Hrs/week | CO4 |
| Text Books (MUST Know) | 1. Building Machine Learning Systems with Python - Willi Richert, Luis Pedro Coelho<br>2. Learning scikit-learn: Machine Learning in Python - Raúl Garreta, Guillermo Moncecchi<br>3. Machine Learning: An Algorithmic Perspective - Stephen Marsland<br>4. Sunita Vikrant Dhavale, "Advanced Image-based Spam Detection and Filtering Techniques", IGI Global, 2017<br>5. Trevor Hastie, Robert Tibshirani, Jerome Friedman - The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Second Edition. February 2009 | | | |
| Reference Books (SHOULD Know) | 1. Stuart Russell, Peter Norvig (2009), "Artificial Intelligence – A Modern Approach", Pearson Elaine Rich & Kevin Knight (1999), "Artificial Intelligence", TMH, 2nd Edition<br>2. NP Padhy (2010), "Artificial Intelligence & Intelligent System", Oxford<br>3. ZM Zurada (1992), "Introduction to Artificial Neural Systems", West Publishing Company | | | |

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| | 4. Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/ NVidia sources. | | | |
| Laboratory Assignments/ Demonstrations | | | | |
| 1 | Study and implement algorithms for data pre-processing and data cleaning | Unit -1 | 02 hours | CO1, CO3, & CO4 |
| 2 | Study and implement algorithms for data feature selection reduction. | Unit -1 | 02 hours | CO1, CO3, & CO4 |
| 3 | Study and Implement Linear Regression Algorithm for any standard dataset | Unit -2 | 02 hours | CO2, CO3, & CO4 |
| 4 | Study and Implement unsupervised clustering Algorithms for any standard dataset | Unit -3 | 02 hours | CO1, CO3, & CO4 |
| 5 | Study and Implement KNN for any standard dataset | Unit -3 | 04 hours | CO1, & CO4 |
| 6 | Study and Implement ANN for any standard dataset | Unit -3 | 02 hours | CO2, & CO3 |
| 7 | Study and Implement PCA for any standard dataset | Unit -3 | 02 hours | CO3, & CO4 |
| 8 | Case Study: Use of ML along with Fuzzy Logic/ GA/PSO/ACO to solve real world Problem | Unit -4 | 04 hours | CO2, & CO3 |
| 9 | Mini assignment: Apply ML to solve any real world problem | Unit -4 | 04 hours | CO2, & CO4 |
| 10 | ML Practice Test – 1 Quiz | Unit - 1,2,3,4 | 02 hours | CO1,CO2, CO3, & CO4 |

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|---|---|
| **Course Code** | **CE634** |
| **Course Title** | **Natural Language Processing** |
| **Credit** | **04** |
| Type of Course | -Core (MTech in CSE)<br>-Professional Open Elective for All Engineering and Science disciplines |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. |
| Evaluation Pattern | 03 – monthly test + 01 Final Evaluation |
| Total Marks | 100 |

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| Prerequisite | Programming, Data Structures, Algorithms | | | | |
| Dept | CSE | | | | |
| Course Objectives | Understanding of basic issues, concepts, principles and mechanisms of Natural Language Processing. Build knowledge in the following areas of theory, programming, application development in NLP, Machine Learning in NLP. Develop, test and validate NLP applications which use machine learning. | | | | |
| Course Outcomes | Bloom's Taxonomy:<br><br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze<br>Level-5 Evaluate; Level-6 Create | | | | |
| | **CO Title** | | **Le vel** | **Descriptor** | |
| | CO1: Students are able to understand the basic concepts of NLP | | L1, L2 | Remember, Learn, Understand | |
| | CO2: Students are able to process raw text, write structured programs, algorithms, categorizing and tagging words using Automatic and N-Gram Taggers | | L3, L4 | Apply, Analyse | |
| | CO3: Use supervised and unsupervised learning, Classify text using Decision Trees, Extract information from text | | L4, L5 | Analyse, Evaluate | |
| | CO4: Analyze Sentence structure, understand and apply grammar development. | | L5, L6 | Evaluate, Create | |
| | CO5: Analyze meaning of sentences, Natural Language understanding, managing linguistic data, use deep learning for NLP | | | | |
| **Syllabus Description** | | | | | |
| **Basics & Preliminaries** | Details | Books & References | | Duration | COs |
| Unit-1 | Introduction, Language Processing with Python, Accessing Text Corpora, Conditional Frequency Distribution, Lexical Resources | Text 1, Chap1, 2 | | 3hr | CO1 |
| Unit-2 | Processing Raw Text, Accessing Text from Web and Disk, Strings, Regular | Text1, Chap3 | | 4hr | CO1, CO2 |

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| | Expressions, Segmentation, Formatting | | | |
| Unit-3 | Writing Structured Program, Structured Programming, Python Basics, Algorithm Design | Text 1,Chap 4 | 4hr | CO2 |
| Unit-4 | Categorizing and Tagging Words, Tagger, Tagged Corpora, Automatic Tagging, N-Gram Tagging, Transformation based Tagging | Text 1, Chap5 | 4hr | CO2 |
| Unit-5 | Learning to classify Text, Supervised Classification, Evaluation, Decision Trees, Naïve Bayes Classifier, Maximum Entropy Classifiers, Extracting Information from Text, Information Extraction, Chunking, Evaluation of Chunking, Recursion, Relation | Text 1, Chap6, 7 | 6hr | CO3 |
| Unit-6 | Analyzing Sentence Structure, Context Free Grammar, Parsing, Dependency, Grammar development. | Text1, Chap 8 | 4hr | CO3, CO4 |
| Unit -7 | Building Feature based Grammar, Grammatical Features, Processing Feature Structures, Extending Feature based Grammar | Text 1, Chap 9 | 4hr | CO4 |
| Unit -8 | Analyzing the Meaning of Sentences, Natural Language Understanding, Propositional Logic, First Order Logic, English Semantics Discourse Semantics | Text 1, Chap 10 | 6hr | CO4, CO5 |
| Unit -9 | Managing Lingusitic Data, Corpus Structure, Working with XML, Working with Toolbox, OLAC | Text 1, Chap 11 | 6hr | CO5 |
| Unit-10 | Unit – X<br>Deep Learning, Transformers, LSTM for NLP | Ref 2 | 8hr | CO5 |
| Text Books (MUST Know) | S.Bird, E Klein and E Loper, “Natural Language Processing with Python”, O’Reilly, 2009. | | | |
| Reference Books (SHOULD Know) | D. Jurafsky and JH Martin, “Speech and Language Processing: An Introduction to NLP”, Updated, Pearson, 2020. Speech and Language Processing (stanford.edu) | | | |

| Laboratory Assignments/ Demonstrations | | | |
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| **Lab No** | **Lab Experiment** | **Unit** | Hours |
| 1 | NLTK , Installation and Commands in NLTK | Unit 1 | 2 |
| 2 | Python Programming for NLP | Unit 3 | 2 |
| 3 | Corpora, Installing and Checking Various Text Corpora | Unit 1, 3 | 2 |
| 4 | Processing Raw text, Using NLTK, using Regular expression | Unit 2 | 2 |
| 5 | Tagging words, Tagging, N-gram tagging | Unit 4 | 2 |
| 6 | Classifying Text, Using classifiers to classify text | Unit 5 | 2 |
| 7 | Extracting Information from Text, Chunking, Recursion | Unit 5 | 2 |
| 8 | Analysing Sentence Structure, Context Free Grammar, Parsing | Unit 7 | 2 |
| 9 | Analysing Meaning of Sentences, Propositional and First Order Logic | Unit 8 | 2 |
| 10 | Creating Corpora, Working with XML | Unit 9 | 2 |

| **Course Code** | **AM 607** |
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| **Course Title** | **Mathematics for Engineers** |
| **Credit** | **04** |
| TeachingScheme | Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week. |
| Evaluation Pattern | 03 monthly tests + 01 final evaluation + assignments for internal assessment |
| Total Marks | 100 |
| Prerequisite | NIL |
| Course Instructor | Faculty from Math Dept |
| Course offered from Mathematics Department, DIAT | |

**Syllabus:**

**Elements of Probability and Statistics:** Basic concepts of Probability, Discrete Probability Distributions (Binomial, Poisson etc.),Continuous Probability Distributions (Normal, Exponential, etc.,).

**Components of Operations Research:**

Introduction to Operations Research, Linear programming (Simplex Method, Revised Simplex Method, Dual simplex, Duality theory),Transportation Models.

**Linear Algebra:**

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| General (real) vector spaces, Subspaces, Linear Independence of Vectors, Basis and Dimension, Linear Transformations, Span, Norms,Orthogonal basis and Gram-Schmidt Orthogonalization.<br>**Ordinary Differential Equations :**<br>Review of solution methods for first order as well as second order equations, Power Series methods. Higher Order Linear Equations,Boundary Value Problems for Second Order Equations.<br>**Transform Techniques :**<br>Overview of Laplace transforms, Fourier Transforms, Z transform.<br>**Numerical Methods for ODE and P.D.E.:**<br>Taylor series method – Euler and Modified Euler methods – Runge-Kutta method. Parabolic, Hyperbolic and Elliptic Equations using finite difference method |
| **Text/References:**<br>Advanced Engineering Mathematics, 11th Ed, 2010, Erwin Kreyszig, Wiley Eastern.<br>Linear Algebra and its Applications, 4th Ed., 2008, Gilbert Strang, Academic Press.<br>Numerical Methods for Scientists and Engineers, Joe D. Hoffman, Marcel Dekker Inc.<br>Numerical Methods for Engineers, Sixth Edition, Steven Chapra and Raymond Canale, McGraw-Hill Education<br>Elements of Numerical Analysis, 2nd Edition, Radhey S. Gupta**,** Cambridge University Press<br>Numerical Solutions of Partial Differential Equations: An Introduction, 2nd Ed., 2005, K. W. Morton, D. F. Mayers, CambridgeUniversity Press.<br>Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.<br>Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.<br>Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.<br>An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.<br>Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko, 3rd Ed., Vol. 7, 2006, Springer Verlag,New York.<br>.S. Gupta.. Calculus of Variation, Prentice Hall of India Pvt. Ltd. |

| **Course Code** | **PGC-601** |
|---|---|
| **Course Title** | **IPR and Research Methodology** |
| **Credit** | **02** |
| TeachingScheme | Lectures: 02 hours/week |
| Evaluation Pattern | 03 monthly tests + 01 final evaluation + assignments for internal assessment |
| Total Marks | |
| Prerequisite | |
| Course Instructor | **Institute-level conduct** |
| **Syllabus Contents:**<br>**Unit 1:** Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope | |

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| and objectives of research problem.<br>Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations<br>**Unit 2:** Effective literature studies approaches, analysis<br>Plagiarism, Research ethics,<br>**Unit 3:** Effective technical writing, how to write report, Paper<br>Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee<br>**Unit 4:** Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.<br>**Unit 5:** Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.<br>**Unit 6:** New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |
| **References:**<br>Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"<br>Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"<br>Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for<br>Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.<br>Mayall, "Industrial Design", McGraw Hill, 1992.<br>Niebel, "Product Design", McGraw Hill, 1974.<br>Asimov, "Introduction to Design", Prentice Hall, 1962.<br>Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.<br>. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008 |

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|---|---|
| **Course Code** | **CE631** |
| **Course Title** | **Deep Learning** |
| **Credit** | **04** |
| Type of Course | -Core (MTech in CSE)<br>-Professional Open Elective for All Engineering and Science disciplines |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. |
| Evaluation Pattern | 03 – monthly test + 01 Final Evaluation |

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| Total Marks | 100 |
| Prerequisite | Knowledge of Statistical Techniques, Probability Theory, Data Structures and Algorithms, Programming Language such as Python, Matlab. |
| Dept | CSE |
| Course Objectives | To understand concepts of Deep Learning and Basics of Machine Learning. To understand how to train Deep Models and Convolutional Networks. To understanding and analyze the related study and refer different latest research views in Latest trend and techniques. |
| Course Outcomes | Bloom’s Taxonomy:<br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze<br>Level-5 Evaluate; Level-6 Create |

| | **CO Title** | **Level** | **Descriptor** |
|---|---|---|---|
| | CO1 Remembering the basics of Machine Learning and Deep learning | Level 1 & 2 | Remembering, Understanding |
| | CO2 Understanding the different learning algorithms and techniques in machine Learning | Level 2 | Understanding |
| | CO3 Applying different convolution operation, pooling, Functions and sequence modelling | Level 3 | Applying |
| | CO4 Analyze Various other Deep Learning architectures like RNN, Autoencoders and GANSs | Level 4 | Analyzing |
| | CO5 Analyzing and gain knowledge about Deep Learning Applications | Level 4 | Analyzing |

**Syllabus Description**

| **Basics & Preliminaries** | Details | Books & References | Duration | Cos |
|---|---|---|---|---|
| Unit-1 | Introduction : Overview of machine learning, linear classifiers, loss functions Optimization : Stochastic gradient descent and contemporary variants, backpropagation | T1, R1 | 5hr | CO1& CO2 |
| Unit-2 | Feedforward networks and training : Activation functions, initialization, regularization, batch normalization, model selection, ensembles. | T1, R1 | 9hr | |

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|---|---|---|---|---|
| Unit-3 | Convolutional neural networks : Fundamentals, architectures, pooling, Visualization, Image Classification and Object Detection using CNN | T1, R4 | 16hr | CO3 |
| Unit-4 | Recurrent neural networks : Recurrent neural networks (RNN), long-short term memory (LSTM), language models, machine translation, image captioning, video processing, visual question answering, video processing, learning from descriptions, attention | T1, R4 | 10hr | CO4 |
| Unit-5 | Deep generative models : Auto-encoders, generative adversarial networks | T1, R4 | 5hr | CO4 |
| **Text Books (MUST Know)** | Ian Goodfellow, Y. Bengio, A. Courville, Deep Learning, MIT Press, 2016. http://www. deeplearningbook.org. | | | |
| **Reference Books (SHOULD Know)** | K. P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012.<br>C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.<br>A National Initiative on AI Skilling and Research (leadingindia.ai)<br>NPTEL Course Lecture Material: Deep Learning Part-1 By Dr. Mitesh Kapra, IIT Chennai. | | | |

Laboratory Assignments/ Demonstrations

| **Lab No** | **Lab Experiment** | **Unit** | Hours | CO's |
|---|---|---|---|---|
| 1 | Implementation of Linear Classifier using ML | Unit 1 | 2 | CO1 & 2 |
| 2 | Implementation of Activation Functions and analyze the significance of Weight and Bias for ML Model | Unit 2 | 2 | CO1 & 2 |
| 3 | Implementation of Perceptron Model for Binary Logic. | Unit 2 | 2 | CO1 & 2 |
| 4 | Implementation of XOR using Multi Layer Perceptron | Unit 2 | 2 | CO1 & 2 |
| 5 | Implementation of Convolutional Neural Networks | Unit 3 | 2 | CO3 |
| 6 | Object Detection using CNNs | Unit 3 | 2 | CO3 |
| 7 | Image Classification Using CNNs | Unit 3 | 2 | CO3 |
| 8 | Analyzing various CNN Architectures | Unit 3 | 2 | CO3 |
| 9 | Implementing RNNs and LSTM | Unit 4 | 2 | CO4 |
| 10 | Analyzing CNNs and RNNs for DeepLearning Applications | Unit 5 | 2 | CO4 |

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|---|---|---|---|
| **Subject Code** | **CE632** | | |
| **Subject Title** | **Computer Vision** | | |
| **Credit** | **04** | | |
| Type of Subject | -Core (MTech in CSE)<br>-Professional Open Elective for All Engineering and Science disciplines | | |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. | | |
| Evaluation Pattern | Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>One Final Evaluation at the End of the Term **50 Marks**<br>Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** | | |
| Total Marks | 100 Marks | | |
| Prerequisite | Statistical techniques, Linear algebra and computer programming knowledge is required. | | |
| Dept | CSE | | |
| Course Objectives | To introduce students the fundamentals of image formation; To introduce students the major ideas, methods, and techniques of computer vision and pattern recognition; To develop an appreciation for various issues in the design of computer vision and object recognition systems; and To provide the student with programming experience from implementing computer vision and object recognition applications. | | |
| Course Outcomes | Bloom's Taxonomy:<br><br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze<br>Level-5 Evaluate; Level-6 Create | | |
| | **CO Title** | **Level** | **Descriptor** |
| | CO1: Students will be able to understand and apply image processing techniques including filtering operations, thresholding techniques, edge detection techniques etc. (PO1, PO2, PO3, PSO2) | L1, L2 | Remember, Understand |
| | CO2: Students will be able to understand and extract image features using techniques like corner and interest point detection, shape analysis, fourier descriptors, Ransac, GHT etc. (PO1, PO2, PO3, PSO2) | L3 | Remember, Understand Analyse |
| | CO3: Students will be able to understand and learn how the extracted features can be used to solve problems in various computer vision related applications. (PO1, PO2, PO3, PSO2) | L3 | Remember, Understand Analyse |

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| | CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in computer vision related domain. (PO1, PO2, PO3, PSO2) | L4 | Apply, Analyse |

**Syllabus Description**

| **Basics & Preliminaries** | Details | Books & References | Duration | COs |
|---|---|---|---|---|
| Unit-1 | Image processing foundations: Review of image processing techniques, classical filtering operations, thresholding techniques, edge detection techniques, mathematical morphology, texture analysis, Shapes and regions: Binary shape analysis – connectedness – object labeling and counting – size filtering – distance functions – skeletons and thinning | Textbooks - 1 | 12L | CO1 |
| Unit-2 | Corner and interest point detection, deformable shape analysis – boundary tracking, procedures – active contours – shape models and shape recognition – centroidal profiles – handling occlusion – boundary length measures – boundary descriptors – chain codes, Fourier descriptors – region descriptors – moments, Hough transform: Line detection – Hough Transform (HT) for line detection – foot-of-normal method – line localization – line fitting | Textbooks - 2 | 12L | CO2 |
| Unit-3 | Case study: spatial matched filtering – GHT for ellipse detection – object location – GHT for feature collation RANSAC for straight line detection – HT based circular object detection – accurate center location – speed problem – ellipse detection | Textbooks - 2,3 | 12L | CO2 |
| Unit-4 | Case Study: Image based spam detection, Case Study: CV Applications - Face detection – Face recognition – Eigen faces, Case Study: CV Applications - human gait analysis, Case Study: CV based Surveillance Applications | Textbooks/ References -4-8 | 12L | CO3 |
| | LAB/ Assignments/Student Presentations [2T/P per week] | | 02L/Week | CO4 |

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|---|---|---|---|---|
| Text Books | E. R. Davies, "Computer & Machine Vision", Fourth Edition, Academic Press, 2012.<br>R. Szeliski, "Computer Vision: Algorithms and Applications", Springer 2011.<br>Simon J. D. Prince, "Computer Vision: Models, Learning, and Inference", Cambridge University Press, 2012.<br>Mark Nixon and Alberto S. Aquado, "Feature Extraction & Image Processing for Computer Vision", Third Edition, Academic Press, 2012. | | | |
| Reference Books | D. L. Baggio et al., "Mastering OpenCV with Practical Computer Vision Projects", Packt Publishing, 2012.<br>Jan Erik Solem, "Programming Computer Vision with Python: Tools and algorithms for analyzing images", O'Reilly Media, 2012.<br>Sunita Vikrant Dhavale, "Advanced Image-based Spam Detection and Filtering Techniques", IGI Global, 2017<br>Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/ NVidia sources. | | | |
| Laboratory Assignments/ Demonstrations | | | | |
| 1 | Introduction to Digital Image Processing using python | Unit -1 | 02 hours | CO1, CO2,CO3, & CO4 |
| 2 | Study and Implement Image Transformation Techniques | Unit -1 | 02 hours | CO1, CO3, & CO4 |
| 3 | Study and Implement Image Transformation Techniques | Unit -1 | 02 hours | CO2, CO3, & CO4 |
| 4 | Study and Implement Edge Detection Techniques | Unit -1 | 02 hours | CO1, CO3, & CO4 |
| 5 | Study and Implement Image Thresholding Transform | Unit -1 | 04 hours | CO1, & CO4 |
| 6 | Study and Implement Morphological Operations | Unit -2 | 02 hours | CO2, & CO3 |
| 7 | Study and Implement Harris Corner Point Detection | Unit -2 | 02 hours | CO3, & CO4 |
| 8 | Study and Implement SIFT | Unit -3 | 04 hours | CO2, & CO3 |
| 9 | Mini assignment: Apply CV techniques to solve any real world problem/ Presentations | Unit -4 | 04 hours | CO2, & CO4 |
| 10 | CV Practice Test -1Quiz/ Presentations | Unit -4 | 02 hours | CO1,CO2, CO3, & CO4 |

## SEMESTER II ELECTIVE COURSES

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|---|---|
| **Subject Code** | **CE695A** |
| **Subject Title** | **Cyber Physical Systems** |
| **Credit** | **04** |
| Type of Sub | - Open Elective for All Engineering and Science disciplines |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. |
| Evaluation Pattern | Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>One Final Evaluation at the End of the Term **50 Marks**<br>Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** |
| Total Marks | 100 Marks |
| Prerequisite | None.<br>First 10 hours will be devoted for Prerequisite learnings related to basics of Databases (04 hours), Computer Networks (02 Hours), Operating System (02 Hours), Trends in evolutions of Compute-Devices (02 Hours) |
| Dept | CSE |
| About the Course | This course examines a new class of computational systems called Cyber-Physical Systems CPS. Such systems have the potential to provide far-reaching benefits in addressing some of the toughest problems we face as a society, such as: reducing healthcare costs, minimizing traffic congestion, and constructing zero-net energy buildings. Four important features characterize CPS: their ability monitors the underlying physical environment, reason about the monitored data, control the physical environment through actuation, in a coordinated manner using a communication medium. It can be seen in CPS, the computational element (cyber) and the environment (physical) are tightly coupled, with one influencing the other.<br>CPS sits at the confluence of several traditional disciplines, such as: embedded systems, real-time systems, sensor networks, control and hybrid systems, and security. It presents many challenging problems and opportunities for research. With guidance from the professor, students will survey recent CPS publications, develop an aptitude.<br>Readings will include papers on CPS applications (e.g., Body Area Networks, smart automobiles, and energy-efficient buildings), issues involved in designing CPS (e.g., monitoring, communication, and control), and how to ensure that the designed systems satisfy certain essential properties (e.g., safety and security).<br>CPS combine cyber capabilities (computation and/or communication) with physical capabilities (motion or other physical processes). Cars, aircraft, and robots are prime examples, because they move physically in space in a way |

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| | that is determined by discrete computerized control algorithms. Designing these algorithms to control CPSs is challenging due to their tight coupling with physical behavior. At the same time, it is vital that these algorithms be correct, since we rely on CPSs for safety-critical tasks like keeping aircraft from colliding, its role in Command & Control environments.<br>To meet end-user, Administrator & System Designer perspectives, develop skill sets to be resourceful in knowledge & information systems. Enhance analytical capabilities to evaluate a domain specific and technical area. Multi-Disciplinary Course useful to any engineering discipline who are keen to contribute in digitization, like be it smart cities, smart telemedicine systems, automated and autonomous systems. | | | |
| Course Outcomes | Bloom's Taxonomy:<br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create | | | |
| | **CO Title** | **Level** | **Descriptor** | **Out come** |
| | CO1: Students will be able to understand the scope of applications of CPS. | L1, L2 | Remember, Learn, Understand | 20% |
| | CO2: Students will be able to analyse the various components of CPS | L3, L4 | Apply, Analyse | 20% |
| | CO3: Students will apply mechanisms to enable autonomous and self-organising techniques | L4, L5 | Analyse, Evaluate | 20% |
| | CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in cyber and information security domain along with scope to apply AIML and build secure digitized systems. (PO1, PO2, PO3, PSO1, PSO2) | L5, L6 | Evaluate, Create | 40% |
| Summary of the Course Out Come | At the end of the course, a student will understand the concepts of CPS. Develop skills to relate a CPS as a feedback system along with its designing, modelling and implementation challenges. Evaluate the requirements to address emerging areas of digitization, AIML, and Secure environments. | | | |
| **Syllabus Description** | | | | |
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| **Basics & Preliminaries** | Role of Basic and Advanced Data Structures in Data Models, Types of Data Models, Basic Dictionary Data Types; Algorithms and basics of analysis,<br><br>OS & Algorithms in Parallel Environments. | Cormen et al, Horowitz Sahani, Bipin Desai, | 10 Hours | CO1, PO1 |

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| | Protocols of Computer Networks preliminaries, Concerns for Data Security and Privacy | Korth et al. Kurose Ross | | |
| Unit-1 | CPS**:** Introduction Main Concepts, Challenges; Background role of Computer Networks, Data, Algorithms | Text Book-1, Ch-1 | 08 Hours | CO1, CO2, PO1 |
| Unit-2 | Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software, | Text Book-1, Ch-2, 3 | 04 Hours | CO1, PO1 |
| Unit-3 | Agents and Multi-Agent Systems Computing trends, Data device proliferation, Confluence of trends | Text Book-1, Ch-4 | 06 Hours | CO1 CO2, PO1 |
| Unit-4 | Technological and economic drivers Self-organisation Mechanisms, Stigmergy, Gossip, Trust and Reputation for Successful Software Self-organisation, Cooperation , Immune Systems, Holonic Multi-Agent Systems Engineering Artificial Self-organising Systems | Text Book-1, Ch-4, 5 | 06 Hours | CO3, PO2 |
| Unit-5 | Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems | Text Book-1, Ch 5,6,7,8 | 06 Hours | CO3, PO2 |
| Unit-6 | CPS design Standards, Time Models, CPS Special Interest Groups and Mitre Commendations in Design and developments | Weblink References | 06 Hours | C04, PO4 |
| Unit-7 | Applications of Self-organising Software, Self-organisation in Constraint Problem Solving, Adaptive Trust Management, Security in Artificial Systems<br><br>Project Cases: SCADA, Industry 4.0 applications, Telemedicine, Environment Monitoring, IoTs, etc. | Text book-1, Ch-8,9 | 06 Hours | CO1, CO4, PO1, PO3 |
| Text Books (MUST Know) | Text Books<br>Self-Organising Software from Natural to artificial Adaptation, Di- MarzoSerugendo, ;Gleizer, M-p; Karageorgos, A (Eds), 2011, XVIII,462P; Hardcover ISBN:978-3642-17347-9 | | Must Know | |

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|---|---|---|---|---|
| Reference Books (SHOULD Know) | Reference Book-1<br><br>“Principles of Cyber-Physical Systems” - Rajeev Alur, MIT Press, 2015<br><br>Data Mining, Jiawei Han & Micheline Kamber, $2^{nd}$ edition, Elsevier, 2006<br><br>Kurose and Ross, Top Down Approach of Computer Networks, Prentice Hall, $8^{th}$ Edition 2021. | | Should Know | |
| Consortium, e-books and Web Link references (SHOULD/ Could Know) | https://iveybusinessjournal.com/publication/why-big-data-is-the-new-competitive-advantage/https://www.cdsaonline.org/cps-standard/<br><br>https://pages.nist.gov/cpspwg/<br><br>International Association for Automation<br><br>Research Papers shared by the subject incharge | | Should and May know | |
| Laboratory Assignments/ Demonstrations | | | | |
| LAB Assignments | *Each student will work on unique case study. Will require approval of the same at the beginning. Report submission is essential for each Lab Assignment. | | | |
| | | | | |
| 1 | Describe the Use Case*. Model the case study. Abstract. | Unit-1 | 02 hours | CO1 |
| 2 | Modelling Tools exploration and implementation of the subsystems/ systems of the case study. | Unit-2 | 02 hours | CO2 |
| 3 | Depiction of Agents in the designed model, and modelling their state, transitions and parameters status. Any one scenario for automous execution using algorithms. | Unit-3 & 4 | 02 hours | C03 |
| 4 | Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations. | Unit 4 & 5 | 02 hours | CO3 |
| 5 | Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations.<br>Develop the methods to audit and parameters of importance. | Unit 4 & 5 | 02 hours | CO4 |

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| | Generate the incidence response reports. | | | |
| 6 | Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations. Specify the security concern and mitigation technique. Generate the incidence response reports. | Unit 6 | 02 hours | CO4 |
| 7 | Create use case environment, implement & perform intra and Inter-system mappings. | Unit 6 | 02 hours | CO4 |
| 8 | Create model and implement any one security feature to demonstrate cyber security concern, intra and inter and mitigation. | Unit-7 | 02 hours | CO4 |
| 9 | Study of Research paper on the assigned topic and its presentation. | Unit 1 to 7 | Sem | CO4 |
| 10 | Mini-project. Implementation and Demonstration. Report Submission is essential | Unit 1 to 7 | Sem | CO4 |

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| **Subject Code** | **CE-664A** |
| **Subject Title** | **Network and Cloud Security** |
| **Credit** | **04** |
| Teaching Scheme | Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week. |
| Evaluation Pattern | 03 monthly tests + 01 final evaluation + assignments for internal assessment |
| Total Marks | 100 |
| Prerequisite | Basic computer networking, operating systems and computer programming knowledge is required. |

**Objective:**

Understanding basic issues, concepts, principles and mechanisms in Network and Cloud Security.

Basic Security concepts

Authentication

Access Control

IPSec and Internet Key Management

SSL/TLS Protocol

Firewall/UTM

Malicious Software

Intruder Detection Systems

Cloud Computing and Security

Be able to determine appropriate mechanisms for protecting networked systems. Network and Cloud Security Laboratory.

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| To facilitate individual in gaining knowledge on Network and Cloud Security Protocols, Appliances and systems.<br>To facilitate individual in gaining hands on experience on various attacks and countermeasures |
| **Course Outcomes:**<br>CO1: Students will be able to understand and apply Network and Cloud security Concepts along with various countermeasures. (PO1, PO3, PSO1)<br>CO2: Students will be able to understand and apply Network and Cloud Security concepts, hardware, software, standards and policies required for an organization. (PO1, PO2, PO3, PSO1)<br>CO3: Students will be able to understand the importance of implementation of Network and Cloud Security protocols, Devices, policies. (PO1, PO3, PSO1)<br>CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in Network and Cloud Security. (PO1, PO2, PO3, PSO1, PSO2) |
| **Syllabus:** |

| **Syllabus Details** | | **Text Book** | **Hours** | **Outcome** |
|---|---|---|---|---|
| Unit 1 | Introduction, OSI security Architecture, Security Principles, Attacks and Threats, Model of Network Security<br>Security at Application Layer: Email Architecture, PGP, S/MIME | Text book 1 Chap 1, & 8 | 6 | CO1 |
| Unit 2 | Security at Transport Layer: SSL Architecture, TLS, SET, HTTPS protocols<br>Security at Network Layer, IPSec, VPN, ISKMP<br>Firewall: Types of Firewalls, Firewall configuration, DMZ, UTMs | Text Book1, Chap 6 & 9**, 12** | 12 | CO1 |
| Unit 3 | Intrusion Detection and Intrusion Prevention Systems, Honeypots, Distributed IDS, Password Management<br>Authentication: kerberos, X509, Authentication, PKI | Text Book 1 Chap 11 & 4 | 7 | CO2 |
| Unit 4 | Wireless Security: Wireless LAN, 802.11 Standards, Security of WLAN<br>Cloud Security: Cloud Computing, Security Issues and Challenges, Applications | Text Book 1 Chap 5, 7 | 9 | CO2 |
| Unit 5 | DDoS : Direct, Reflector and Amplifier Attacks, TCP Syn Flooding, Countermeasures, Digital Attack Maps<br>Malicious Software: Viruses, Worms, Ransomware etc, Anti-virus Architecture, Generation of Anti-Virus, Types of Viruses in network and cloud<br>Network and cloud Reconnaissance, | Text Book 1 Chap 10<br>Text Book 2,3 | 9 | CO3 |

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|---|---|---|---|---|
| | Traceroute, Port Scanning, ICMP Scanning, Sniffing, Probing Routers in cloud | | | |
| Unit 6 | Game Theory applications in Network Security<br>Miscellaneous topics and current developments, Dark Web<br>Network Security Observatory: Monitoring Networks | Research Papers & Ref 1 | 11 | CO3 |

**Text Book:**

1. William Stallings, “Network Security Essentials”, $6^{th}$ Edition, Pearson Education, 2019.
2. B. Menezes, “Network Security and Cryptography”, Cengage, 2013.
3. W. Du, “Computer and Internet Security: A Hands On Approach”, $3^{rd}$ Edition, 2022.

**Reference Books:**

1. T.Alpcan and T. Basar, “Network Security: A Decision and Game-Theoritic Apparoach”, Cambridge University Press, 2010.
2. Bragg et al. “Network Security: The complete Reference”, McGraw Hill, 2004
3. Seedlabs: https://seedsecuritylabs.org/ ( last accessed on $12^{th}$ June 2022).

**Lab Assignments**

| **Sl No** | **Lab Experiment** | **Unit** | **Hours** | **Outcome** |
|---|---|---|---|---|
| 1 | Packet Sniffing and Spoofing Lab | 1 | 2 | CO1, CO4 |
| 2 | TCP attacks Lab | 2 | 2 | CO1, CO4 |
| 3 | Firewall Exploration Lab | 2 | 2 | CO1, CO4 |
| 4 | VPN Lab | 2 | 2 | CO1, CO4 |
| 5 | Wireshark Lab | 5 | 2 | CO3, CO4 |
| 6 | Snort: Intrusion Detection Lab | 3 | 2 | CO2, CO4 |
| 7 | CyberCiege Lab | 1 | 2 | CO1, CO4 |
| 8 | OpenSSL Exploration Lab | 2 | 2 | CO1, CO4 |
| 9 | Digital Attack Maps DOS lab | 5 | 2 | CO3, CO4 |
| 10 | Cloud Computing Lab | 4 | 2 | CO2, CO4 |

<table>
<tr><td>Subject Code</td><td colspan="3">CE630</td></tr>
<tr><td>Subject Title</td><td colspan="3">Virtual Reality</td></tr>
<tr><td>Credit</td><td colspan="3">04</td></tr>
<tr><td>Type of Subject</td><td colspan="3">-Core (MTech in CSE)<br>-Professional Open Elective for All Engineering and Science disciplines</td></tr>
<tr><td>Teaching Scheme</td><td colspan="3">Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week.</td></tr>
<tr><td>Evaluation Pattern</td><td colspan="3">. Continuous Evaluations: Three Monthly Test (10 Marks Each) 30 Marks<br>. One Final Evaluation at the End of the Term 50 Marks<br>. Lab Assignments/Mini-Project and Term Work Evaluations: 20 Marks</td></tr>
<tr><td>Total Marks</td><td colspan="3">100 Marks</td></tr>
<tr><td>Prerequisite</td><td colspan="3">Basic Operating systems and Computer Programming, Computer Graphics knowledge is required.</td></tr>
<tr><td>Dept</td><td colspan="3">CSE</td></tr>
<tr><td>Course Objectives</td><td colspan="3">Understanding basic issues, concepts, principles and mechanisms in Virtual Reality.<br>Definition of VR<br>Applications of VR<br>VR/AR/MR<br>Hardware/Software<br>Human Physiology and Perception<br>Light and Optics<br>Human Physiology of Vision<br>Visual Perception, Visual Rendering<br>Motion in Real and Virtual Worlds<br>Tracking and Interaction<br>Audio,<br>Evaluating VR Systems<br>Current trends in VR</td></tr>
<tr><td>Course Outcomes</td><td colspan="3">Bloom’s Taxonomy:<br><br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze<br>Level-5 Evaluate; Level-6 Create</td></tr>
<tr><td></td><td>CO Title</td><td>Le vel</td><td>Descriptor</td></tr>
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|---|---|---|---|
| | CO1: Students will be able to understand and apply Virtual Reality Concepts along with various applications. (PO1, PO3, PSO1) | L2 | Remember, Understand |
| | CO2: Students will be able to understand and apply Virtual Reality concepts, hardware, software, standards and policies required for various applications. (PO1,PO2, PO3, PSO1) | L3, | Remember, Understand Analyse |
| | CO3 - Students will be able to understand the importance of implementation of Virtual Reality Systems, Applications with Benefits and limitations(PO1, PO3, PSO1) | L2 | Remember, Understand |
| | CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in Virtual Reality. (PO1, PO2, PO3, PSO1, PSO2) | L4 | Apply, Analyse |

**Syllabus Description**

| **Basics & Preliminaries** | **Details** | **Books & References** | **Duration** | **COs** |
|---|---|---|---|---|
| Unit-1 | Introduction, Definition, Applications | Lavalle, Chap1 | 3L | 1,2 |
| Unit-2 | Bird’s Eye View, Hardware, Software, Human Physiology and Perception | Lavalle, Chap2 | 3L | 1,2 |
| Unit-3 | Geometry of Virtual Worlds, Geometric models, Viewing Transformations, Chaining Transformations | Lavalle, Chap 3 | 4L | 1,2 |
| Unit-4 | Light and Optics, Lenses, optical aberrations, Human Eye, Cameras, displays | Lavalle, Chap 4 | 4L | 1,2 |
| Unit-5 | Physiology of Human Vision: Cornea, Photoreceptors, Eye Movements, Implications for VR | Lavalle, Chap 5 | 3L | 1,2 |
| Unit-6 | Visual Perception: Perception of Depth, Perception of Motion, Perception of Color, Combining sources of information | Lavalle, Chap 6 | 4L | 1,2,3 |
| Unit-7 | Visual Rendering: Ray tracing and Shading models, Rasterization, Correcting optical distortions, Improving latency and frame rates, Immersive photos and videos | Lavalle, Chap 7 | 4L | 1,2 |

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|---|---|---|---|---|
| Unit-8 | Motion in Real and Virtual Worlds: Velocities and accelerations, Vestibular system, Physics in virtual world, Mismatched motion and vection | Lavalle, Chap 8 | 4L | 1.2 |
| Unit-9 | Tracking: Tracking in 2D, Tracking in 3D, Tracking position and orientation, Tracking attached bodies, 3D scanning of environment | Lavalle, Chap 9 | 4L | 1,2 |
| Unit-10 | Interaction: Motor programming and remapping, Locomotion and manipulation, social interaction and other interaction mechanisms | Lavalle, Chap 10 | 3L | 1,2,3 |
| Unit-11 | Audio: Physics and sound, physiology of human hearing, Auditory perception, Auditory hearing | Lavalle, Chap 11 | 3L | 1,2 |
| Unit-12 | Evaluation of VR Systems and Experiences: Perceptual training, recommendation for developers, Comfort and VR Sickness, Experiments on Human Subjects | Lavalle, Chap 12 | 6L | 4 |
| Unit-13 | Frontiers: Touch and Proprioception, Smell and taste, Robotic interfaces and Brain-machine interfaces | Lavalle, Chap 13 | 3L | 2 |
| Text Books (MUST Know) | 1. Steven Lavalle, "Virtual Reality", Cambridge Univerisity Press, (lavalle.pl/vr/book.html), 2020 | | | |
| Reference Books (SHOULD Know) | 1. Sherman W.R. and A B Craig, "Understanding Virtual Reality- Interface Application, and Design", Morgan Kaufmann, 2002.<br>2. Burdea G C and P Coffet, "Virtual Reality Technology", Second Edition, Wiley-IEEE presss, 2006. | | | |
| Laboratory Assignments/ Demonstrations | | | | |
| 1 | Introduction to Unity 3D | Install Unity 3d and learn hands-on various features and functionalities | Unit 1 | 2 |
| 2 | Virtual Reality App development using Unity3d | Develop a sample VR application and install it on target device for viewing | Unit 1-4 | 2 |

| | | | | |
|---|---|---|---|---|
| 3 | Augmented Reality App development using Unity3d and Vuforia | Develop a sample AR app and install it on target device for testing | Unit 1-4 | 2 |
| 4 | AR App using Python, OpenCV and ARuco marker | Develop and Test python and OpenCV app to use ARUCO marker | Unit 10, 12 | 2 |
| 5 | Virtual Tour app development and testing | Develop a VR Tour app and test it on target device | Unit 6,7 | 2 |
| 6 | Points Cloud generation using Matterport for VR | Collect and install the images in Matterport to generate Point for testing | Unit 8 | 2 |
| 7 | VR App: Case Study | Industry standard VR app is installed, tested and explored | Unit 1-12 | 2 |
| 8 | AR App: Case Study | Industry standard AR App is installed, tested and explored | Units 1-12 | 2 |
| 9 | Advanced VR App development using Unreal Engine/Unity 3d | An advanced app which involves scripting in C++/C# is developed using UnrealEnging or Unity3d | Units 1-12 | 2 |
| 10 | Advanced AR App development using AR Tool kit | Develop and test the AR App | Units 1-12 | 2 |

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|---|---|
| **Subject Code** | **CE665A** |
| **Subject Title** | **Security Standards & Penetration Testing** |
| **Credit** | **04** |
| Type of Subject | -Core (MTech in CSE)<br>-Professional Open Elective for All Engineering and Science disciplines |
| Teaching Scheme | Lectures: 03 hours/week<br>Tutorial/Practical: 02 hours/week<br>Total Contact hours 05 per week. |
| Evaluation Pattern | . Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks**<br>. One Final Evaluation at the End of the Term **50 Marks**<br>. Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks** |
| Total Marks | 100 Marks |
| Prerequisite | Basic computer networking, operating systems and computer programming knowledge is required. |

| | |
|---|---|
| Dept | CSE |
| Course Objectives | This course examines the methods for securing information existing in different forms. This course will provide an introduction to the different technical and administrative aspects of Information Security and Assurance. Also, one cannot protect his information assets if he doesn't know how attackers think and what techniques attackers use to exploit systems. Hence, learning offensive security techniques like Ethical Hacking and penetration testing is becoming a need of future cyber security world. Objectives are: 1. To facilitate individual in gaining knowledge on information security management systems,.2. To facilitate individual in gaining knowledge on security standards like ISO-27001 standards, TCSEC, ITSEC, Secure coding etc. 3. To train individual to become competent information security professional by learning both theoretical as well as practical ethical hacking and penetration testing knowledge base |
| **Course Outcomes** | Bloom's Taxonomy:<br>Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze<br>Level-5 Evaluate; Level-6 Create |

| | **CO Title** | **Level** | **Descriptor** |
|---|---|---|---|
| | CO1: Students will able to identify and apply basic concepts, terminology, theories, models and methods in the field of information security management field. (PO1, PO3, PSO1) | L1, L2 | Remember, Understand |
| | CO2: Student will able to design policies for managing information security effectively adhering to ISO- 27001 standards, TCSEC, ITSEC, Secure coding practices etc. (PO1,PO2, PO3, PSO1) | L3 | Remember, Understand Analyse |
| | CO3: Student will learn to design, implement, integrate and manage various security countermeasures/tools/mechanisms/best practices and penetration testing through hands- on activities. (PO1, PO3, PSO1) attacks like Network Intrusion, DDOS, Malware attacks are carried out successfully by attackers. (PO1, PO2, PO3, PSO1, PSO2) | L3 | Remember, Understand Analyse |
| | CO1, 03: End semester Exam | L4 | Apply, Analyse |

**Syllabus Description**

| **Basics & Preliminaries** | **Details** | **Books & References** | **Duration** | **COs** |
|---|---|---|---|---|
| Unit-1 | Introduction to Information security, Concepts, Threats, Attacks, and Assets, Security Functional Requirements, Countermeasures , Access Control Principles, Access Rights , Discretionary Access Control, Role - Based Access Control, Mandatory | Textbooks - 1,2 | 12L | CO1 |

| | | | | |
|---|---|---|---|---|
| | Access Control , Trusted Computing and Multilevel Security, Security Design Principles, Cryptographic Tools, Common Criteria for Information Technology Security Evaluation, Information security management systems (ISMS), ISO27000 and other security standards, Management responsibility, Responsibilities of Chief Information Security Officer (CISO) | | | |
| Unit-2 | Security audits and assurance, Information Security Policy, Standards, and Practices, Asset Management, Human Resource Security, Security awareness training, Physical Security, Risk Management, Business continuity planning, Disaster Recovery planning, Penetration Testing Methodologies Security Assessments, Penetration Testing Methodologies, Penetration Testing Steps, Setting up own virtual ethical hacking lab for experimentation, Ethical Hacking and penetration Basics - Hacking terminology & attacks, Ethics, Legality. | Textbooks - 2,3 | 12L | CO3 |
| Unit-3 | Phases - Reconnaissance, Scanning,Gaining access, Maintaining access, Covering tracks; Reconnaissance – Information gathering,Vulnerability research, Foot -printing, whois, DNS enumeration, Social Engineering, E - Mail Tracking,Web Spiders; Scanning & Enumeration - Sniffing techniques & tools, arp/icmp/tcp/ip host discovery, types of Scanning , Ping Sweep Techniques, Nmap, Command Switches, SYN, Stealth, XMAS, NULL, IDLE, and FIN Scansdetecting OS fingerprinting, banner grabbing, Null Sessions, SNMP/DHCP/DNS enumeration, Proxy Servers, Anonymizers, HTTP Tunneling Techniques, IP Spoofing Techniques; Cryptographic Techniques | Textbooks - 2,3,4,5,6 References -1-7 | 12L | CO2 |
| Unit-4 | Attacking System and Maintaining Access– Password/hashcracking, NetBIOS DoS Attacks, PasswordCracking Countermeasures; escalating privileges - exploiting vulnerabilities, Buffer Overflows,Rootkits, Hiding FilesNTFS Stream Countermeasures, Steganography Technologies, Cover tracks and Erase Evidence, Disabling Auditing, Clearing the event Log, Malware attacks- Trojan, Backdoor, Viruses, Worms, DoS/DDoS; Attacks, Windows Hacking; Linux Hacking; Web | Textbooks - 4-6, / References -1-7 | 12L | CO2 |

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|---|---|---|---|---|
| | and Database Hacking; Google Hacking; Wireless Hacking; Mobile Hacking; Penetration Testing Tools like Kali Linux, Metasploit ,Pen-Test Deliverables | | | |
| | LAB/ Assignments/Student Presentations [2T/P per week | | 02L/ Week | CO4 |
| Text Books (MUST Know) | Michael E Whitman, Herbert J Mattord, “Principles of Information Security”, Course Technology, 3rd Edition, 2008.<br>Dhavale, S. V. (2019). Constructing an Ethical Hacking Knowledge Base for Threat Awareness and Prevention (pp. 1-305). Hershey, PA: IGI Global.<br>Stuart McClure, Joel Scambray, George Kurtz, “Hacking Exposed:n/w sec secrets and solutions”, Mcgraw Hill, 2012 | | | |
| Reference Books (SHOULD Know) | Various Security Standards - ISO 27000 series published by ISO.<br>Department of Defense Standard, Department of Defense, “Trusted Computer System Evaluation Criteria”, Orange Book.<br>Dieter Gollmann, “Computer Security”, John Wiley and Sons, Inc., 3rd edition, 2011<br>David Kennedy, Jim O’Gorman, Devon Kearns, and MatiAharoni, ”Metasploitpentest guide”,No starch Press, san Francisco, 2011<br>Bastian ballman, “Understanding n/w hacks:attack and defense with python”, Springer,2012<br>Rich Annings, HimanshuDwivedi, Zane Lackey, ”Hacking Exponsed Web 2.0”, Tata Mcgraw hill Edition<br>Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/IBM/EC-Council sources<br>Krutz, R. L. & Vines, R. D., “The CISSP and CAP Prep Guide”, Platinum Edition, New York, Wiley Publishing., 2006.<br>Nina Godbole, “Information Systems Security: Security Management, Metrics, Frameworks and Best Practices”, Wiley India Pvt Ltd, 2012.<br>William Stallings and Lawrie Brown, “Computer Security: Principles and Practice”, 2nd edition, Pearson, 2012. | | | |
| **Laboratory Assignments/ Demonstrations** | | | | |
| 1 | Study Windows Essential Tools-Part 1 | Unit - 1 | 02 hours | CO1, CO2,CO3, & CO4 |
| 2 | Study Windows Essential Tools-Part 2 | Unit - 1 | 02 hours | CO1, CO3, & CO4 |
| 3 | Study Sysinternals utilities to manage, diagnose, troubleshoot, and monitor a Microsoft Windows environment | Unit - 2 | 02 hours | CO2, CO3, & CO4 |
| 4 | Study passive information gathering tools. | Unit - 3 | 02 hours | CO1, CO3, & CO4 |
| 5 | Write Security Policy Document | Unit - 3 | 04 hours | CO1, & CO4 |

| | | | | |
|---|---|---|---|---|
| 6 | Case study: LDRA and Parasoft tools | Unit - 3 | 02 hours | CO2, & CO3 |
| 7 | Kali Linux Attacks – Part1 | Unit - 3 | 02 hours | CO3, & CO4 |
| 8 | Kali Linux Attacks – Part2 | Unit - 4 | 04 hours | CO2, & CO3 |
| 9 | SSPT Practice Test -1Quiz | Unit - 4 | 02 hours | CO2, & CO4 |
| 10 | Apply data mining tools for cyber security related data analysis | Unit - 4 | 04 hours | CO1,CO2, CO3, & CO4 |

**CE633 Pattern RecognitionSyllabus:**

**Unit I: Basics of Probability, Random Processes and Linear Algebra (recap): Probability: independence of events, conditional and joint probability, Bayes theorem Random Processes: Stationary and non-stationary processes, Expectation, Autocorrelation, Cross-Correlation, spectra.**

**Unit II : Linear Algebra**: Inner product, outer product, inverses, eigen values, eigen vectors, singular values, singular vectors.

**Unit III: Bayes Decision Theory** : Minimum-error-rate classification. Classifiers, Discriminant functions, Decision surfaces.Normal density and discriminant functions. Discrete features.

**Unit IV: Parameter Estimation Methods** : Maximum-Likelihood estimation :Gaussian case. Maximum a Posteriori estimation. Bayesian estimation: Gaussian case. Unsupervised learning and clustering - Criterion functions for clustering. Algorithms for clustering: K- Means, Hierarchical and other methods. Cluster validation. Gaussian mixture models, Expectation-Maximization method for parameter estimation. Maximum entropy estimation.Sequential Pattern Recognition. Hidden Markov Models (HMMs). Discrete HMMs. Continuous HMMs. Nonparametric techniques for density estimation.Parzen-window method.K-Nearest Neighbour method.

**Unit V: Dimensionality reduction**: Principal component analysis - it relationship to eigen analysis. Fisher discriminant analysis - Generalised eigen analysis. Eigen vectors/Singular vectors as dictionaries. Factor Analysis, Total variability space - a dictionary learning methods.Non negative matrix factorisation - a dictionary learning method.

**Unit VI: Linear discriminant functions** : Gradient descent procedures, Perceptron, Support vector machines - a brief introduction.

**Unit VII: Artificial neural networks**: Multilayer perceptron - feedforwark neural network. A brief introduction to deep neural networks, convolutional neural networks, recurrent neural networks.

**Unit VIII: Non-metric methods for pattern classification** : Non-numeric data or nominal data. Decision trees: Classification and Regression Trees (CART).

**Text /Reference Books:**

1. R.O.Duda, P.E.Hart and D.G.Stork, Pattern Classification, John Wiley, 2001
2. S.Theodoridis and K.Koutroumbas, Pattern Recognition, 4th Ed., Academic Press, 2009
3. C.M.Bishop, Pattern Recognition and Machine Learning, Springer, 2006

## CE691 SECURE WIRELESS SENSOR NETWORKS

Background: Wireless Sensor networks (WSN) is an emerging technology and have great potential to be employed in critical situations like battlefields and commercial applications such as building, traffic surveillance, habitat monitoring and smart homes and many more scenarios. One of the major challenges wireless sensor networks face today is security. While the deployment of sensor nodes in an unattended environment makes the networks vulnerable to a variety of potential attacks, the inherent power and memory limitations of sensor nodes makes conventional security solutions unfeasible. The sensing technology combined with processing power and wireless communication makes it profitable for being exploited in great quantity in future. The wireless communication technology also acquires various types of security threats.

Objective: To meet End-User, Network-Administrator and Network-Designer perspectives

Prerequisite: Computer Networks Fundamentals, Programming,

**Syllabus:**

Unit I: Introduction, WSN Resources & constraints, Relevance to IoTs, Relevance to Cyber-Physical Systems, Relevance to Network Centric Operations, Relevance to Data Stream Management Systems, Relevance to the increasing demand of high performance computations, SCADA, battle sensor.

Unit II: WSN Network Architecture, MAC Layer protocols, Naming and Addressing, Synchronization, Location & positioning, Topology control, Connected Dominating Sets, Routing Protocols, Data-Centric & Content-based networking, Data-Centric querying, WSNs versus IoTs

Unit III: Vulnerabilities, threats, attacks & safeguards in WSN, key distribution methods & protocols, multi-party computations inclusion, RF-Id communications, open source hardware concept, Security goals for WSNs, Attacks on WSNs: Passive & Active Attacks, Security Mechanisms, Security Models for WSNs, Challenges in WSNs: with respect to wireless medium, resource scarcity, ad-hoc deployments, hostile environments, immense scale, etc. Application oriented: Secure Wireless Networks.

**Text Book:**

**1. FUNDAMENTALS OF WIRELESS SENSOR NETWORKS: THEORY AND PRACTICE, Authors: Waltenegus Dargie, Technical University of Dresden, Germany, Christian Poellabauer, University of Notre Dame, USA, Wiley, First Edition, 2010**

**Research Paper References:**


1. Ian F. Akykildiz, Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci, ―A Survey on Sensor Networks‖, IEEE Communication Magazine, year 2002.
2. Culler, D. E and Hong, W., ―Wireless Sensor Networks‖, Communication of the ACM, Vol. 47, No. 6, June 2004, pp. 30-33.
3. Adrian Perrig, John Stankovic, David Wagner, ―Security in Wireless Sensor Networks‖ Communications of the ACM, Page53-57, 2004
4. Chris Karlof, David Wagner, ―Secure Routing in Wireless Sensor Networks: Attacks and Countermeasures‖, AdHoc Networks (elsevier), Page: 299-302, year 2003
5. Al-Sakib Khan Pathan, Hyung-Woo Lee, Choong Seon Hong, ―Security in Wireless Sensor Networks: Issues and Challenges‖, International conference on Advanced Computing Technologies, Page1043-1045, year 2006
6. John Paul Walters, Zhengqiang Liang, Weisong Shi, Vipin Chaudhary, ―Wireless Sensor Network Security: A Survey‖, Security in Distributed, Grid and Pervasive Computing Yang Xiao (Eds), Page3-5, 10-15, year 2006

7. Pathan, A.S.K.; Hyung-Woo Lee; Choong Seon Hong, ―Security in wireless sensor networks: issues and challenges‖ Advanced Communication Technology (ICACT), Page(s):6, year 2006
8. Tahir Naeem, Kok-Keong Loo, Common Security Issues and Challenges in Wireless Sensor Networks and IEEE 802.11 Wireless Mesh Networks, International Journal of Digital Content Technology and its Applications, Page 89-90 Volume 3, Number 1, year 2009
9. Undercoffer, J., Avancha, S., Joshi, A. and Pinkston, J. ―Security for sensor networks‖. In Proceedings of the CADIP Research Symposium, University of Maryland, Baltimore County, USA, year 2002 http://www.cs.sfu.ca/~angiez/personal/paper/sensor-ids.pdf
10. Zia, T.; Zomaya, A., ―Security Issues in Wireless Sensor Networks‖, Systems and Networks Communications (ICSNC) Page(s):40 – 40, year 2006
11. Xiangqian Chen, Kia Makki, Kang Yen, and Niki Pissinou, Sensor Network Security: A Survey, IEEE Communications Surveys & Tutorials, vol. 11, no. 2,page(s): 52-62, year 2009
12. D. Djenouri, L. Khelladi, and N. Badache, ―A Survey of Security Issues in Mobile ad hoc and Sensor Networks,‖ IEEE Commun. Surveys Tutorials, vol. 7, pp. 2–28, year 2005.
13. S. Schmidt, H. Krahn, S. Fischer, and D. Watjen, ―A Security Architecture for Mobile Wireless Sensor Networks,‖ in Proc. 1st European Workshop Security Ad-Hoc Sensor Networks (ESAS), 2004.
14. Y. Wang, G. Attebury, and B. Ramamurthy, ―A Survey of Security Issues in Wireless Sensor Networks,‖ IEEE Commun. Surveys Tutorials, vol. 8, pp. 2–23, year 2006.
15. Yun Zhou, Yuguang Fang, Yanchao Zhang, Securing Wireless Sensor Networks: A Survey, IEEE Communications Surveys & Tutorials, year 2008
16. Xiuli Ren, Security Methods for Wireless Sensor Networks, Proceedings of the 2006 IEEE International Conference on Mechatronics and Automation , Page: 1925 ,year 2006
17. R.Roman, J. Zhou, and J. Lopez, ―On the security of wireless sensor networks,‖ in International Conference on Computational Science and Its Applications – ICCSA 2005, May 9-12 2005, vol. 3482 of Lecture Notes in Computer Science, (Singapore), pp. 681– 690, Springer Verlag, Heidelberg, D-69121, Germany, 2005.
18. N. Sastry and D. Wagner, ―Security considerations for ieee 802.15.4 networks,‖ in Proceedings of the 2004 ACM workshop on Wireless security, pp. 32–42, Philadelphia, PA, USA: ACM Press, 2004.
19. WSN Security Models: Refer 4 papers: Paper 1: Wireless sensor network security model using zero knowledge protocol, ICC 2011; Paper 2. An energy efficient link-layer security protocol for wireless sensor networks, EIT 2007; Paper 3. Toward resilient security in wireless sensor networks, MobiHoc 2005; Paper 4. TinySec: a link layer security architecture for wireless sensor networks, SenSys 2004.

**Tutorials:**

a. Routing techniques: Overview of Proactive and reactive routing protocols, significance of *a hop* in adhoc networks
b. Flooding, Gossiping, Zonal Routing Protocols ZRP, Hybrid Routing, TTL significance with respect to routing protocols
c. Impact of hardware and software on Battery Performances/Utilisation
d. IEEE 802.15.4: A study, Features, Types of Devices FFD (PAN coordinators, Coordinators), RFDs Reduced Function Devices, Network Setup process & parameters in Consideration, Programming Strategies to suit the standards, MAC and PHY structure
e. Demo 1: Controlling DIOs. Demonstrate the usage of DIO using LEDs. Learning how to handle data sampling period.
f. Demo 2. Reading data from a single IoT device. Interpretation of data.

g. Demo 3: Create a broadcast wireless network and capture the traffic generated by the participating nodes.
h. Demo 4. Creating a multi-hop network using MBR routing.
i. Understanding MBR & LBR (MAC Based Routing and LBR Level-Based Routing)
j. Understanding exiting API, Libraries & its association with pre-existing demonstration codes.

**CE699 Internet of Things**

**Syllabus:**

**Unit I** Introduction to Internet of Things, Definition and Characteristics of IoT, Physical Design of IoT, IoT Protocols, IoT communication models, IoT Communication APIs

**Unit II** IoTenablingTechnologies, Wireless Sensor Networks, Cloud Computing, Big data analytics, Communication protocols, Embedded Systems, IoT Levels and Deployment Templates, Domain Specific IoTs: Home, City, Environment, Energy, Retail, Logistics, Agriculture, Industry, health and Lifestyle

**Unit III** IoT and M2M, Software defined networks, network function virtualization, difference between SDN and NFV for IoT, Basics of IoT System Management with NETCOZF, YANG, NETCONF,YANG, SNMP NETOPEER

**Unit IV** IoT physical end devices & end points, IoT Physical Servers & Cloudofferings,Software environments, NEO, Security

**Text /Reference Books:**

1. "Internet of Things: A Hands-on Approach", by ArshdeepBahga and Vijay Madisetti(Universities Press), 2014
2. "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by PethuruRaj and Anupama C. Raman (CRC Press)
3. “Designing the internet of things”, McEwen, Adrian, and Hakim Cassimally. John Wiley& Sons, 2013.
4. Research Papers discussed in the classroom discussions.

## M. Tech in Modelling and Simulation

**Introduction:** The School of Computer Engineering and Mathematical Sciences was formed by the merger of the Department of Applied Mathematics and the Department of Computer Science & Engineering in 2022. Prior to this merger, **M. Tech. (Modelling & Simulation) programme and MTech (Data Science) programme were offered under the Department of Applied Mathematics**. **M. Tech in Modelling and Simulation programme was provisionally accredited by NBA.** The Department of Applied Mathematics came into existence with the inception of the Institute of Armament Studies in 1953 as the Faculty of Applied Mathematics. The faculty constituted of three departments: (1) Applied Mathematics (2) Ballistics (3) Statistics. In 1991 the three departments merged into one and named it as Department of Applied Mathematics.

The aim of the programme is to provide training in-depth knowledge of various modelling and simulation techniques and also mathematical topics to various courses conducted at DIAT. The present faculty strength of the school is twelve. The school is also actively engaged in handling the projects from various agencies. Since then, the school members have been actively involved in the research in different fields of numerical solution to partial differential equations, numerical methods, optimization, applied mathematics such as ballistics, flight dynamics, hydro-dynamics, hydro-ballistics, computer science, image processing, statistics and probability. Recently the school has also developed expertise in the advanced Modelling and Simulation techniques like Neural Network, Fuzzy Logic and Genetic Algorithm, Parallel Computing, Cryptography and Machine Learning, Cyber Security, IoT and Computer Networks.

The programme is of two years duration where the student undergoes basic training in the subjects related to mathematical modelling & simulation through classroom teaching in the first and second year. During this period the student is also exposed to various simulation tools and practical's. The second year is the dissertation phase where the student works under the guidance of a recognized guide on a problem related to modelling and simulation. Course curriculum will be updated periodically to keep pace with contemporary technological advancement.

**Research Areas**

- Mathematical Modelling & Simulation
- Partial Differential Equations & their applications
- Image Processing
- Numerical Analysis of PDEs
- Finite Elements Method
- Boundary Element Method
- Domain Decomposition Method & Fictitious Domain Method
- Finite Element Analysis in Fluid Flow through Porous Media
- Boundary Layer Theory
- Computational Fluid Dynamics
- Numerical Parallel Algorithms and Parallel Computing.
- Bio-Mechanics
- Cryptography
- IoT
- Computer Vision
- Computer Networks
- Cyber Security

**Programme Outcomes (POs)**

| | |
|---|---|
| **PO1** | Ability to independently carry out research/investigation and development work to solve practical problems. |
| **PO2** | Ability to create, select, learn and apply appropriate techniques, resources, and advanced tools, including Modeling and Simulation with an understanding of limitations |
| **PO3** | Recognize the opportunities and contribute to collaborative-multidisciplinary scientific research to achieve common goals. |
| **PO4** | Demonstrate knowledge and understanding of mathematics and modelling principles and apply the same in solving the problems faced by society. |

**Eligibility Criteria for Admission to join in this programme**

| | |
|---|---|
| M. Tech Modelling & Simulation | The candidate must have a Valid GATE Score and marks / CPI (Cumulative Performance Index), referred to in subsequent section, implies a minimum of 55% marks/SPI of 5.5 (on a 10-point scale) as long as it is at least seven percent higher than the minimum pass marks/CPI from a recognized Institute / University in<br>B. Tech / BE degree<br>OR<br>MSc / MS degree in CS / IT / Mathematics / Statistics / Physics / Electronics<br>Provided |

| | |
|---|---|
| | 1) Mathematics is one of the subject at the graduate level and<br>2) Knowledge in computer programming is desirable<br>3) Valid GATE Score in CSE / IT / ECE / ME / AE / CE / EE / IN / MA / ST |

CSE - Computer Science Engineering
IT - Information Technology
AE - Aerospace Engineering
ECE - Electronics & Communication Engineering
ME - Mechanical Engineering
CE – Civil Engineering
EE – Electrical Engineering
IN – Instrumentation Engineering
MA- Mathematics
ST- Statistics

**Organization of M.Tech programme:**

This programme is of four-semester duration. In first and second semester have seven courses along with practical component of some courses. The respective course instructor will give assignments / practical problems from the course component and these will be solved in Modelling and Simulation Lab. The practice problems can be solved by using Advanced Data structures (C / C++) / MATLAB / MATHEMATICA / Simula8 / Maplesim / SPSS / R / Extend Sim. etc., and all these software are licensed version and available in the school.

In the first semester all courses are compulsory. But in the second semester 2 courses are compulsory and there is an option to choose 4 elective courses, out of which two elective courses must be chosen from the department only and rest of the two elective courses can be chosen from either department or inter department courses and am audit course. In each of the course component, there will be three tests and a final semester examination of every course. Half yearly evaluation of the project takes place at the end of the third semester. After the second semester, scholarship students are encouraged do a summer internship for about one and half months at their place of choice whereas the sponsored category students are encouraged to identify their project work related to their field (labs) to have collaboration a with DIAT. The third and fourth semester will have only dissertation phase (work) – 1, and dissertation phase (work) – 2 (this is in continuation of dissertation phase (work) – 1) respectively. The department faculty will encourage and help to students to take their projects from DRDO labs / premier institutes or as per student’s choice. This will be entirely based student’s own arrangements and expenses. The department will not sponsor for this; except official arrangements, like issuing no-objection certificate etc. At the end of the final semester, he/she submits a thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners. No credits will be counted for attending an audit course.

**Semester I:**

| Sl. No. | Course Code | Course Name | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T / P | |
| 1. | AM 601 | Numerical Methods for Differential Equations | 3 | 1 | 4 |
| 2. | AM 602 | Mathematical Modelling & System Analysis | 3 | 1 | 4 |
| 3. | AM 603 | Optimization Techniques | 3 | 1 | 4 |
| 4. | AM 604 | Advanced Statistical Techniques | 3 | 1 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| 5. | AM 605 | Linear Algebra and Applications | 3 | 1 | 4 |
| 6. | AM 609 | Data Science: Tools & Techniques | 3 | 1 | 4 |
| 7. | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

**Semester II:**

| Sl. No. | Course Code | Course Name | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T / P | |
| 1. | AM 621 | Advanced Modelling Techniques | 3 | 1 | 4 |
| 2. | AM 622 | Simulation of Linear and Nonlinear Systems | 3 | 1 | 4 |
| 3. | | Elective I [From School] | 3 | 1 | 4 |
| 4. | | Elective II [From School] | 3 | 1 | 4 |
| 5. | | Elective III | 3 | 1 | 4 |
| 6. | | Elective IV | 3 | 1 | 4 |
| 7. | PGC-602 | Audit Course | 2 | 0 | 0 |
| | | **Total** | **20** | **6** | **24** |

**Semester III:**

| Sl. No. | Course Code | Course Name | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T / P | |
| 1. | AM 651 | M.Tech Dissertation Phase – I | 28** | | 14 |
| | | **Total** | **28** | | **14** |

**Semester IV:**

| Sl. No. | Course Code | Course Name | Credits | | Total Credits (*) |
|---|---|---|---|---|---|
| | | | L | T / P | |
| 1. | AM 652 | M.Tech Dissertation Phase - II | 28** | | 14 |
| | | **Total** | **28** | | **14** |

***** 1 Credit for Theory (or Tutorial) means 1 contact hour in a week and 1 credit for practical means 2 contact hours in a week.
**Contact Hours/ weekNote: During summer vacation (4 Weeks), Summer Internship / Industrial Tour will be accepted for all students relevant to the dissertation work especially modeling and Simulation.

**List of Electives are given Below:**

| Sl. No. | Course Code | Course |
|---|---|---|
| | AM 623 | Machine Learning |
| | AM 624 | Big Data Analytics |

| | | |
|---|---|---|
| | AM 625 | Image and Video Analytics |
| | AM 626 | Computational Heat and Mass Transfer |
| | AM 627 | Ballistics |
| | AM 628 | Computational Number Theory and Cryptography |
| | AM 629 | Calculus of Variations and Integral Equations |
| | AM 630 | Domain Decomposition Methods for Partial Differential Equations |
| | AM 631 | Multigrid Methods |
| | AM 632 | Introduction to Non-Newtonian Fluids |
| | AM 633 | Bio-Mechanics |
| | AM 635 | Finite Elements: Theory and Algorithms |
| | AM 636 | Cloud Computing |
| | AM 640 | AI for Medical Image Analysis |
| | AM 642 | Computer Vision with Pattern Recognition |
| | CE 631 | Deep Learning |
| | CE 632 | Computer Vision |

## *AM 601* **:** *Numerical Methods for Differential Equations*

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| Course Code | **AM 601** |
| Course Name | ***Numerical Methods for Differential Equations*** |
| L – T – P – C | **03 – 01 - 0 – 4 / 03 – 0 - 2 - 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in (SPRING / AUTUMN) | **AUTUMN** |
| Offered by (Name of Department/ Centre) | **School of Computer Engineering & Mathematical Sciences** |
| CO1: Understand the methods for solving ODE's and PDE's using various Numerical methods that can help to make decisions for practical problems in industries and apply basic concepts of mathematics to formulate problem which can be solved by an appropriate Numerical method.<br><br>CO2: Students are able to understand the importance of Numerical method that could arise out of various processes and judge an appropriate method that could be used to solve the governing equations of a model.<br><br>CO3: Students are able to analyse and appreciate the variety numerical methods such as FDM and FVM that can be applied to solve a specific model.<br><br>CO4: Students are able to implement, develop and promote research interest in applying numerical methods in problems of Engineering and Technology. | |
| **Solution of Ordinary Differential Equations:** Taylor series method – Euler and Modified Euler methods – Runge kutta methods– Multistep methods – Milne"s method – Adams Moulton method.<br>**Boundary Value Problems and Characteristic Value Problems:** The shooting method – solution through a set of equations – Derivative boundary conditions – Characteristic value problems – Eigen values of a matrix by Iteration – The power method.<br>**Numerical Solution of Partial Differential Equations- Finite Difference Methods (FDMs)** : | |

(Solutions of Elliptic, Parabolic and Hyperbolic partial differential equations). Representation as a difference equation – Laplace‟s equation on a rectangular region – Iterative methods for Laplace equation – The Poisson equation – Derivative boundary conditions – Solving the equation for time-dependent heat flow (i) The Explicit method (ii) The Crank Nicolson method – solving the wave equation by FDMs. Alternate Direction Implicit (ADI) method, Maccormack predictor-corrector method, Lax-Wendroff Method. Dirichlet's problem, Neumann problem, mixed boundary value problem. Higher order compact (HOC) scheme.

**Basic concepts of finite volume method (FVM):**

Gauss-divergence theorem. Four basic rules. General discretization techniques. Source term linearization and boundary conditions. Over relaxation and under relaxation techniques. Location of control volume faces. Staggered grid concept. Application of FVM. Advantage and disadvantage with the FDM.

**Text Books:**

Numerical Solutions of Differential Equations, 2nd Ed., 1984, M. K. Jain, Wiley Eastern.

Numerical Solution of Partial Differential Equations, 3rd Ed., 1986, G.D. Smith, Oxford Univ. Press.

**Reference Books:**

Finite Difference Schemes and Partial Differential Equations, 2004, J. C. Strikwerda, SIAM.

Computational Methods for Partial Differential Equations, 2007, M. K. Jain, S. R. K. Iyengar, New Age International.

Applied Numerical Analysis, 7th Ed., 2003, Curtis F. Gerald, Patrick O. Wheatley, Pearson Education.

Numerical Methods Using MATLAB, 4th Ed., 2004, John H. Mathews, Kurtis D. Fink, Pearson Education.

An Introduction to Computational Fluid Dynamics - The Finite Volume Method, 2$^{nd}$ Ed., 2007, H. K. Versteeg, W. Malalasekera, Pearson Education.

### *AM 602 : Mathematical Modelling and System Analysis*

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|---|---|
| Course Code | **AM 602** |
| Course Name | ***Mathematical Modelling and System Analysis*** |
| L – T – P – C | **03 – 01- 0 – 4 / 03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in (SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:**

CO1: Students are able to understand the importance of modeling the physical phenomenons and their simulation on a digital machine over the physical experiments. Students also understand the power of numerical experiments over physical experiments with mathematical modeling techniques.

CO2: Students are able to analyze the continuous and discrete models with dimensional analysis and their applications in real-life scenarios.

CO3: Students are able to understand and model the time-invariant systems with the linear approximation of the nonlinear systems.

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| CO4: Students are able to understand the basics of the simulator technology with their application in developing cutting-edge technology, in particular with the applications in the defence sector. |
| **Course Contents**<br>**Mathematical Modelling:** Introduction to modelling and simulation, Classification of systems into continuous and discrete, Structural characterization of mathematical model and validation techniques.<br>**Modelling Techniques:** Dimensional analysis: Concept behind dimensional approach, Buckingham Pi theorem, Models using dimensional approach.<br>**Continuous approach:** Models based on physical laws.<br>**Discrete Approach:** Models based on discrete approach. Prey - Predator models.<br>**Combat Modelling:** Modelling the Lanchester laws with System Dynamics.<br>**System Analysis:** The state of a system, mathematical models of continuous linear lumped parameter, time invariant systems, Discrete time systems, Linear approximation of non-linear systems, Topological models of system, Block diagram representation, Signal flow graph, and Mason's rule. A generalized approach to modelling. Principles of conservation and continuity and Applications. Basics of simulator technology.<br>**Text Books**<br>Modelling Mathematical Methods & Scientific Computations, 1995, Nicola Bellomo & Luigi Preziosi, CRC Press.<br>Systems Modelling and Analysis, 2003, I.J. Nagrath, M. Gopal, Tata McGraw Hill, New Delhi.<br>Introduction to Mathematical Systems Theory - A behavioural approach, 2nd Ed., 2008, Jan Willen Polderman, Jan C. Willems, Springer.<br>**Reference Books:**<br>Introduction to System Dynamics, 1967, J.L. Shearer, A.T. Murphy, H.H. Richardson, Addison& Wesley.<br>Introduction to System Analysis, 1985, T.H. Glisson, McGraw Hill. |

## *AM – 603* : *Optimization Techniques*

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|---|---|
| Course Code | **AM 603** |
| Course Name | **Optimization Techniques** |
| L – T – P – C | **03 – 01 - 0 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |
| **Course Outcomes:** After completing this course, the students will be able to:<br>CO1: Understand the application of various optimization techniques that can help to make decisions for practical problems in industries and apply basic concepts of mathematics to formulate an optimization problem.<br>CO2: Understand the importance of optimization of industrial process management with the theory of optimization methods and algorithms developed for solving various types of optimization problems.<br>CO3: Analyze and appreciate the variety of performance measures for various optimization problems such as Sensitivity analysis, Risk analysis and Portfolio Management, etc.<br>CO4: Implement, develop and promote research interest in applying optimization techniques in problems of Engineering and Technology. And the mathematical results and numerical techniques of optimization | |

theory to concrete Engineering problems.

**Course Contents**

**Linear programming:** Simplex method, Two-phase method, Big-M method, Duality, Integer linear Programming, Dynamic Programming, Sensitivity analysis.

**Assignment problem:** Hungarian's algorithm, Degeneracy, applications, unbalanced problems, traveling salesman problem.

**Classical optimization techniques:** Single variable optimization with and without constraints, multi–variable optimization without constraints, multi–variable optimization with constraints – method of Penalty methods Lagrange multipliers, Kuhn-Tucker conditions.

**Numerical methods for optimization:** Minimization and maximization of convex functions- Local & Global optimum- Convergence-Speed of convergence. One dimensional minimization - Elimination methods: Fibonacci & Golden section search - Gradient methods - Steepest descent method, Nelder Mead's Simplex search method, methods of line search; Quasi-Newton methods: DFP, BFGS.

**CPM/PERT:** Simulation of CPM/PERT network, Analysis of an activity network, Simulation of inventory system and manufacturing system.

**Text Books**

Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
Engineering Optimization: Theory and Practice, 4th Ed., 2009, S.S. Rao, Wieley Eastern Ltd.
Optimization: Theory and Practice, 2004, MC Joshi, KM Moudgalya, Narosa.

**Reference Books**

Mathematical Programming Techniques, 3rd Ed., 1991, N. S. Kambo, East-West Press, New Delhi.
An Introduction to Optimization, 2nd Ed., 2001, Chong, E. k. and Zak, S. H., Wiley India.
Linear and Nonlinear Programming, 3rd Ed., 2008, Luenberger, D. G. and Ye, Y., Springer.
Mathematical Programming Techniques, 1997, Kambo, N.S., East-West Press.
Introduction to Optimization, 1988, Beale, John Wiley.
Numerical Methods and Optimization, Hari Arora, S.K. Kataria& Sons
Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer
Nonlinear Programming Theory and Algorithms, 1979, Bazarra M.S., Sherali H.D. & Shetty C.M., John Wiley, New York.

## *AM 604 : Advanced Statistical Techniques*

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|---|---|
| Course Code | **AM 604** |
| Course Name | ***Advanced Statistical Techniques*** |
| L – T – P – C | **03 – 01- 0 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:** After completing this course, the students will be able to:

CO1: Understand the fundamental concepts of probability and statistics such as Axioms, addition law, conditional probability, Baye's principle etc., and their real-life application to predict the data.

CO2: Understand the importance of Probability Distributions such as Binomial, Poisson, Normal and Exponential Distributions and their properties and problems on special probability distributions.

CO3: Analyze and appreciate the statistical theory behind Curve fitting, regression modeling and Chi Square Test, student test & Fisherman test.

CO4: Understand the theory behind Design and Analysis of Experiments: Need for conducting Experiments, and their possible applications.

**Course Contents**

**Probability Theory:** Sample Spaces- Events - Axioms – Counting - Conditional Probability and Bayes' Theorem – The Binomial Theorem – Random variable and distributions: Mean and Variance of a Random Variable-Binomial-Poisson-Exponential and Normal distributions.

**Sampling Distributions & Descriptive Statistics**: The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Sampling distributions (Chi-Square, t, F, z). Test of Hypothesis- Testing for Attributes – Mean of Normal Population – One-tailed and two-tailed tests, F-test and Chi-Square test - - Analysis of variance ANOVA – One way and two-way classifications.

**Introduction to Statistical modelling, Regression modeling for Normal response and quantitative explanatory**: Introduction to Statistical modeling, Variables, Simple and Multiple regressions, Model building and validation Comparison of regressions.

**Stochastic process**: Basic idea of random processes, Stationary, Markov processes, Markov chains and applications, Introduction to ergodicity.

**Introduction to R- Packages**: Scientific Calculator- Inspecting Variables- Vectors Matrices and Arrays- Lists and Data Frames- Functions- Strings and Factors-Flow Control and Loops- Advanced Looping- Date and Times.

**Text Books**

Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd.

Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.

An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.

**Reference Books**

All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer.

Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press.

Schaum's outlines Probability and statistics, 4th Ed., 2013, Murray R. Speigel, John Schiller, R Alu Srinivasan, Tata McGraw Hill

Learning R, O'Reilly, 2013, Richard Cotton.

Introductory statistics with R, 2008, Dalgaard, Peter Springer Science & Business Media.

A Handbook of Statistical Analysis Using R, Second Edition LLC, 2014, Brain S. Everitt.

Introduction to Probability and Statistics for Engineers and Scientists", 4th Ed., 2009, Sheldon M. Ross, Academic Press.

R Cookbook, O'Reilly, 2011, Paul Teetor.

*AM 605* **:** ***Linear Algebra and Applications***

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|---|---|---|
| Course Code | **AM 606** | |
| Course Name | **Linear Algebra and Applications** | |
| L – T – P - C | **03 – 01- 0 – 4** | |
| Offered as (Compulsory / Elective): | | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:
CO1: Students will build the fundamentals of linear algebra
CO2: Students appreciate the applications of different matrix decomposition methods
CO3: Students can correlate the related applications of linear algebra
CO4: Students should be in a position to formulate the relevant real-world problems using the understanding of linear algebra

**Course Contents**

**Unit I:** Introduction to Fundamental Linear Algebra Problems and Their Importance, Linear Transformations, Linear Variety, Range Space and Rank, Null Space and Nullity, Homomorphism, Matrix of Linear Transformations, Matrix Representation of a linear transformation, Structure of the solutions of the matrix equation $Ax = b$, Change of bases.

**Unit II:** Matrix and vector norms, floating points arithmetic, forward and backward stability of algorithms, conditioning of a problem, perturbation analysis, solving linear systems, Gaussian elimination, LU factorization, Pivoting, Cholesky decomposition, Iterative refinement, QR factorization, Gram-Schmidt orthogonalization, Projections, Householder reflectors, Given's rotation.

**Unit III:** Singular Value Decomposition, Rank and matrix approximations, image compression using SVD, Least squares and least norm solution of linear systems, pseudoinverse, normal equations, Eigenvalue problems, Gershgorin theorem, Similarity transform, Eigenvalue & eigenvector computations and sensitivity, Power method, Schur decomposition, QR iteration with & without shifts, Hessenberg transformation, Rayleigh quotient, Symmetric eigenvalue problem, Computing the Singular Value Decomposition,Golub-Kahan-Reinsch algorithm, Chan SVD algorithm, Krylov subspace methods: Lanczos, Arnoldi, MINRES, GMRES, Conjugate Gradient.

**Text Books**

Iterative Methods for Sparse Linear Systems, 2$^{nd}$ Ed., 2003, Y. Saad, SIAM.
Introduction to Linear Algebra, 6$^{th}$ Ed., 2023, Gilbert Strang, Wellesley-Cambridge Press.

**Reference Books**

Fundamentals of Matrix Computations, 2$^{nd}$ Ed,. 2002, D. S. Watkins, John-Wiley.
Numerical Linear Algebra and Applications, 2nd Ed., 2010, B. N. Datta, SIAM.
Applied Numerical Linear Algebra, 1997, J. W. Demmel, SIAM.
An Introduction to numerical linear algebra, 1994, C. G. Cullen, Charles PWS Publishing.
Linear Algebra and its Applications, 2013, C. Lay David, Pearson.
Matrix Computation, 1996, G. Golub, C. F. Van Loan, John Hopkins

*AM 609* **:** ***Data Science*****:** ***Tools and Techniques***

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|---|---|
| Course Code | **AM 609** |
| Course Name | **Data Science: Tools and Techniques** |

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| L – T – P – C | **3-0- 2-4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:** After completing this course, the students will be able to:

CO1: Understand the fundamental concepts of data science and terminology.

CO2: Understand the fundamental concepts of data science process and machine learning concepts.

CO3: Understand the fundamental concepts of tools used in data science.

CO4: Fundamental concepts of large data & Data Visualization.

CO5: To implement the aspects of Data Science through case studies.

**Programming Language:** Introduction to Python, Programming Interfaces, Spyder, Python script file, Print Message to Standard Output, variables and data types, Reading Input from console, Type Conversion, Arithmetic Operators and Conditions

**Control Flow -** Relational Operators, if…else statement, if…else if…else statement, Logical operators, While Loops, break and continue statement, Loops with else statement, pass statement, Python for loop, Range Function, **Lists:** Creating List, Accessing elements from List, Inserting and Deleting Elements from List, List Slicing, Joining two list, Repeating sequence, Nested List, Built-in List Methods and Functions, Searching elements in List, Sorting elements of List

**Python Data Structures:** Python Set, Creating Set, Adding/Removing elements to/from set, Python Set **Operations**: Union, Intersection, Difference and Symmetric Difference, Python Tuple, Creating Tuple, Understanding Difference between Tuple and List, Accessing Elements in Tuple, Python Dictionary, Creating Dictionary, Accessing / Changing / Deleting Elements in Dictionary

**Data Pre-processing Numpy, Dask, Xarray:** Numpy**,** Creating Numpy array, Numpy data type, Accessing Elements in Numpy, Element wise calculations, Vectorized Operation, Numpy Subsetting, Built-in Methods of Numpy, Array creation Methods: arange, linspace, eye, Numpy 2D Array, 2D Array Indexing, Matrix Calculations , Dask, Parallel computing with Dask, Xarray integration with Dask

**Pandas:** Reading Files, Writing Files, Loading Data with Pandas, Selecting Specific Columns, Selecting rows using labels: loc, Selecting rows using position: iloc, Adding and Removing rows and Columns, Filtering Data Frames, Importing Data from csv Files, Missing Data Handling, OnHot Encoder, Label Encoding, Data Splitting, Training Data, Importance of Test Data.

**Built-in Dictionary Methods and Functions:** Data Analytics**,** Data preprocessing, Analyzing data, Handling missing data, Applying Machine learning techniques to analyze data

**Functions:** Defining Functions in Python, Function Argument, Single Parameter Functions, Function Returning single Values, Functions with multiple parameters, Function that return Multiple Values, Functions with Default arguments, Named arguments, Scope and Lifetime of Variables, Global specifier

**Data Visulization with MatplotLib, Seaborn:** Introduction to Matplotlib, Basic Plotting with Matplotlib, Line Plot on Example DataSet, Exploring the plot Options, Other types of Plots, Bar Plot, Pie Plot, Histograms

**Regression for data analysis:** Introduction to regression and Classification, Types of Classification, Simple Linear regression Intuition, Sci kit Learn Library, Hands on Lab on Simple Linear Regression, Performance Evaluation

**Regression and Classification Part 2:** Multivariable Linear regression, Handson Example on

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| Multivariable LR, Performance Evaluation, Improving the Performance, Backward Elimination method, Other types of Regression Models, Performance Evaluation of different Regression Models<br>**Classification in Machine Learning :** Classification Introduction, K-Nearest Neighbours, Decision Tress, Naïve Bayes algorithm, Introduction to Neural Networks |
| **Text Books** |
| Mastering Python for Data Science, 2015, Samir Madhavan, Packt Publishing.<br>Python Machine Learning, 2015, Sebastian Raschka Packt Publishing.<br>Python Basics: A Self-Teaching Introduction, 2018, H. Bhasin, Mercury Learning and Information.<br>Beginning Python, 2008, Magnus Lie Hetland, Apress Berkeley, CA. |
| **Reference Books** |
| Michael Roberts Beginning Python, 2005, Peter Norton, Alex Samuel, David Aitel, Eric Foster-Johnson, Leonard Richardson, Jason Diamond, Aleatha Parker,Wiley Publishing.<br>Expert Python Programming: Best practices for designing, coding, and distributing your Python software Tarek Ziadé, 2008, Packt Publishing.<br>Programming Python, 2010, Mark Lutz, O'Reilly Media.<br>Programming in Python 3: A Complete Introduction to the Python Language, 2010, Mark Summerfield, Addison-Wesley.<br>Practical programming: An introduction to computer science using Python, 2009, Jennifer Campbell, Paul Gries, Jason Montojo, Greg Wilson, Pragmatic Bookshelf.<br>Core Python Programming, 2$^{nd}$ Ed., 2006, Wesley Chun, Prentice Hall.<br>Core Python Applications Programming, 2012, Wesley J Chun, Prentice Hall.<br>Programming Computer Vision with Python: Tools and algorithms for analyzing images, 2012, Jan Erik Solem, O'Reilly Media. |

## *PGC-601* : *Research Methodology and IPR*

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|---|---|
| Course Code | **PGC-601** |
| Course Name | **Research Methodology and IPR** |
| L – T – P - C | **2 – 0- 0 – 2** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **PGC/All Departments DIAT** |

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| Course Outcomes: After completing this course, the students will be able to:<br>CO1: Understanding the fundamentals of research and its methodology<br>CO2: Choose the appropriate research design and develop appropriate research hypothesis for a research project<br>CO3: Knowledge of manuscript preparation, patents and Intellectual property<br>CO4: Technology transfer and application of IPR in various domains. |
| **Course Contents** |
| Unit I : Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, |

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| Necessary instrumentations<br>Unit II : Effective literature studies approaches, analysis Plagiarism, Research ethics,<br>Unit III : Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee<br>Unit IV : Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.<br>Unit V : Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications<br>Unit VI : New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |
| **Texts / References** |
| Research methodology: an introduction for science & engineering students, Stuart Melville and Wayne Goddard.<br>Research Methodology: An Introduction, Wayne Goddard and Stuart Melville.<br>Research Methodology: A Step-by-Step Guide for beginners, 2nd Ed., Ranjit Kumar.<br>Resisting Intellectual Property, 2007, Halbert, Taylor & Francis Ltd.<br>Industrial Design, 1992, Mayall, McGraw Hill.<br>Product Design, 1974, Niebel, McGraw Hill.<br>Introduction to Design, 1962, Asimov, Prentice Hall.<br>Intellectual Property in New Technological Age, 2016, Robert P. Merges, Peter S. Menell, Mark A. Lemley.<br>Intellectual Property Rights Under WTO, 2008, T. Ramappa, S. Chand. |

## *AM 621* : *Advanced Modelling Techniques*

| Course Code | **AM 621** |
|---|---|
| Course Name | ***Advanced Modelling Techniques*** |
| L – T – P – C | **03 – 01- 0 – 4 / 03 – 0- 2 - 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |
| Course Outcomes: After completing this course, the students will be able to:<br>CO1: Understand basic concepts of Fuzzy sets, neural networks, chaos, fractals and their applicability in various fields of science and technology that can help to make decisions for practical problems in industries.<br>CO2: Students are be able to understand the importance of fuzzy sets and fuzziness that could arise out of various processes and judge an appropriate method that could be used to solve the governing model as fuzziness i9s inherent in large no. of models.<br>CO3: Students are be able to analyze and appreciate the mathematics behind the variety neural networks such as perceptron learning, back propagation methods etc., that can be applied to solve a specific model.<br>CO4: Students are be able to understand the theory behind chaos mathematically using a specific water wheel model. Also, to understand the theory behind fractals and their possible applications | |

**Fuzzy logic:** Basic concepts of fuzzy set, Operation on fuzzy sets, Fuzzy numbers Fuzzy relation, Fuzzification, Fuzzy logic as generalization of two valued logic, Fuzzy system, fuzzy control, fuzzy clustering.

**Artificial Neural Networks –** Introduction, Neural network representation, Appropriate problems for neural network learning, Perceptions, Multilayer networks and the back propagation algorithm, Remarks on the back propagation algorithm, An illustrative example face recognition Advanced topics in artificial neural networks

**Dynamics of Chaos:** Introduction to chaos, Lorenz system, Lorenz attractor, Dimension of chaotic attractor, applications in communications.

**Fractals:** Introduction to fractals, Types of fractal dimensions, Generation of fractals by mathematical approach, Julia and Mandelbrot sets.

**Text Books**

Fuzzy Logic with Engineering Applications, 2009, Timothy J Ross, Wiley.
Neural Computing: An Introduction, 2010, R. Beale, T. Jackson, Adam Hilger, CRC Press.

**References Books**

Neural fuzzy systems: A Neurofuzzy Synergism to Intelligent Systems, 1996, Chin- Teng Lin and C.S.G. Lee, Prentice Hall International, INC.
Encounter With Chaos, 1992, Denny Gulick, McGraw Hill Inc.

***AM 622 : Simulation of Linear and Nonlinear Systems***

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|---|---|
| Course Code | **AM 622** |
| Course Name | ***Simulation of Linear and Nonlinear Systems*** |
| L – T – P – C | **03 – 01- 0 – 4 / 03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:
CO1: Students can understand the basics concepts of real systems, mathematical model, types of models, simulation and their applications.
CO2: Students are be able to understand the importance of Generation of random numbers, Pseudo random numbers, generation of random variates using discrete and continuous probability distributions such as uniform, triangular. CO3: Students are be able to analyze and appreciate the uniformity and independence properties using testing of hypothesis and Chi-square, auto correlation tests.
CO4: Students are be able to understand the simulation theory related to Queuing, Inventory and CPM/PERT and implement industrial and real-world problems.

Simulation of single server and multiple server queuing system. Design (component & organisation) of a simulation experiment. Rational selection of input distribution. Output data analysis. Variance reduction techniques, Model validation. Discrete event systems, Time advance mechanism, Simulation, Monte Carlo & Stochastic Simulation
Generation of random numbers, Pseudo random numbers, Test for random number simulation of probability

distribution. Discrete event simulation: simulation of single server and multiple server queuing system.
Concept of systems, Classification of systems, General Properties of Linear and nonlinear systems.
Periodic orbits, Poincare Bendixson criterion, limit cycle, bifurcation, Lyapunov Stability, basic stability and instability theorems, uniform stability, asymptotic stability, exponential stability

**Text Books**

An Introduction to Mathematical Control Theory, 1990, S. Barnett and R. G. Cameron, Oxford University Press.

Nonlinear Systems, 3rd Ed., 2003, H.K. Khalil, Prentice Hall.

Applied Nonlinear Control, 1991, J.J.E. Slotine, W. Li, Prentice Hall

Simulation Modeling & Analysis, 2008, Law A.M., Tata McGraw Hill.

**Reference Books**

System Modelling and Computer Simulation, 1996, Kheir N.A, Marcell Dekker.

Discrete-Event System Simulation, 5th Ed., 2009, Jerry Banks, John Carson, Barry L. Nelson, David Nicol, Prentice Hall

Operations Research: An Introduction, 2002, Taha H.A, Prentice Hall.

***AM 623* : *Machine Learning***

| | |
|---|---|
| Course Code | **AM 623** |
| Course Name | **Machine Learning** |
| L – T – P – C | **03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:** After completing this course, the students will be able to:

CO1 Understand the scenarios where machine learning algorithms can and cannot be used. Understand different types of machine learning algorithms namely unsupervised, supervised, and reinforcement learning algorithms, and get exposure to scenarios/applications where these algorithms can be applied.

CO2 learn the concepts of Regression, Classification and Clustering algorithms, and how to choose metrics to evaluate the performance of various machine learning models.

CO3 understand the concepts of overfitting, underfitting, right fit while learning a machine learning model, and learns the different techniques to address overfitting, underfitting problems to obtain the right fit. Students also learns how to setup a machine learning experiment, and how to report the performance of the model.

CO4 acquire knowledge on programming languages such as Python, Matlab, R, and also on libraries like NumPy, Pandas, Matplotlib, Scikit learn, etc. which helps them to apply machine learning models on any data sets.

| Course Contents |
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| **UNIT I -** Well-posed learning problems, Designing a learning system, Perspectives and issues in machine learning. Types of Machine Learning-Supervised, Unsupervised, Reinforcement learning.<br>**UNIT II-**Supervised Learning Algorithms- Regression and Classification-Linear, Polynomial-Regularization, Regression based on Normal Equations, Instance-based learning-Decision Trees, Artificial Neural Networks Support Vector Machines, Support Vector Regression<br>**UNIT III**- Unsupervised learning- k-means, Gaussian Mixture Models, Expectation Maximization, Hierarchical clustering, Spectral clustering**.**<br>**UNIT IV:** Bias variance trade-off, VC dimension, Model selection, AUC-ROC, Metrics-Regression, Classification, Clustering, K Fold cross-validation.<br>**UNIT V:** Python Implementation of Regression, Classification, and Clustering Algorithms. |
| **Text Books** |
| Machine Learning, Indian Ed., 2017, Tom M. Mitchell, Tata McGraw Hill Education.<br>Machine Learning: An Algorithmic Perspective, 2$^{nd}$ Ed., 2014, Stephen Marsland, Taylor & Francis (CRC).<br>Machine Learning, A probabilistic perspective, 2012, Kevin Murphy, MIT Press.<br>Hands on Machine Learning with Scikit-Learn, Keras & TensorFlow, O'Reilly- 3$^{rd}$ Edition, 2022 |
| **Reference Books** |
| 1. Pattern Recognition and Machine Learning, 2006, Christopher M. Bishop, Springer.<br>2. Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press. |

### *AM 624* : *Big Data Analytics*

| Course Code | **AM 624** |
|---|---|
| Course Name | **Big Data Analytics** |
| L – T – P - C | **03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

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| Course Outcomes: After completing this course, the students will be able to:<br>CO1: understand the building blocks of Big Data<br>CO2: articulate the programming aspects of cloud computing (map Reduce etc)<br>CO3: understand the specialized aspects of big data with the help of different big data application<br>CO3: represent the analytical aspects of Big Data<br>CO5: know the recent research trends related to Hadoop File System, MapReduce and Google File System etc |
| **Course Contents** |
| **Unit I : Introduction to Big Data:** Types of Digital Data-Characteristics of Data – Evolution of Big Data – Definition of Big Data – Challenges with Big Data – 3Vs of Big Data – Non Definitional traits of Big Data – Business Intelligence vs. Big Data – Data warehouse and Hadoop environment – Coexistence. Big Data Analytics: Classification of analytics – Data Science – Terminologies in Big Data – CAP Theorem – BASE Concept. NoSQL: Types of Databases – Advantages – NewSQL – SQL vs. NOSQL vs NewSQL. |

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| Introduction to Hadoop: Features – Advantages – Versions – Overview of Hadoop Eco systems – Hadoop distributions – Hadoop vs. SQL – RDBMS vs. Hadoop – Hadoop Components – Architecture – HDFS – Map Reduce: Mapper – Reducer – Combiner – Partitioner – Searching – Sorting – Compression. Hadoop 2 (YARN): Architecture – Interacting with Hadoop Eco systems.<br>**Unit II: No SQL databases:** Mongo DB: Introduction – Features – Data types – Mongo DB Query language – CRUD operations – Arrays – Functions: Count – Sort – Limit – Skip – Aggregate – Map Reduce. Cursors – Indexes – Mongo Import – Mongo Export. Cassandra: Introduction – Features – Data types – CQLSH – Key spaces – CRUD operations – Collections – Counter – TTL – Alter commands – Import and Export – Querying System tables.<br>**Unit III: Hadoop Eco systems:** Hive – Architecture – data type – File format – HQL – SerDe – User defined functions – Pig: Features – Anatomy – Pig on Hadoop – Pig Philosophy – Pig Latin overview – Data types – Running pig – Execution modes of Pig – HDFS commands – Relational operators – Eval Functions – Complex data type – Piggy Bank – User defined Functions – Parameter substitution – Diagnostic operator. Jasper Report: Introduction – Connecting to Mongo DB – Connecting to Cassandra – Introduction to Machine learning: Linear Regression – Clustering – Collaborative filtering – Association rule mining – Decision tree.<br>**Unit IV: Algorithms for massive data sets**, Algorithms for SISD, SIMD environments, Linked Big Data Analysis – Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications<br>**Unit V: Applications for massive data sets:** finding similar items, mining data streams, page rank algorithm, link analysis, mining social-network graphs, semantic analysis, study of applications of big spatial-temporal data, social media data, scientific data and others. |
| **Text Books** |
| Big Data Fundamentals: Concepts, Drivers & Techniques, 2016, Thomas Erl, Wajid Khattak, Paul Buhler, Prentice Hall, Service Tech Press.<br>Big Data and Analytics, 2015, Seema Acharya, Subhashini Chellappan, Wiley Publication.<br>Data Mining, 2012, 3rd Ed., Jiawei Han, Micheline Kamber, Micheline Kamber, Jian Pei, Elsevier. |
| **Reference Books** |
| Introduction To Algorithms, 2009, 3rd Ed., Thomas H. Cormen, Charles E. Leiserson, Ronaldo L. Rivest, Clifford Stien, The MIT Press.<br>Big Data for Dummies, 2013, Judith Hurwitz, Alan Nugent, Fern Halper, Marcia Kaufman, John Wiley & Sons, Inc.<br>Hadoop: The Definitive Guide, 2011, Tom White, O'Reilly Publications.<br>Mongo DB in Action, 2012, Kyle Banker, Manning Publications Company.<br>Mining of Massive Datasets, 2012, Jure Leskovec, Anand Rajaraman, Jeffrey David Ulman, Cambridge University Press.<br>Big Data Analytics, 2015, Seema Acharya, Subhasini Chellappan, Wiley.<br>Big Data Fundamentals: Concepts, Drivers & Techniques, 2016, Thomas Erl, Wajid Khattak, Paul Buhler, Prentice Hall, Service Tech Press.<br>HADOOP: The definitive Guide, 2012, Tom White, O'Reilly.<br>Data Mining, 2nd Ed., 2006, Jiawei Han, Micheline Kamber, Elsevier. |

***AM 625* : *Image and Video Analytics***

| Course Code | **AM 625** |
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| Course Name | ***Image and Video Analytics*** |
| L – T – P - C | **03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:** After completing this course, the students will be able to:

CO1: understand basic image model, and will learn basic image processing techniques to analyze the image in terms of histogram, contrast, sharpness, etc.

CO2: learn different image enhancement techniques, and also understand the factors which degrades the quality of an image, and also learns the image restoration techniques. Different spatial filtering operations for image enhancement will be learnt along with the morphological operations.

CO3: learn image segmentation algorithms, understands the need for image compression and learn the spatial and frequency domain techniques used for image compression.

CO4: learn different feature extraction techniques employed for image analysis and recognition, and gets an overview on applications of image processing in Machine vision

**Course Contents**

**Digital Image Fundamentals:** Introduction – Origin –Steps in Digital Image Processing – Components; Elements of Visual Perception – Light and Electromagnetic Spectrum – Image Sensing and Acquisition – Image Sampling and Quantization – Relationships between pixels.

**Image Enhancement**: Spatial Domain: Gray level transformations – Histogram processing – Basics of Spatial Filtering–Smoothing and Sharpening Spatial Filtering – Frequency Domain: Introduction to Fourier Transform – Smoothing and Sharpening frequency domain filters – Ideal, Butterworth and Gaussian filters.

**Image Restoration**: Noise models – Mean filters – Order Statistics – Adaptive filters – Band reject – Band pass – Notch – Optimum notch filtering – Inverse Filtering – Constrained Least Square Filtering – Wiener filtering.

**Morphological image processing**: Dilation, Erosion, Opening, Closing, Applications to; Boundary extraction, Region filling, Extraction of connected components.

**Image Compression:** Fundamentals – Image Compression models – Error Free Compression – Variable Length Coding –Bit – Plane Coding – Lossless Predictive Coding – Lossy Compression – Lossy Predictive Coding –Wavelet Coding – Compression Standards – JPEG2000.

**Image Segmentation and Representation:** Segmentation – Detection of Discontinuities – Edge Linking and Boundary detection – Region based segmentation; Representation – Boundary descriptors – Simple Descriptors – Shape numbers –Regional descriptors – Simple and Topological Descriptors – Introduction to Image Processing Toolbox – Practice of Image Processing Toolbox – Case studies– Various Image Processing Techniques.

**Object recognition**: Decision-theoretic methods, SVM, feature selection methods, feature extraction methods, Maximum Output Information (MOI) for joint selection and classifier training.

**Colour models and Transformations** – Image and Video segmentation - Image and video demonising- Image and Video enhancement- Image and Video compression. Object detection and recognition in image and video - Texture models Image and Video classification models- Object tracking in Video

**Text Books**

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| Digital Image Processing, 3rd Ed., 2007, R. C. Gonzalez, Richard E. Woods, Prentice Hall.<br>Digital Image Processing Using MATLAB, 2nd Ed., 2009, R. C. Gonzalez, Richard E. Woods, Steven L. Eddins, Gatesmark Publishing. |
| **Reference Books** |
| Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press.<br>Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India.<br>Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley.<br>Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker.<br>Computer Vision: Algorithms and Applications, 2011, Rick Szelisk, Springer.<br>Intelligent Video Surveillance Systems, 2013, Jean-Yves Dufour, Wiley.<br>Video Analytics for Business Intelligence, 2012, Caifeng Shan, Fatih Porikli, Tao Xiang, Shaogang Gong, Springer. |

***AM 626 : Computational Heat and Mass Transfer***

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| Course Code | **AM 626** |
| Course Name | ***Computational Heat and Mass Transfer*** |
| L – T – P – C | **03 – 01- 0 – 4 / 03 – 0- 2 - 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |
| Course Outcomes: After completing this course, the students will be able to:<br>CO1: The students have would get an intuitive idea about the practical applications of convective fluid flow into various industrial field.<br>CO2: After completion of this course, students can have explicit knowledge about mixed convection phenomena<br>CO3: The computation of convective heat and mass transfer analysis would be easy for students<br>CO4: The numerical analysis associated with the flow characteristics could be helpful in the other branches of CFD | |
| **Philosophy of Computational Fluid Dynamics:** Introduction to CFD, CFD- a research tool, CFD- a design tool, Applications and Advantages of CFD, The basic governing fluid flow equations in differential form, Models of Fluid flow, Concept of Substantial derivative, Navier-Stoke‘s model and Euler‘s model equations.<br>**Convective Heat Transfer:**<br>Introduction to convection, review of conservation equations - Forced convection in laminar flow - Exact and approximate solutions of Boundary layer energy equation for plane isothermal plate in longitudinal flow - problems. Forced convection heat transfer in laminar tube flow - forced convection in turbulent flow – Internal Flows-Correlations-Problems. Approximate analysis of laminar free convective heat transfer on a vertical plate-external flows-correlations-problems.<br>**Convective Mass Transfer**<br>Definitions of concentration and velocities relevant to mass transfer, Fick's law, species conservation equation in different forms. Steady state diffusion in dilute solutions in stationary media, transient diffusion in dilute solutions in stationary media, one dimensional non dilute diffusion in gases with one component stationary. Convective mass transfer - governing equations-forced diffusion from flat plate-Dimension less | |

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| correlation's for mass transfer. Simultaneous heat and mass transfer - analogy between heat, mass and momentum transfer<br>**Finite Element Method Technique:** Formulation Techniques: Methodology, Engineering problems and governing differential equations, finite elements, Variational methods-potential energy method, Raleigh Ritz method, strong and weak forms, Galerkin and weighted residual methods, Piecewise Defined Shape functions, Essential and natural boundary conditions. One-dimensional finite element methods: Bar elements. Element matrices, assembling of global stiffness matrix, Application of boundary conditions, Quadratic Element, Implementation of the FEM - The Solution Procedure.<br>**Finite Element Method Techniques in Heat & Mass Transfer problems:** One-dimensional, conduction and convection problems examples. Two dimensional problems: CST, LST, four noded and eight nodded rectangular elements, Lagrange basis for triangles and rectangles, serendipity interpolation functions. Axisymmetric Problems: Axisymmetric formulations, Element matrices, boundary conditions. Examples: - two-dimensional fin. Isoperimetric formulation: Concepts, sub parametric, super parametric elements, numerical integration.<br>**Text Books:**<br>Computational Fluid Dynamics-Basics with applications, 1st Ed., 1995, John D. Anderson: McGraw-Hill Science.<br>An Introduction to Fluid Dynamics, 2010, G. K. Batchelor, Cambridge University Press.<br>Computational Fluid Mechanics and Heat Transfer, 3rd Ed., 2011, Richard H. Pletcher, John C. Tannehill, Dale Anderson, Taylor & Francis.<br>**Reference Books:**<br>Computational Fluid Dynamics: A Practical Approach, 1st Ed., 2008, Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu, Butterworth-Heinemann.<br>Computational Methods for Fluid Dynamics, 3rd Ed., 2013, J. H. Ferziger, M. Peric, Springer.<br>Convection in Porous Media, 4$^{th}$ Ed., 2013, Donald A. Nield, Adrian Bejan, Springer.<br>Convective Heat and Mass Transfer, 1$^{st}$ Ed., 2011, S. Mostafa Ghiaasiaan, Cambridge University Press.<br>Fundamentals of Heat & Mass Transfer, Thirumaleshwar, Pearson<br>Conduction Heat transfer, 1994, Poulikakos, Prentice Hall.<br>Analytical methods in Conduction Heat Transfer, 1971, G. E. Mayers, McGraw Hill.<br>Convective Heat and Mass Transfer, 3rd Ed., 1993, W. M. Kays, M. E. Crawford, McGraw Hill.<br>Introduction to Convective Mass Transfer, 1963, D. B. Spalding, McGraw Hill. |

## *AM 627* : *Ballistics*

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| Course Code | **AM 627** |
| Course Name | ***Ballistics*** |
| L – T – P – C | **03 – 01- 0 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |
| CO1: Have a knowledge and understanding of Newtonian mechanics relating to the flight of projectiles. Energy considerations in ballistics. Weapon mechanisms. Ammunition. Overview of the main stages of ballistics (Internal, Intermediate, External and Terminal).<br>CO2: The application of mechanics to different scenarios of ballistics. | |

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| CO3: The application of law to ballistics.<br>CO4: Develop practical skills in ballistics further, for higher level ballistics modules. |
| **Explosives:** Explosive compounds and explosive mixtures-classification of explosives: Measurement of various explosive parameters<br>**Internal Ballistics:** General introduction –Propellants-Driving Band engraving process, and the resistance to the in–bore motion of a projectile- Heating of gun barrel- Heat conduction in thick walled barrels-Numerical solution for heat conduction- Wear in gun barrels- Prediction of pressure history and muzzle velocity- The internal ballistics of leaking gun.<br>**External Ballistics:** Projectile Aerodynamics: General introduction-yaw-The aerodynamic forces and moments acting on a projectile-linearised aerodynamics-centre of pressure and stability-Aerodynamic coefficients-Drag laws-Angular motion of projectiles-Gyroscopic stability-Yawing behaviour-The linearised theory of yawing motion-projectiles with slight configurational asymmetries-projectiles not obeying classical linear theory.<br>**Projectile Transitional Motion:** Motion in vacuum-Motion of point mass-Trajectory modelling-constant corrections to the plane-particle trajectory, biases-variable corrections to the plane-particle trajectory, dispersion-the effect of wind.<br>**Terminal Ballistics:** Kinetic Energy projectiles: Penetration into resisting medium-Empirical formulae for the prediction of penetration-Analytical models of failure modes-Numerical methods-plate charges.<br>**Design and Defeat of Armour:** Introduction –Mechanical property requirements-Armour material Characteristics –Armour structure-stress-strain relationship-Waves in rods-Defeat of armour-Failure<br>**Wound Ballistics:** Threshold velocity for penetration of skin, flesh, bones- Nature of wounds on entry, exit-Explosive wounds- Evaluation of injuries caused due to shot gun, rifle, hand guns and country made firearms- Method of measurement of wound ballistic parameters- post mortem and ante- mortem firearm injuries.<br><br>**Text Books:**<br>The Books of Ballistics and Gunnery, 1987, War Office, UK.<br>Modern Exterior Ballistics, 1999, Robert McCoy-Schiffer publishing Ltd.<br>Interior Ballistics, 1951, HMSO publication<br>Terminal Ballistics- A Text Book and atlas of gunshot wounds, 2005, Malcom J Dodd, CRC press, Taylor & Francis publications<br><br>**Reference Books:**<br>Firearms in criminal investigation and trials, 2017, 3rd Ed., B R Sharma, Universal Law publishing Co. Pvt Ltd.<br>Gunshot wounds- practical aspects of Firearms. Ballistics and Forensic Techniques, 3rd Ed., 2016, Vincent J. M. DiMaio, CRC press.<br>Wound Ballistics and the Scientific Background, 1995, Karl G Sellier, Beat P Kneubuehl Elseviour Science publishing Co. Inc. |

***AM 628 : Computational Number Theory and Cryptography***

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| Course Code | **AM 628** |
| Course Name | ***Computational Number Theory and Cryptography*** |
| L – T – P - C | **03 – 01- 0 – 4** |

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| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes**: After completing this course, the students will be able to:

CO1: learn computational methods in Algebra and Number Theory.

CO2: understand fundamental number-theoretic algorithms such as the Euclidean algorithm, the Chinese Remainder algorithm, binary powering, and algorithms for integer arithmetic.

CO3: understand the number-theoretic foundations of modern cryptography and the principles behind their security.

CO4: Understand the mathematical foundations for security of modern cryptography, asymmetric crypto-systems based on hard computational problems from Algebra and Number Theory.

CO5: apply fundamental algorithms for symmetric key and public-key cryptography.

**Course Contents**

**Introduction:** Introduction to Cryptosystems, Classical Ciphers, Cryptanalysis of Classical ciphers, LFSR based stream ciphers. Shannon's Theory**,** Diffie-Helman Key Exchange, Rabin Cryptosystem, Knapsack Ciphers, Digital Signature, Secret Sharing, ElGamal Cryptosystem

**Number Theory:**

**Divisibility:** Representations of Integers, Computer Operations with Integers, Complexity of Integer Operations, Divisibility, Prime Numbers, The Fundamental Theorem of Arithmetic, Sieve of Eratosthenes, The Distribution of Primes, Greatest Common Divisor, Euclidean Algorithm, Mersenne Numbers, Fermat Numbers, Perfect numbers

**Congruence:** Congruences, Congruence Applications, Linear Congruences, The Chinese Remainder Theorem, Theorems of Fermat and Euler- Fermat, Wilson's Theorem, Pseudo Primes, Carmichael Numbers, The Euler Phi-Function, The Sum and Number of Divisors, Quadratic Residue, Quadratic Reciprocity. Legendre and Jacobi Symbols, Computing Legendre symbols, Primitive Roots, Quadratic Reciprocity Law,

**Inter Factorization and Primality Testing Algorithms:** Complexity of Number Theoretic Algorithms, Fermat's Factorization, Kraitchik's Improvement, Trial division, Pollard Rho Algorithm, p-1 method, CFRAC method, quadratic sieve method, elliptic curve method. **Primality testing algorithms:** Fermat test, Miller-Rabin test, Solovay-Strassen test, AKS test.

**Computing discrete logarithms over finite fields:** Baby-step-giant-step method, Pollard rho method, Pohlig-Hellman method, index calculus methods, linear sieve method, Coppersmith's algorithm.

**Representation of finite fields:** Groups, Fields, Finite Fields, Arithmetic in Finite Field, Finding Multiplicative Inverses in finite fields, Prime and extension fields, representation of extension fields, polynomial basis, primitive elements, normal basis, optimal normal basis, irreducible polynomials. Binary Fields and their application in Cryptosystems.

**Elliptic Curve Cryptography:** Introduction to Elliptic Curves, the elliptic curve group, elliptic curves over finite fields, Schoof's point counting algorithm, Discrete Log problem for Elliptic curves, Factorization using Elliptic Curve, Advantage of Elliptic Curve Cryptography over other Public Key Cryptosystems.

**Text Books**

Introduction to Modern Cryptography, 2nd Ed., 2008, J. Katz, Y. Lindell, Chapman & Hall/CRC.
Computational number theory, 2018, Abhijit Das, Chapman and Hall/CRC.
A Course in Number Theory and Cryptography, 2006, N. Koblitz, Springer.
An Introduction to theory of numbers, 2006, I. Niven, H.S. Zuckerman, H.L. Montgomery, John Wiley & Sons, Inc.

**Refernece Books**

Elliptic curves: number theory and cryptography, 2003, L. C. Washington, Chapman & Hall/CRC.
Rational Points on Elliptic Curves, 2005, J. Silverman, J. Tate, Springer-Verlag.
Guide to elliptic curve cryptography, 2004, D. Hankerson, A. Menezes, S. Vanstone, Springer-Verlag.
An Introduction to Mathematical Cryptography, 2008, J. Pipher, J. Hoffstein, J. H. Silverman, Springer-Verlag.
Elementary Number Theory, 1998, G. A. Jones, J. M. Jones, Springer-Verlag.
An Introduction to Cryptography, 2001, R. A. Mollin, Chapman & Hall.
Number Theory for Computing, $2^{nd}$ Ed., 2002, Song Y. Yan, Springer-Verlag.
Introduction to Algorithms, Second Edition, 1994, T. H. Cormen, C. E. Leiserson, R. L. Rivest, Prentice Hall of India.
Elementary Theory of Numbers, $5^{th}$ Ed., 2004, K. Rosen, Addison Wesley.
Factorization and Primality Testing, 1989, D. M. Bressoud, Springer-Verlag.
A computational introduction to number theory and algebra, 2009, V. Shoup, Cambridge University Press.
Mathematics for computer algebra, 1992, M. Mignotte, Springer-Verlag.
An introduction to the theory of numbers, 2011, I. Niven, H. S. Zuckerman, H. L. Montgomery, John Wiley.
Modern computer algebra, $3^{rd}$ Ed., 2013, J. Von zur Gathen, J. Gerhard, Cambridge University Press.
Introduction to finite fields and their applications, 2012, R. Lidl, H. Niederreiter, Cambridge University Press.
Applications of finite fields, 1993, A. J. Menezes, Kluwer Academic Publishers.
Rational points on elliptic curves, 2015, J. H. Silverman, J. Tate, Springer International Edition.
Guide to elliptic curve cryptography, 2004, D. R. Hankerson, A. J. Menezes, S. A. Vanstone, Springer-Verlag.
Public-key cryptography: Theory and practice, 2009, A. Das, C. E. Veni Madhavan, Pearson Education Asia.
A course in computational algebraic number theory, 1993, H. Cohen, Springer-Verlag.

### *AM 629 : Calculus of Variations and Integral Equations*

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| Course Code | **AM 629** |
| Course Name | ***Calculus of Variations and Integral Equations*** |
| L – T – P – C | **03 – 01- 0 – 4 / 03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

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| **Course Outcomes**:<br>CO1: Students will learn the core concepts of multi variable calculus and integral equations with voltera and freedholm alternatives.<br>CO2: Students will learn the applications of these techniques in several engineering problems.<br>CO3: Students will learn the Greens functions, and Galerkin and Ritz approach of variational equations.<br>CO4: Students will also learn the minimum surface of revolution and fundamental results of calculus of variations |
| **Course Contents** |
| Linear integral equations, some basic identities, Initial value problems reduced to Volterra integral equations, Methods of successive substitution and successive approximation to solve Volterra integral equations of second kind, Iterated kernels and Neumann series for Volterra equations. Resolvent kernel as a series in, Laplace transforms method for a difference kernel, Solution of a Volterra integral equation of the first kind.<br>Boundary value problems reduced to Fredholm integral equations, Methods of successive approximation and successive substitution to solve Fredholm equations of second kind, Iterated kernels and Neumann series for Fredholm equations. Resolvent kernel as a sum of series. Fredholm Resolvent kernel as a ratio of two series. Fredholm equations with separable kernels, Approximation of a kernel by a separable kernel, Fredholm Alternative, non-homogenous Fredholm equations with degenerate kernels.<br>Green's function, use of method of variation of parameters to construct the Green's function for a non-homogeneous linear second order boundary value problem, Basic four properties of the Green's function, Orthogonal series representation of Green's function, Alternate procedure for construction of the Green's function by using its basic four properties. Reduction of a boundary value problem to a Fredholm integral equation with kernel as Green's function. Hilbert-Schmidt theory for symmetric kernels.<br>Motivating problems of calculus of variations, shortest distance, Minimum surface of revolution, Branchistochrone problem, Isoperimetric problem, Geodesic. Fundamental lemma of calculus of variations, Euler's equation for one dependant function and its generalization to 'n' dependant functions and to higher order derivatives, Conditional extremum under geometric constraints and under integral constraints.<br><br>**Text Books:**<br>Introduction to Integral Equations with Applications, 1999, A. J. Jerri, Wiley-Interscience.<br>Linear Integral Equations: Theory and Techniques, 2013, R. P. Kanwal, New York: Academic Press.<br>Calculus of Variations, 1963, J. M. Gelfand, S. V. Fomin. Inc., Englewood Cliffs: Prentice-Hall.<br><br>**Reference Books:**<br>Calculus of Variations with Applications to Physics and Engineering,1974, R. Weinstock, McGraw-Hall.<br>A First Course in Integral Equations, 2nd Ed., 2015, Abdul-Majid Wazwaz World Scientific Pub.<br>Integral equations: a practical treatment, from spectral theory to applications, 1990, P. David, S. G. David Stirling, Cambridge University Press. |

***AM 630* : *Domain Decomposition Methods for Partial Differential Equations***

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|---|---|
| Course Code | **AM 630** |
| Course Name | **Domain Decomposition Methods for Partial Differential Equations** |

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|---|---|
| L – T – P – C | **03 – 01- 0 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes**:
CO1: Students will learn the core concepts of domain decomposition methods
CO2: Students will learn the applications domain decomposition method to solve the elliptic and parabolic problems
CO3: Students will learn the stability analysis and error analysis of the various PDEs by domain decomposition methods
CO4: Students will also learn the practical applications of the method in time dependent physical and engineering problems

**Unit I:** The mathematical Foundation of Domain decomposition Methods. Multi-domain formulation and the Steklov-Poincare Interface Equation, Variational formulation of the multi- domain problem, Iterative Substructuring methods based on transmission conditions at the interface, The Steklov-Poincare equation for Neumann Boundary Value Problems, Iterations on many Subdomains.
**Unit II:** Discretised equations and Domain Decomposition Methods, Finite Element approximations of elliptic equations, Finite Element approximation of the Steklov-Poincare operator, the Schur Complement matrix.
**Unit III**: Iterative Domain Decomposition Methods at the Discrete Level, Iterative Sub- structuring Algorithms, The Schwarz Method, Two-level methods.
**Unit IV:** Domain Decomposition Methods with Time-dependent problems. Multilevel and local grid refinement methods.

**Text Books**
Domain Decomposition Methods for Partial Differential Equations, 1999, Alfio Quarteroni and Alberto Valli, Clarendon Press, Oxford.
The Finite Element Method for Elliptic Problem, 1989, P. G. Ciarlet, North-Holland Publishing Company, Newyork.

**Reference Books:**
Domain Decomposition Methods Algorithms and Theory, 2004, A. Toselli and O. Widlund, Springer-Verlag.
Domain Decomposition Methods for the Numerical Solution of Partial Differential Equations, 2008, Tarek P.A. Mathew, Springer-Verlag Berlin Heidelberg.
*Domain Decomposition: Parallel Multilevel Methods for Elliptic Partial Differential Equations,* 1996, B. Smith, P. Bjorstad, W. Gropp, Cambridge.

***AM 631* : *Multigrid Methods***

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|---|---|
| Course Code | **AM 631** |
| Course Name | **Multigrid Methods** |
| L – T – P – C | **03 – 01- 0 – 4 / 03 – 0- 2 – 4** |

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|---|---|
| Offered as (Compulsory / Elective): | ***Elective*** |
| Offered in ( SPRING / AUTUMN ) | ***SPRING*** |
| Offered by (Name of Department/ Centre ) | ***School of Computer Engineering & Mathematical Sciences*** |

CO1: Students will learn the core concepts of multigrid methods with local and global processing.

CO2: Students will learn the convergence analysis and classical and advanced relaxation methods

CO3: Students will learn the grid refinement algorithms and Fourier analysis of the convergence results.

CO4: Students will also learn the anisotropic problems and their practical applications.

Unit I: Basic concepts, local and global processing, discretization, 1D model problem and its direct and iterative solution, convergence analysis.

Unit II: 2D model problem, classical relaxation methods, error-smoothing by relaxation, grid-refinement algorithm, two-grid and multigrid algorithm, Fourier analysis of convergence, ellipticity and h-ellipticity.

Unit III: Classical iterative methods, convergence of classical iterative methods, Richardson iteration method, Krylov subspace methods: Generalized minimal residual (GMRES), Conjugate Gradient (CG), Bi-CG method.

Unit IV: Geometric Multigrid Method: Grid transfer, Prolongation and restriction operators, two-level method, Convergence of coarse grid approximation, Smoothing analysis.

Unit V : Multigrid Cycles: Vcycle, W-cycle, F-cycle, convergence of multigrid cycles, remarks on Computational complexity.

**Pre-requisites:** Good knowledge of Linear Algebra and/or consent from the instructor.

**Text Books:**

A Multigrid Tutorial, 2$^{nd}$ Ed., 2000, E. Henson, and S. F. McCormick, SIAM.
Multigrid, 2001, U. Trottenberg, C. W. Oosterlee, A. Schueller, Academic Press.
Multigrid Methods, 1982, W. Hackbusch and U. Trottenberg, Springer-Verlag, Berlin.
An Introduction to Multigrid Methods, 1992, P. Wesseling, Wiley, Chichester.

**Reference Books:**
Multi-grid Methods and Applications, 1985, W. Hackbusch, Springer, Berlin.
Multi-level Adaptive Solutions to Boundary-Value Problems, 1997, Brandt, Math. Comput, Vol. 31, 333-390.
An Introduction to Multigrid Methods, 2004, R.T. Edwards, Inc.
A Multigrid Tutorial, 2nd Ed., 2000, William L. Briggs, Van Emden Henson, Steve F. McCormick, SIAM.
Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics, 3rd Ed., 2007, Dietrich Braess,

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| Cambridge University Press. |

***AM 632* : *Introduction to Non-Newtonian Fluids***

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| Course Code | **AM 632** |
| Course Name | **Introduction to Non-Newtonian Fluids** |
| L – T – P – C | **03 – 01- 0 – 4 / 03 – 0- 2 - 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

CO1:The applications areas of non-newtonian fluids are broad and this course could help students to apply the theoretical knowledge into the industrial fields

CO2: The thermophysical properties of various nanofluids are utilizes to enhance the convective heat transport process. Thus, this course could help a student to actively apply such fluids according to their application areas.

CO3: The solar power collector, and nuclear waste managements are very well utilized such nanofluids that fulfil their aim. Thus, this course can help to choa perfect applicable fluid in these areas

**Course Contents**

**Kinematics of Fluids Flow:** Introduction, Velocity Gradient Tensor, Rate of Deformation Tensor, Analysis of Strain Rates, Spin Tensor, Curvature-Twist Rate Tensor, Objective Tensors, Balance of Mass.

**Governing Equations:** Introduction, Measure of Mechanical Interactions, Euler‘s Laws of Motion, Stress and Couple Stress Vectors, Stress and Couple Stress Tensors, Cauchy‘s Laws of Motion, Analysis of Stress, Energy Balance Equations, Entropy Inequality.

**Couple Stress Fluids:** Introduction, Constitutive Equations, Equations of Motion, Boundary Conditions, Steady Flow between Parallel Plates, Steady Dimensional Flow between Two Co-axial Cylinders, Poiseuille Flow through Circular Pipes, Creeping Flow Past a Sphere, Some Time- Dependent Flows, Hydromagnetic Channel Flows.

**Micro Fluids:** Introduction, Description of Micro motion, Kinematics of Deformation, Conservation of Mass, Balance of Moments, Micro Inertia Moments, Balance of Energy, Entropy Inequality, Constitutive Equations for Micro Fluids, Linear Theory of Micro Fluids, Equations of Motions.

**Micropolar Fluids:** Introduction, Skew-symmetric of the Gyration Tensor and Micro Isotropy, Micropolar Fluids, Thermodynamics of Micropolar Fluids, Equations of Motion, Boundary and Initial Conditions, Two Limiting Cases, Steady Flow between Parallel Plates, Steady Couette Flow between Two Co-axial Cylinders, Pipe Poiseuille Flow, Micropolar Fluids with Stretch.

**Text Books**

An Introduction to Fluid Dynamics, 1976, R. K. Rathy, Oxford & IBH Publishing.
Theory of Fluids with Microstructure – An Introduction, 1984, Vijay Kumar Stokes, Springer – Verlag

**Reference Books**

| |
|---|
| Micropolar Fluids Theory and Applications, 1999, Grzegorz Lukaszewicz, Birkhauser Boston.<br>Fluid Dynamics, 3rd Ed., 2004, William F. Hughes, John A. Brighton, Tata McGraw- Hill. |

**AM 633** : ***Bio-Mechanics***

| | |
|---|---|
| Course Code | **AM 633** |
| Course Name | ***Bio-Mechanics*** |
| L – T – P – C | **03 – 01- 0 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

CO1: Students will learn the mathematical aspects of the Bio-mechanics and toll for the investigations in blood flow through the arteries and heart.
CO2: Students will learn the mass conservation and energy conservation with the momentum conservation in the blood flow problems
CO3: Students will learn the Rheological properties of bio fluid dynamics concepts
CO4: Students will also learn the transport phenomena and cardiovascular system.

**Course Contents**

Biomechanics, Method of approach, Tools of investigation, Stresses and rates of strain, Constitutive equations, Newtonian viscous fluid, Hookean elastic solid, Viscoelasticity, Biological transport process, Basic momentum, Heat and mass transport concepts. Conservation laws; mass conservation, Momentum conservation, Energy conservation.
Introduction - Continuum Approach - Blood Flow in Heart, Lung, Arteries and Veins: Introduction - The geometry of the circulation system - Field equations and Boundary conditions, Pulsatile Flow in Arteries - Progressive
The Rheological Properties of Blood Bio-fluid dynamics concept, Transport phenomena and the cardiovascular system.
Biofluid mechanics of organ systems, The lungs, The Kidneys and the lever. Micro-circulation, Pressure distribution in micro vessels, Pressure in the intesstitial space, Velocity distribution in micro vessels, The velocity-Hemotocrit relationship, mechanics of flow at very low Reynolds numbers.

**Text Books:**
Biomechanics, 1993, Y.C. Fung, Springer-Verlag.
Bio-fluid Dynamics, 2003, 1$^{st}$ Ed., Clement Kleinstreuer, CRC Press.

**Reference Books:**
Frontier in Mathematical Biology, 1994, S. A. Levin, Part of the book series: Lecture Notes in Biomathematics (LNBM, volume 100).
Biomathematics and Related Computational Problems, 1988, L. M.Ricciardi, Springer.

***AM 635* : *Finite Elements: Theory and Algorithms***

| | |
|---|---|
| Course Code | **AM 635** |

| | | |
|---|---|---|
| Course Name | **Finite Elements: Theory and Algorithms** | |
| L – T – P - C | **03 – 01- 0 – 4** | |
| Offered as (Compulsory / Elective): | | **Elective** |
| Offered in ( SPRING / AUTUMN ) | | **SPRING** |
| Offered by (Name of Department/ Centre ) | | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:

CO1: Students will independently formulate, implement and use various finite element methods for linear and non-linear PDEs and use fundamental PDE in applications.

CO2: Students will solve the systems of equations resulting from a finite element method in a numerically efficient manner.

CO3: Students will derive common error estimates for finite element methods.

CO4: Students will be able to numerically evaluate the efficiency of the finite element method

CO5: Students will show the existence and uniqueness for analytical and numerical solutions to elliptic PDEs.

**Course Contents**

**Unit I :** Review of Lebesgue Integration Theory, Generalized (weak) derivatives, Sobolev norms and associated spaces, inner-product spaces, Hilbert spaces, Trace Theorems

**Unit II :** Variational Formulation of Elliptic Boundary Value Problems, Reisz Representation Theorem, The Lax -Milgram Theorem, Formulation of Symmetric Variational Problems, Formulation of Nonsymmetric Variational Problems.

**Unit III:** Construction of finite element spaces, Triangular finite elements, two- and three- dimensional finite elements, Rectangular Elements, Interpolation

**Unit IV:** Polynomial Approximation Theory, Error Representation, Interpolation Error, Inverse Estimates, A Discrete Sobolev Inequality**.**

**Unit V:** Finite element algorithms and implementation for linear elasticity, Mindlin-Reissner plate problem, Systems in fluid mechanics**.**

**Pre-requisites:** Good knowledge of numerical analysis along with basic programming background and/or consent from the instructor.

**Text Books**

The Finite Element Method for Elliptic Problems, 1978, P. G. Ciarlet, North-Holland,Amsterdam, New York, Oxford.

Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics,2007, 3rd Ed., Dietrich Braess, Cambridge University Press.

Numerical Solution of Partial Differential Equations by the Finite Element Method, 2009, C. Johnson, Dover Publications.

**Reference Books**

The Mathematical Theory of Finite Element Methods, 2008, 3rd Ed., Susanne C. Brenner, Ridgway Scott, Springer-Verlag.

Finite elements: Theory and Algorithms, 2017, Sashikumaar Ganesan, Lutz Tobiska, Cambridge- IISc Series, Cambridge University Press.

***AM 636* : *Cloud Computing***

| | |
|---|---|
| Course Code | **AM 636** |

| | | |
|---|---|---|
| Course Name | ***Cloud Computing*** | |
| L – T – P - C | **03 – 01- 0 – 4** | |
| Offered as (Compulsory / Elective): | | **Elective** |
| Offered in ( SPRING / AUTUMN ) | | **SPRING** |
| Offered by (Name of Department/ Centre ) | | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes**: After completing this course, the students will be able to:

CO1: Articulate the main concepts, key technologies, strengths, limitations of cloud computing and the possible applications for state-of-the-art cloud computing.

CO2: Identify the architecture and infrastructure of cloud computing, including cloud delivery and deployment models.

CO3: Identify problems, analyze, and evaluate various cloud computing solutions.

CO4: Analyze appropriate cloud computing solutions and recommendations according to the applications used.

**Course Contents**

**Unit I:** Context: Shared/distributed memory computing; Data/task parallel computing; Role of Cloud computing.

**Unit II:** Layers in cloud architecture, Software as a Service (SaaS), features of SaaS and benefits, Platform as a Service (PaaS), features of PaaS and benefits, Infrastructure as a Service ( IaaS), features of IaaS and benefits, Service providers, challenges and risks in cloud adoption. Public/Private Clouds; Service-oriented architectures; Mobile, Edge and Fog computing; Multi-clouds.

**Unit III:** Application Design Patterns: Workflow and dataflow; Batch, transactional and continuous; Scaling, locality and speedup; Cloud, Mobile and Internet of Things (IoT) applications.

**Unit IV:** Execution Models: Synchronous/asynchronous patterns; Scale up/Scale out; Data marshalling/unmarshalling; Load balancing; stateful/stateless applications; Performance metrics; Consistency, Availability, and Partitioning (CAP theorem).

**Unit V:** Introduction to Simulator, understanding CloudSim simulator, CloudSim Architecture (User code, CloudSim, GridSim, SimJava) Understanding Working platform for CloudSim

**Text Books**

Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, 2011, Kai Hwang, Jack Dongarra, Geoffrey Fox, Morgan Kaufmann.

Cloud computing a practical approach, 2010, Anthony T. Velde, Toby J. Velte Robert Elsenpeter, TATA McGraw- Hill, New Delhi.

**Reference Books**

Cloud Computing: Web-Based Applications That Change the Way You Work and Collaborate Online, 2008, Michael Miller, Que.

Cloud computing for dummies, 2010, Judith Hurwitz, Robin Bloor, Marcia Kaufman, Fern Halper, Wiley Publishing, Inc.

Cloud Computing (Principles and Paradigms), 2011, Edited by Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley & Sons, Inc.

***AM 640* : *AI for Medical Image Analysis***

| | |
|---|---|
| Course Code | **AM 640** |
| Course Name | ***AI for Medical Image Analysis*** |

| | | |
|---|---|---|
| L – T – P - C | **03 – 0- 2 - 4** | |
| Offered as (Compulsory / Elective): | | **Elective** |
| Offered in ( SPRING / AUTUMN ) | | **SPRING** |
| Offered by (Name of Department/ Centre ) | | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:
CO1: Understand medical different medical imaging modalities
CO2: Learn the feature extraction schemes specific to imaging modalities
CO3: Design the applications in line with the requirement of medical imaging
CO4: Handling the intricacies of medical data and how to address the,
CO5: Propose and develop an AI solution in Medical Imaging using Open-source datasets and custom datasets

**Course Contents**

Unit I: Introduction to Medical Imaging and AI-Overview of medical imaging modalities, Enhancement-Fundamental Enhancement Techniques, Adaptive Image Filtering, Enhancement by Multiscale Non-linear operators, medical image enhancement with Hybrid filters
Unit II: Introduction to machine learning and deep learning for medical imaging, Applications of AI in medical imaging.
Unit III: Medical Image Segmentation- Principles and Basic Techniques-Segmentation Strategies, Data Knowledge. Image segmentation by fuzzy clustering, Segmentation with Neural Networks.
Unit IV: Active Contours and Surfaces- Explicit Active Contours and Surfaces, The levels set model
Unit V: Medical Image Classification and Diagnosis, Classification methods for different imaging modalities, Diagnosis using deep learning models, Evaluation metrics for classification and diagnosis algorithms.

**Text Books**

Handbook of Medical Imaging-Processing and Analysis, $2^{nd}$ Ed., 2008, Issac N Bankman, Academic Press.
Guide to Medical image Analysis, 2012, Klaus D. Toennies, Springer-Verlag London.

**Reference Books**

Deep Learning for Medical Image Analysis, 2017, S. Kevin Zhou, Hayit Greenspan, Academic Press.
Computer Vision: Algorithms and Applications, $2^{nd}$ Ed., 2022, Richard Szeliski, Springer.

***AM 642* : *Computer Vision with Pattern Recognition***

| | | |
|---|---|---|
| Course Code | **AM 642** | |
| Course Name | ***Computer Vision with Pattern Recognition*** | |
| L – T – P - C | **03 – 0- 2 – 4** | |
| Offered as (Compulsory / Elective): | | **Elective** |
| Offered in ( SPRING / AUTUMN ) | | **SPRING** |
| Offered by (Name of Department/ Centre ) | | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:

| |
|---|
| CO1: Understand the concepts of computer vision with conventional feature engineering<br>CO2: Learn the different standard architectures of object detection and classification<br>CO3: Perform segmentation algorithms in different domains<br>CO4: Create the datasets and gets an overview of annotation<br>CO5: Apply the learned concepts to real world problems in the area of medical imaging, automation, self-driving cars, etc. |
| **Course Contents** |
| Unit I: Introduction and Overview: Course Overview and Motivation; Introduction to Image Formation, Capture and Representation; Linear Filtering, Correlation, Convolution.<br><br>Unit II: Visual Features and Representations: Edge, Blobs, Corner Detection; Scale Space and Scale Selection; SIFT, SURF; HoG, LBP, etc.<br><br>Unit III: Visual Matching: Bag-of-words, VLAD; RANSAC, Hough transform; Pyramid Matching; Optical Flow.<br><br>Unit IV: Convolutions Neural Networks: Evolution of CNN Architectures: Alexnet, ZFNet, VGG, InceptionNets, ResNets, DenseNets: Recurrent Neural Networks-Review of RNNs; CNN + RNN Models for Video Understanding: Spatio-temporal Models, Action/Activity Recognition.<br><br>Unit V: Recent Trends: Zero-shot, One-shot, Few-shot Learning; Self-supervised Learning; Reinforcement Learning in Vision; Other Recent Topics and Applications. |
| **Text Books** |
| Computer Vision: Algorithms and Applications, 2$^{nd}$ Ed., 2022, Richard Szeliski, Springer.<br>Digital Image Processing, 4$^{th}$ Ed., 2017, Rafael C Gonzalez, Richard E Woods, Pearson. |
| **Reference Books** |
| Computer Vision: Models, Learning, and Inferences, 2012, 1$^{st}$ Ed., Simon J D Prince, Cambridge University.<br>Christopher M. Pattern Recognition and Machine Learning, 2006, Bishop, Springer.<br>Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press. |

***PGC-602* : *Audit Course***

| | |
|---|---|
| Course Code | **PGC-602** |
| Course Name | **Audit Course** |
| L – T – P - C | **2 – 0- 0 – 0** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **PGC/All Departments DIAT** |

| |
|---|
| Unit I: English for Research Paper Writing<br>Unit II: Disaster Management<br>Unit II: Sanskrit for Technical Knowledge<br>Unit IV: Value Education<br>Unit V: Constitution of India<br>Unit VI: Pedagogy Studies<br>Unit VII: Stress Management by Yoga<br>Unit VIII: Personality Development through Life Enlightenment Skills |

**M.Tech (Data Science)**

**Institute Vision**

To be a centre of Excellence of international repute for Education, Training and research in Advanced Technologies with a view to strengthen national security and self-reliance.

**Institute Mission**

To evolve as an Innovative Unique Research University to develop indigenous contemporary Defence related technologies in Navigation Systems, Wireless Sensors, Efficient Propulsion Systems, Weapon Systems for DRDO and Defence Services, provide technological solutions to the Services to optimize combat battlefield effectiveness and above all produce qualified quality manpower which can truly become an instrument for building a strong indigenous technology base in the context of creating a performing Defence Industrial Base in India.

**School Vision**

To be a Center of Excellence of International repute to provide high-quality education, research, and training in the area of Modelling & Simulation (M&S), Data Science (DS), Cyber Security (CS) and Artificial Intelligence (AI) to promote innovation and entrepreneurship skills among the students with a view to strengthen national security and self-reliance.

**School Mission**

The School of Computer Engineering and Mathematical Sciences is committed to providing quality education, research, and service that promotes the development of critical thinking, problem-solving, and innovation in the fields of computer engineering and mathematical sciences. Our mission is to:

| | |
|---|---|
| M1: | To build strong education, teaching and research environment in the field of Modelling & Simulation (M&S), Data Science (DS), Cyber Security (CS) and Artificial Intelligence (AI) to meet requirements from Defence, specially related to national security. |
| M2: | To strive for continuous learning, innovation, entrepreneurship and quality research culture amongst the student community through effective government, industry & academia collaboration. |
| M3: | To encourage ethics, team work and technological leadership skills among students to solve complex engineering problems collaboratively by imparting strong theoretical foundation complemented with extensive practical training. |
| M4: | Engage with industry, government, DRDO, Tri-services and PSUs to transfer knowledge and technology, and to contribute to the social and economic development of our region and beyond. |

# M.Tech. in Data Science

**Introduction:** The School of Computer Engineering and Mathematical Sciences was formed by the merger of the Department of Applied Mathematics and the Department of Computer Science & Engineering in 2022. Prior to this merger, **M. Tech. (Modelling & Simulation) programme and M.Tech (Data Science) programme were offered under the Department of Applied Mathematics**. The Department of Applied Mathematics came into existence with the inception of Institute of Armament Studies in 1953 as Faculty of Applied Mathematics. The faculty constituted of three departments: (1) Applied Mathematics (2) Ballistics (3) Statistics. In 1991 the three departments merged into one and named it as Department of Applied Mathematics.

The faculty of School of Computer Engineering and Mathematical Sciences has been actively involved in the research in different fields of applied mathematics such as ballistics, flight dynamics, hydro-dynamics, hydro-ballistics, Numerical Methods and Optimization, Statistics, Probability, Neural Network, Fuzzy Logic and Genetic Algorithm, Parallel Computing, Cryptography and Machine Learning, Deep Learning, IoT, Cyber Security, Computer Networks etc.

This MTech. (Data Sciences) programme is of two years duration where the student undergoes basic training in the subjects(Core and Elective) related to **probability and statistics, inference, regression, optimization, statistical simulation and data analysis, sampling theory (Math and Statistics); management decision analysis, decision models, programming, algorithms, operating systems, databases, signal processing, image processing, machine learning and data mining techniques of data science (CS, EE). Information Theory (information, entropy, conditional information, coding), ANN, SVM, Projection pursuit Artificial Intelligence and DSS** through classroom teaching in the first and second year. During this period the student is also exposed to various simulation tools and practical. The second year is the dissertation phase where the student works under the guidance of a recognized guide on a problem related to Data Science. Course curriculum will be updated periodically to keep pace with contemporary technological advancement.

**Program Outcomes (POs) :**

| | |
|---|---|
| PO1: | Apply mathematical principles for data analysis and visualization for analysing and processing the data. |
| PO2: | Ability to carry out research and development for solving real world problems using data science tools and techniques. |
| PO3: | Ability to work with industry, government, DRDO, Tri-services and PSUs to contribute to the social and economic development by using their expertise in Data Science. |

**Why Data Science:** Data science is concerned with the acquisition, storage, retrieval, processing and finally the conversion of data into knowledge where the quantum of data is very large. Experiments, observations, and numerical simulations in many areas of science and business are currently generating terabytes ($2^{40}$ bytes) of data, and in some cases are on the verge of generating petabytes ($2^{50}$ bytes) and beyond**.** Today we have been witnessing to an exponential growth of the volume of data produced and stored. This can be explained by the evolution of the technology that results in the proliferation of data with different formats from the most various domains (e.g., health care, banking, government or logistics) and sources (e.g., sensors, social networks or mobile devices). Facebook, for example, has an average of

4.75 billion pieces of content shared among friends every day. Business is generating enormous quantities of data that are too big to be processed and analyzed by the traditional Relational Database Management Systems (RDBMSs) and Data Warehouses (DWs) technologies, which are struggling to meet the performance and scalability requirements. Therefore, in the recent years, a new approach that aims to mitigate these limitations has emerged. Companies like Facebook, Google, Yahoo and Amazon etc. are the pioneers in creating solutions as well as recruiting technologies to deal with these "Big Data" scenarios. Adopting Big Data-based technologies not only mitigates the problems presented above, but also opens new perspectives that allow extracting value from Big Data. Big Data-based technologies are being applied with success in multiple scenarios like in: (1) e-commerce and marketing, the crowds do on the web allow identifying trends that improve campaigns, evaluate personal profiles of a user, so that the content shown is the one he will most likely enjoy; (2) government and public health, allowing the detection and tracking of disease outbreaks via social media or detect frauds; (3) transportation, industry and surveillance, with real-time improved estimated times of arrival and smart use of resources.

Data science is concerned with the acquisition, storage, retrieval, processing and finally the conversion of data into knowledge where the quantum of data is very large. Two current disciplines that have strong overlap with data science are computer science and statistics. An important difference between Data Science and Computer Science is that Data science heavily uses the more continuous aspects of mathematics together with considerable statistics. In order to handle voluminous data (ranging from terabytes to petabytes) in various forms (structured, semi-structured, unstructured formats and from different sources) of different Veracity (managing the reliability and predictability of inherently imprecise data types will be challenging) and its complexity (relationships, hierarchies, and multiple data linkages will have to be connected and correlated), a systematic approach is required before meaningful output expected from the data collected or received.

Basic four steps which are adapted in Data Science are:

- **Data Collection:** Proliferation of smart devices, sensors, web, mobile and social media has led to explosive amount of complex data. To make use of this data, one needs expertise in Internet of Things and Databases to effectively collect and manage such huge volumes of data.
- **Data Processing:** The next step is to convert the raw data into forms that can be scientifically analyzed, which includes data cleaning and transformation. For example, by transforming social network data into graph data, one can use concepts from Graph Theory to analyze social network data. To process huge volumes of data, one needs expertise in Databases, High Performance Computing and mainly Statistics. The data one needs to handle is a heterogeneous mix of different types of data, such as images, videos, text, social networks, etc. To handle these different types of data one needs expertise in areas such as Image and Video Analytics, Information Retrieval, Social Media Analytics, etc.
- **Data Analysis:** The third step is to analyze the processed data using various Statistical, Data Mining and Machine Learning algorithms. Most of the existing data analysis algorithms do not scale to large datasets. As a result, one needs expertise in Statistics, Data Mining and High-Performance Computing to design systems that can efficiently analyze large volumes of complex data.
- **Data Product:** The final step is to make decisions from the data analysis and also deliver the analyzed information to the world in the form of various data products. This is often done using data visualization techniques, which are integrated with various smart devices. This step requires expertise in Information Visualization, Databases and Computer Networks.

Two current disciplines that have strong overlap with data science are computer science and statistics. An important difference between Data Science and Computer Science is that Data science heavily uses the more continuous aspects of mathematics together with considerable statistics. Data Science is the combination of statistics, mathematics, programming, problem-solving, capturing data in ingenious ways, the ability to look at things differently, and the activity of cleansing, preparing and aligning the data.

## Eligibility Criteria for Admission to join in this programme

| | |
|---|---|
| M. Tech<br>Data Sciences | The candidate must have a Valid GATE Score and marks / CPI (Cumulative Performance Index), referred to in subsequent section, implies a minimum of 55% marks/SPI of 5.5 (on a 10-point scale) as long as it is at least seven percent higher than the minimum pass marks/CPI from a recognized Institute / University in<br>B. Tech / BE degree<br>OR<br>MSc / MS degree in CS / IT / Mathematics/ Statistics / Physics / Electronics<br>Provided<br>1) Mathematics is one of the subject at the graduate level and<br>2) Knowledge in computer programming is desirable<br>3) Valid GATE Score in CSE / IT / ECE / ME / AE / CE / EE / IN / MA / ST |

CSE - Computer Science Engineering
IT - Information Technology
AE - Aerospace Engineering
ECE - Electronics & Communication Engineering
ME - Mechanical Engineering
CE – Civil Engineering
EE – Electrical Engineering
IN – Instrumentation Engineering
MA- Mathematics
ST- Statistics

**Semester I:**

| Sl. No. | Course Code | Course Name | Contact hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T /P | |
| 1. | AM 603 | Optimization Techniques | 3 | 1 | 4 |
| 2. | AM 604 | Advanced Statistical Techniques | 3 | 1 | 4 |
| 3. | AM 605 | Linear Algebra and Applications | 3 | 1 | 4 |
| 4. | AM 608 | Data Structures and Algorithms | 3 | 1 | 4 |
| 5. | AM 609 | Data Science: Tools and Techniques | 3 | 1 | 4 |
| 6. | AM 610 | Data Analysis and Visualization | 3 | 1 | 4 |
| 7. | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | TOTAL | 20 | 6 | 26 |

**Semester II:**

| Sl. No. | Course Code | Course Name | Contact hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T / P | |
| 1. | AM 623 | Machine Learning | 3 | 1 | 4 |
| 2. | AM 624 | Big Data Analytics | 3 | 1 | 4 |
| 3. | | Elective I (School Elective) | 3 | 1 | 4 |
| 4. | | Elective II (School Elective) | 3 | 1 | 4 |
| 5. | | Elective III | 3 | 1 | 4 |
| 6. | | Elective IV | 3 | 1 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| 7. | PGC-602 | Audit Course | 2 | 0 | 0 |
| | | TOTAL | 20 | 6 | 24 |

**Semester III:**

| Sl. No. | Course Code | Course Name | Contact hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T / P | |
| 1. | AM 651 | M. Tech Dissertation - 1 | 28** | | 14 |
| | | TOTAL | 28 | | 14 |

**Semester IV:**

| Sl. No. | Course Code | Course Name | Contact hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T / P | |
| 8. | AM 652 | M. Tech Dissertation - 2 | 28** | | 14 |
| | | TOTAL | 28 | | 14 |

****Contact Hours / week:-**

- ✓ **One credit in Lecture – L (Theory) / Tutorial (T) mean one contact hour and**
- ✓ **One credit in Practical (P)(Lab session) / Thesis mean Two contact hours)**

**<u>List of Electives are given below</u>:**

Few of the elective courses are listed below. However, Students are allowed to choose Elective Course(s) from various M. Tech programmes offering by the respective departments which are as per the DIAT PG Course of Study Book / updates of the course curriculum time to time.

| Sl. No. | Course Code | Course |
|---|---|---|
| | AM 625 | Image and Video Analytics |
| | AM 627 | Information Theory and Coding |
| | AM 628 | Computational Number Theory and Cryptography |
| | AM 635 | Finite Elements: Theory and Algorithms |
| | AM 636 | Cloud Computing |
| | AM 637 | Generative AI |
| | AM 638 | Reinforcement Learning |
| | AM 639 | Deep Learning for Computer Vision |
| | AM 640 | AI for Medical Image Analysis |
| | AM 641 | Accelerated Computing |
| | AM 642 | Computer Vision with Pattern Recognition |
| | AM 643 | Database Systems |
| | CE 631 | Deep Learning |
| | CE 632 | Computer Vision |
| | CE 691 | Secure Wireless Sensor Networks |
| | CE 699 | Internet of things |

*AM 603* **:** *Optimization Techniques*

| | |
|---|---|
| Course Code | **AM 603** |
| Course Name | **Optimization Techniques** |
| L – T – P – C | **03 – 01 - 0 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:** After completing this course, the students will be able to:
CO1: Understand the application of various optimization techniques that can help to make decisions for practical problems in industries and apply basic concepts of mathematics to formulate an optimization problem.
CO2: Understand the importance of optimization of industrial process management with the theory of optimization methods and algorithms developed for solving various types of optimization problems.
CO3: Analyze and appreciate the variety of performance measures for various optimization problems such as Sensitivity analysis, Risk analysis and Portfolio Management, etc.
CO4: Implement, develop and promote research interest in applying optimization techniques in problems of Engineering and Technology. And the mathematical results and numerical techniques of optimization theory to concrete Engineering problems.

**Course Contents**

**Linear programming:** Simplex method, Two-phase method, Big-M method, Duality, Integer linear Programming, Dynamic Programming, Sensitivity analysis.
**Assignment problem:** Hungarian's algorithm, Degeneracy, applications, unbalanced problems, traveling salesman problem.
**Classical optimization techniques:** Single variable optimization with and without constraints, multi–variable optimization without constraints, multi–variable optimization with constraints – method of Penalty methods Lagrange multipliers, Kuhn-Tucker conditions.
**Numerical methods for optimization:** Minimization and maximization of convex functions- Local & Global optimum- Convergence-Speed of convergence. One dimensional minimization - Elimination methods: Fibonacci & Golden section search - Gradient methods - Steepest descent method, Nelder Mead's Simplex search method, methods of line search; Quasi-Newton methods: DFP, BFGS.
**CPM/PERT:** Simulation of CPM/PERT network, Analysis of an activity network, Simulation of inventory system and manufacturing system.

**Text Books**

Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
Engineering Optimization: Theory and Practice, 4th Ed., 2009, S.S. Rao, Wieley Eastern Ltd.
Optimization: Theory and Practice, 2004, MC Joshi, KM Moudgalya, Narosa.

**Reference Books**

Mathematical Programming Techniques, 3rd Ed., 1991, N. S. Kambo, East-West Press, New Delhi.
An Introduction to Optimization, 2nd Ed., 2001, Chong, E. k. and Zak, S. H., Wiley India.
Linear and Nonlinear Programming, 3rd Ed., 2008, Luenberger, D. G. and Ye, Y., Springer.
Mathematical Programming Techniques, 1997, Kambo, N.S., East-West Press.
Introduction to Optimization, 1988, Beale, John Wiley.

| |
|---|
| Numerical Methods and Optimization, Hari Arora, S.K. Kataria & Sons<br>Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer<br>Nonlinear Programming Theory and Algorithms, 1979, Bazarra M.S., Sherali H.D. & Shetty C.M., John Wiley, New York. |

***AM 604* : *Advanced Statistical Techniques***

| | |
|---|---|
| Course Code | **AM 604** |
| Course Name | **Advanced Statistical Techniques** |
| L – T – P – C | **03 – 01- 0 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:** After completing this course, the students will be able to:

CO1: Understand the fundamental concepts of probability and statistics such as Axioms, addition law, conditional probability, Baye's principle etc., and their real-life application to predict the data.

CO2: Understand the importance of Probability Distributions such as Binomial, Poisson, Normal and Exponential Distributions and their properties and problems on special probability distributions.

CO3: Analyze and appreciate the statistical theory behind Curve fitting, regression modeling and Chi Square Test, student test & Fisherman test.

CO4: Understand the theory behind Design and Analysis of Experiments: Need for conducting Experiments, and their possible applications.

**Course Contents**

**Probability Theory:** Sample Spaces- Events - Axioms – Counting - Conditional Probability and Bayes' Theorem – The Binomial Theorem – Random variable and distributions: Mean and Variance of a Random Variable-Binomial-Poisson-Exponential and Normal distributions.

**Sampling Distributions & Descriptive Statistics**: The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Sampling distributions (Chi-Square, t, F, z). Test of Hypothesis- Testing for Attributes –Mean of Normal Population – One-tailed and two-tailed tests, F-test and Chi-Square test - - Analysis of variance ANOVA – One way and two-way classifications.

**Introduction to Statistical modelling.**

**Regression modeling for Normal response and quantitative explanatory**: Introduction to Statistical modelling, Variables, Simple and Multiple regressions, Model building and validation Comparison of regressions.

**Stochastic process**: Basic idea of random processes, Stationary, Markov processes, Markov chains and applications, Introduction to ergodicity.

**Introduction to R- Packages**: Scientific Calculator- Inspecting Variables- Vectors Matrices and Arrays- Lists and Data Frames- Functions- Strings and Factors-Flow Control and Loops- Advanced Looping- Date and Times.

**Text Books**

Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd.

Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.

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| An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd. |
| **Reference Books** |
| All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer.<br>Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press.<br>Schaum's outlines Probability and statistics, 4th Ed., 2013, Murray R. Speigel, John Schiller, R Alu Srinivasan, Tata McGraw Hill<br>Learning R, O'Reilly, 2013, Richard Cotton.<br>Introductory statistics with R, 2008, Dalgaard, Peter Springer Science & Business Media.<br>A Handbook of Statistical Analysis Using R, Second Edition LLC, 2014, Brain S. Everitt.<br>Introduction to Probability and Statistics for Engineers and Scientists", 4th Ed., 2009, Sheldon M. Ross, Academic Press.<br>R Cookbook, O'Reilly, 2011, Paul Teetor. |

## *AM 605 : Linear Algebra and Applications*

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|---|---|
| Course Code | **AM 605** |
| Course Name | **Linear Algebra and Applications** |
| L – T – P - C | **03 – 01- 0 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:
CO1: Students will build the fundamentals of linear algebra
CO2: Students appreciate the applications of different matrix decomposition methods
CO3: Students can correlate the related applications of linear algebra
CO4: Students should be in a position to formulate the relevant real-world problems using the understanding of linear algebra

**Course Contents**

**Unit I:** Introduction to Fundamental Linear Algebra Problems and Their Importance, Linear Transformations, Linear Variety, Range Space and Rank, Null Space and Nullity, Homomorphism, Matrix of Linear Transformations, Matrix Representation of a linear transformation, Structure of the solutions of the matrix equation Ax = b, Change of bases.

**Unit II:** Matrix and vector norms, floating points arithmetic, forward and backward stability of algorithms, conditioning of a problem, perturbation analysis, solving linear systems, Gaussian elimination, LU factorization, Pivoting, Cholesky decomposition, Iterative refinement, QR factorization, Gram-Schmidt orthogonalization, Projections, Householder reflectors, Givens rotation.

**Unit III:** Singular Value Decomposition, Rank and matrix approximations, image compression using SVD, Least squares and least norm solution of linear systems, pseudoinverse, normal equations, Eigenvalue problems, Gershgorin theorem, Similarity transform, Eigenvalue & eigenvector computations and sensitivity, Power method, Schur decomposition, QR iteration with & without shifts, Hessenberg transformation, Rayleigh quotient, Symmetric eigenvalue problem, Computing the Singular Value Decomposition,Golub-Kahan-Reinsch algorithm, Chan SVD algorithm, Krylov subspace methods: Lanczos, Arnoldi, MINRES, GMRES, Conjugate Gradient.

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| **Text Books** |
| Iterative Methods for Sparse Linear Systems, 2nd Ed., 2003, Y. Saad, SIAM.<br>Introduction to Linear Algebra, 6th Ed., 2023, Gilbert Strang, Wellesley-Cambridge Press. |
| **Reference Books** |
| Fundamentals of Matrix Computations, 2nd Ed,. 2002, D. S. Watkins, John-Wiley.<br>Numerical Linear Algebra and Applications, 2nd Ed., 2010, B. N. Datta, SIAM.<br>Applied Numerical Linear Algebra, 1997, J. W. Demmel, SIAM.<br>An Introduction to numerical linear algebra, 1994, C. G. Cullen, Charles PWS Publishing.<br>Linear Algebra and its Applications, 2013, C. Lay David, Pearson.<br>Matrix Computation, 1996, G. Golub, C. F. Van Loan, John Hopkins |

## *AM 608* **:** *Data Structures and Algorithms*

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|---|---|
| Course Code | **AM 608** |
| Course Name | **Data Structures and Algorithms** |
| L – T – P – C | **03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in (SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:** After completing this course, the students will be able to:

CO1 Learn the programming language and get in-depth knowledge of Data structures, and their applications in real world.

CO2 Learn in estimating the complexity of algorithms in terms of space, time and memory.

CO3 Solve problems using sorting, searching, and shortest path finding algorithms and also do the complexity analysis of these algorithms.

CO4: Apply Algorithm for solving problems like sorting, searching, insertion and deletion of data.

**Course Contents**

**Preliminaries:** Concept & notation, common operation on data structures, algorithm complexity, time space trade-off between algorithm, physical & logical representation of different data structures. Arrays: Arrays defined, representing arrays in memory, Various operation (traversal, insertion, deletion), Multidimensional arrays, Sequential allocation, Address calculation, Sparse arrays. List: Simple Array Implementation of Lists, Linked Lists, Doubly Linked Lists, Circularly Linked list. Stack: Stack Model, Implementation of Stacks, Applications of Stacks.

**Queue:** Queue Model, Array Implementation of Queues, Applications of Queues. Trees: Implementation Of Trees, Tree Traversal with an application, Binary Trees-Implementation, Expression trees, Binary Search Tree, Binary Search Trees, Various Operations On BST- Make Empty, Find, Find Min and Find Max, Insert, Delete, Average-Case Analysis, AVL Trees- Single Rotation, Double Rotation, B-trees. Hashing: Definition, Hash Function, Separate Chaining, Open Addressing- Linear Probing, Quadratic Probing, Double Hashing, Rehashing, Extendible Hashing.

**Priority Queues**: Model, Simple Implementation, Binary Heap-Structure Property, Heap Order Property,

Basic Heap Operation, Application of Priority Queues- The Selection Problem, Event Simulation, Heap Sorting: Preliminaries, Insertion Sort- Algorithm, Analysis of Insertion Sort, Shell sort- Analysis Of Shell sort, Heapsort- Analysis of Heapsort, Merge sort- Analysis of Merge sort, Quicksort- Picking the Pivot, Partitioning Strategy, Small Arrays, Analysis of Quicksort, Bucket Sort.
**Graphs:** Definitions, Representation of Graphs, Topological Sort, Shortest Path Algorithms- Unweighted Shortest Paths, Dijkstra's Algorithm, Graph with Negative Edge Costs, Acyclic Graphs, All- Pairs Shortest, Minimal Spanning Tree- Prim's Algorithm, Kruskal's Algorithm, Application of Depth First Search- Undirected Graphs, Biconnectivity, Euler Circuits, Directed Graphs. Algorithm Design Techniques: Greedy Algorithms- A Simple Scheduling Problem, Huffman Codes, Divide and Conquer Running Time of Divide and Conquer Algorithms, Closets-Points Problem, The Selection Problem

**Text Books**

1. Introduction to Algorithms, 4th Ed., 2022, Thomas H. Cormen, Charles E. Leiserson, The MIT Press.
2. Data Structures and Algorithms in Java, 4th Ed., 2004, M. Goodrich, R. Tamassia, John Wiley and Sons, Inc.

**Reference Books**

An Introduction to Data Structures with Applications, 1986, Jean Paul Tremblay, Paul G. Sorenson, Tata McGraw Hill.
Data Structures & Program Design, 1st Ed., 1998, Robert L. Kruse, Pearson.

## *AM 609* : *Data Science: Tools and Techniques*

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|---|---|
| Course Code | **AM 609** |
| Course Name | **Data Science: Tools and Techniques** |
| L – T – P - C | **3-0- 2-4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:** After completing this course, the students will be able to:
CO1: Understand the fundamental concepts of data science and terminology.
CO2: Understand the fundamental concepts of data science process and machine learning concepts.
CO3: Understand the fundamental concepts of tools used in data science.
CO4: Fundamental concepts of large data & Data Visualization.
CO5: To implement the aspects of Data Science through case studies.

**Programming Language:** Introduction to Python, Programming Interfaces, Spyder, Python script file, Print Message to Standard Output, variables and data types, Reading Input from console, Type Conversion, Arithmetic Operators and Conditions
**Control Flow -** Relational Operators, if…else statement, if…else if…else statement, Logical operators, While Loops, break and continue statement, Loops with else statement, pass statement, Python for loop, Range Function, **Lists:** Creating List, Accessing elements from List, Inserting and Deleting Elements from List, List Slicing, Joining two list, Repeating sequence, Nested List, Built-in List Methods and Functions, Searching elements in List, Sorting elements of List
**Python Data Structures:** Python Set, Creating Set, Adding/Removing elements to/from set, Python Set

**Operations**: Union, Intersection, Difference and Symmetric Difference, Python Tuple, Creating Tuple, Understanding Difference between Tuple and List, Accessing Elements in Tuple, Python Dictionary, Creating Dictionary, Accessing / Changing / Deleting Elements in Dictionary

**Data Pre-processing Numpy, Dask, Xarray:** Numpy**,** Creating Numpy array, Numpy data type, Accessing Elements in Numpy, Element wise calculations, Vectorized Operation, Numpy Subsetting, Built-in Methods of Numpy, Array creation Methods: arange, linspace, eye, Numpy 2D Array, 2D Array Indexing, Matrix Calculations , Dask, Parallel computing with Dask, Xarray integration with Dask

**Pandas:** Reading Files, Writing Files, Loading Data with Pandas, Selecting Specific Columns, Selecting rows using labels: loc, Selecting rows using position: iloc, Adding and Removing rows and Columns, Filtering Data Frames, Importing Data from csv Files, Missing Data Handling, OnHot Encoder, Label Encoding, Data Splitting, Training Data, Importance of Test Data.

**Built-in Dictionary Methods and Functions:** Data Analytics**,** Data preprocessing, Analyzing data, Handling missing data, Applying Machine learning techniques to analyze data

**Functions:** Defining Functions in Python, Function Argument, Single Parameter Functions, Function Returning single Values, Functions with multiple parameters, Function that return Multiple Values, Functions with Default arguments, Named arguments, Scope and Lifetime of Variables, Global specifier

**Data Visulization with MatplotLib, Seaborn:** Introduction to Matplotlib, Basic Plotting with Matplotlib, Line Plot on Example DataSet, Exploring the plot Options, Other types of Plots, Bar Plot, Pie Plot, Histograms

**Regression for data analysis:** Introduction to regression and Classification, Types of Classification, Simple Linear regression Intuition, Sci kit Learn Library, Hands on Lab on Simple Linear Regression, Performance Evaluation

**Regression and Classification Part 2:** Multivariable Linear regression, Handson Example on Multivariable LR, Performance Evaluation, Improving the Performance, Backward Elimination method, Other types of Regression Models, Performance Evaluation of different Regression Models

**Classification in Machine Learning :** Classification Introduction, K-Nearest Neighbours, Decision Tress, Naïve Bayes algorithm, Introduction to Neural Networks

**Text Books**

Mastering Python for Data Science, 2015, Samir Madhavan, Packt Publishing.
Python Machine Learning, 2015, Sebastian Raschka Packt Publishing.
Python Basics: A Self-Teaching Introduction, 2018, H. Bhasin, Mercury Learning and Information.
Beginning Python, 2008, Magnus Lie Hetland, Apress Berkeley, CA.

**Reference Books**

Michael Roberts Beginning Python, 2005, Peter Norton, Alex Samuel, David Aitel, Eric Foster-Johnson, Leonard Richardson, Jason Diamond, Aleatha Parker,Wiley Publishing.
Expert Python Programming: Best practices for designing, coding, and distributing your Python software Tarek Ziadé, 2008, Packt Publishing.
Programming Python, 2010, Mark Lutz, O'Reilly Media.
Programming in Python 3: A Complete Introduction to the Python Language, 2010, Mark Summerfield, Addison-Wesley.
Practical programming: An introduction to computer science using Python, 2009, Jennifer Campbell, Paul Gries, Jason Montojo, Greg Wilson, Pragmatic Bookshelf.

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| Core Python Programming, 2nd Ed., 2006, Wesley Chun, Prentice Hall.<br>Core Python Applications Programming, 2012, Wesley J Chun, Prentice Hall.<br>Programming Computer Vision with Python: Tools and algorithms for analyzing images, 2012, Jan Erik Solem, O'Reilly Media. |

### *AM 610* : *Data Analysis and Visualization*

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|---|---|
| Course Code | **AM 610** |
| Course Name | **Data Analysis and Visualization** |
| L – T – P - C | **03 – 01- 0 – 4 / 03 – 0- 2 - 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:
CO1: Understand the concepts of Data Analytics and Data Types.
CO2: Learn different hypothesis testing techniques and data transformation techniques.
CO3 Perform feature scaling, anomaly detection and augmentation on data.
CO4: Handle large scale analytics from various domains.
CO5: Apply cluster analysis for decision support systems.

**Course Contents**

**Unit I :** Introduction to data analytics, Data Types, Feature Engineering, Data Pipelines, Preliminary Data Analysis, DA: exploratory data analysis, bar chart, histogram, box plot, scatter plot, heat map and contour map, parallel coordinates, radar plot.
**Unit II:** Data pre-processing, data representation, machine learning for data processing, visualization pipeline, vector field visualization, applications to biological and medical data, visualization toolkit, linear models.
**Unit III**: Data Cleaning and Transformation, Handling Missing Values, mean/median, kNN, model-driven imputation, Transforming feature types and feature values, OHE: one hot encoding, normalization, log-transform.
**Unit IV:** Feature scaling, Anomaly detection, data augmentation, high-leverage points, collinearity, high dimensions, Curse of dimensionality, intelligibility, computational efficiency, distance functions, principal components, clustering, multidimensional scaling, information visualization.
**Unit V:** Introduction to Cluster Analysis, Classification and Regression Trees (CART).

**Text Books**

1.Python for data analysis: Data wrangling with Pandas, NumPy, and IPython, 2012, W. McKinney, O'Reilly Media, Inc.

**Reference Books**

Information Visualization: Perception for Design, 2nd Ed., 2004, C. Ware, Morgan Kaufmann.
A Byte of Python: Python Tutorial, 2003, C. H. Swaroop.
Business Statistics for Contemporary Decision Making, 4th Ed., 2003, Ken Black, John Wiley & Sons, Inc.
Statistics for Business and Economics : Cengage Learning, 13th Ed., 2011, Anderson Sweeney Williams.

Applied Statistics & Probability for Engineering, 2002, Douglas C. Montgomery, George C. Runger, John Wiley & Sons, Inc.
Probability and Statistics for Engineering and the Sciences : Cengage Learning, 2011, Jay L. Devore.
Applied logistic regression (Wiley Series in probability and statistics), 2000, David W. Hosmer, Stanley Lemeshow, Wiley-Interscience Publication.
Data Mining: Concepts and Techniques, 3rd Ed., 2006, Jiawei Han and Micheline Kamber.
Finding Groups in Data: An Introduction to Cluster Analysis, 1990, Leonard Kaufman, Peter J. Rousseeuw, John Wiley & Sons, Inc.
. Data Pipelines Pocket Reference: Moving and Processing Data for Analytics, 2021, James Densmore. O'Reilly.
. Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems, 2017, Martin K, O'Reilly.
. Visualization Handbook, 2004, C .D. Hansen, C. R. Johnson, Academic Press, 2004.

## *PGC-601* : *Research Methodology and IPR*

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|---|---|
| Course Code | **PGC-601** |
| Course Name | **Research Methodology and IPR** |
| L – T – P - C | **2 – 0- 0 – 2** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **AUTUMN** |
| Offered by (Name of Department/ Centre ) | **PGC/All Departments DIAT** |

Course Outcomes: After completing this course, the students will be able to:
CO1: Understanding the fundamentals of research and its methodology
CO2: Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO3: Knowledge of manuscript preparation, patents and Intellectual property
CO4: Technology transfer and application of IPR in various domains.

**Course Contents**

**Unit I** : Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

**Unit II** : Effective literature studies approaches, analysis Plagiarism, Research ethics,

**Unit III :** Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

**Unit IV :** Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

**Unit V** : Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications

**Unit VI** : New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

| Texts / References |
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| Research methodology: an introduction for science & engineering students, Stuart Melville and Wayne Goddard.<br>Research Methodology: An Introduction, Wayne Goddard and Stuart Melville.<br>Research Methodology: A Step-by-Step Guide for beginners, 2nd Ed., Ranjit Kumar.<br>Resisting Intellectual Property, 2007, Halbert, Taylor & Francis Ltd.<br>Industrial Design, 1992, Mayall, McGraw Hill.<br>Product Design, 1974, Niebel, McGraw Hill.<br>Introduction to Design, 1962, Asimov, Prentice Hall.<br>Intellectual Property in New Technological Age, 2016, Robert P. Merges, Peter S. Menell, Mark A. Lemley.<br>Intellectual Property Rights Under WTO, 2008, T. Ramappa, S. Chand. |

## *AM 623* : *Machine Learning*

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|---|---|
| Course Code | **AM 623** |
| Course Name | **Machine Learning** |
| L – T – P – C | **03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:** After completing this course, the students will be able to:

CO1 Understand the scenarios where machine learning algorithms can and cannot be used. Understand different types of machine learning algorithms namely unsupervised, supervised, and reinforcement learning algorithms, and get exposure to scenarios/applications where these algorithms can be applied.

CO2 learn the concepts of Regression, Classification and Clustering algorithms, and how to choose metrics to evaluate the performance of various machine learning models.

CO3 understand the concepts of overfitting, underfitting, right fit while learning a machine learning model, and learns the different techniques to address overfitting, underfitting problems to obtain the right fit. Students also learns how to setup a machine learning experiment, and how to report the performance of the model.

CO4 acquire knowledge on programming languages such as Python, Matlab, R, and also on libraries like NumPy, Pandas, Matplotlib, Scikit learn, etc. which helps them to apply machine learning models on any data sets.

| Course Contents |
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| **UNIT I -** Well-posed learning problems, Designing a learning system, Perspectives and issues in machine learning. Types of Machine Learning-Supervised, Unsupervised, Reinforcement learning.<br>**UNIT II-**Supervised Learning Algorithms- Regression and Classification-Linear, Polynomial-Regularization, Regression based on Normal Equations, Instance-based learning-Decision Trees, Artificial Neural Networks Support Vector Machines, Support Vector Regression<br>**UNIT III-** Unsupervised learning- k-means, Gaussian Mixture Models, Expectation Maximization, Hierarchical clustering, Spectral clustering**.**<br>**UNIT IV:** Bias variance trade-off, VC dimension, Model selection, AUC-ROC, Metrics-Regression, Classification, Clustering, K Fold cross-validation.<br>**UNIT V:** Python Implementation of Regression, Classification, and Clustering Algorithms. |
| **Text Books** |
| Machine Learning, Indian Ed., 2017, Tom M. Mitchell, Tata McGraw Hill Education.<br>Machine Learning: An Algorithmic Perspective, 2nd Ed., 2014, Stephen Marsland, Taylor & Francis (CRC).<br>Machine Learning, A probabilistic perspective, 2012, Kevin Murphy, MIT Press.<br>Hands on Machine Learning with Scikit-Learn, Keras & TensorFlow, O'Reilly- 3rd Edition, 2022 |
| **Reference Books** |
| 1 Pattern Recognition and Machine Learning, 2006, Christopher M. Bishop, Springer.<br>2. Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press. |

## *AM 624* **:** *Big Data Analytics*

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|---|---|
| Course Code | **AM 624** |
| Course Name | **Big Data Analytics** |
| L – T – P - C | **03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |
| Course Outcomes: After completing this course, the students will be able to:<br>CO1: Understand the building blocks of Big Data<br>CO2: Articulate the programming aspects of cloud computing(map Reduce etc)<br>CO3: Understand the specialized aspects of big data with the help of different big data application<br>CO4: Represent the analytical aspects of Big Data<br>CO5: Know the recent research trends related to Hadoop File System, MapReduce and Google File System etc | |
| **Course Contents** | |
| **Unit I :Introduction to Big Data:** Types of Digital Data-Characteristics of Data – Evolution of Big Data – Definition of Big Data – Challenges with Big Data – 3Vs of Big Data – Non Definitional traits of Big Data – Business Intelligence vs. Big Data – Data warehouse and Hadoop environment – Coexistence. Big Data Analytics: Classification of analytics – Data Science – Terminologies in Big Data – CAP Theorem – BASE Concept. NoSQL: Types of Databases – Advantages – NewSQL – SQL vs. NOSQL vs NewSQL. Introduction to Hadoop: Features – Advantages – Versions – Overview of Hadoop Eco systems – Hadoop | |

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| distributions – Hadoop vs. SQL – RDBMS vs. Hadoop – Hadoop Components – Architecture – HDFS – Map Reduce: Mapper – Reducer – Combiner – Partitioner – Searching – Sorting – Compression. Hadoop 2 (YARN): Architecture – Interacting with Hadoop Eco systems.<br>**Unit II: No SQL databases:** Mongo DB: Introduction – Features – Data types – Mongo DB Query language – CRUD operations – Arrays – Functions: Count – Sort – Limit – Skip – Aggregate – Map Reduce. Cursors – Indexes – Mongo Import – Mongo Export. Cassandra: Introduction – Features – Data types – CQLSH – Key spaces – CRUD operations – Collections – Counter – TTL – Alter commands – Import and Export – Querying System tables.<br>**Unit III: Hadoop Eco systems:** Hive – Architecture – data type – File format – HQL – SerDe – User defined functions – Pig: Features – Anatomy – Pig on Hadoop – Pig Philosophy – Pig Latin overview – Data types – Running pig – Execution modes of Pig – HDFS commands – Relational operators – Eval Functions – Complex data type – Piggy Bank – User defined Functions – Parameter substitution – Diagnostic operator. Jasper Report: Introduction – Connecting to Mongo DB – Connecting to Cassandra – Introduction to Machine learning: Linear Regression – Clustering – Collaborative filtering – Association rule mining – Decision tree.<br>**Unit IV: Algorithms for massive data sets**, Algorithms for SISD, SIMD environments, Linked Big Data Analysis – Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications<br>**Unit V: Applications for massive data sets:** Finding similar items, mining data streams, page rank algorithm, link analysis, mining social-network graphs, semantic analysis, study of applications of big spatial-temporal data, social media data, scientific data and others. |
| **Text Books** |
| Big Data Fundamentals: Concepts, Drivers & Techniques 2016 by Thomas Erl, Wajid Khattak, Paul Buhler, Publisher: Prentice Hall, 2016), Service Tech Press<br>Seema Acharya, Subhashini Chellappan, “Big Data and Analytics”, Wiley Publication, 2015.<br>Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006 |
| **Reference Books** |
| Introduction To Algorithms, 3rd Ed., 2009, Thomas H. Cormen, Charles E. Leiserson, Ronaldo L. Rivest, Clifford Stien, The MIT Press.<br>Big Data for Dummies, 2013, Judith Hurwitz, Alan Nugent, Dr. Fern Halper, Marcia Kaufman, John Wiley & Sons, Inc.<br>Hadoop: The Definitive Guide, 2012, Tom White, O’Reilly Publications.<br>Mongo DB in Action, 2012, Kyle Banker, Manning Publications Company.<br>Mining of Massive Datasets, 2012, Jure Leskovec, Anand Rajaraman and Jeffrey David Ulman, Cambridge University Press.<br>Big Data Analytics, 2015, Seema Acharya, Subhasini Chellappan, Wiley.<br>Big Data Fundamentals: Conpts, Drivers & Techniques, 2016, Thomas Erl, Wajid Khattak, Paul Buhler, Prentice Hall, Service Tech Press.<br>Data Mining, 2nd Ed., 2006, Jiawei Han & Micheline Kamber, Elsevier. |

## *AM 625* : *Image and Video Analytics*

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|---|---|
| Course Code | **AM 625** |
| Course Name | **Image and Video Analytics** |
| L – T – P - C | **03 – 0- 2 – 4** |

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|---|---|
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes:** After completing this course, the students will be able to:
CO1: understand basic image model, and will learn basic image processing techniques to analyze the image in terms of histogram, contrast, sharpness, etc.

CO2: learn different image enhancement techniques, and also understand the factors which degrades the quality of an image, and also learns the image restoration techniques. Different spatial filtering operations for image enhancement will be learnt along with the morphological operations.

CO3: learn image segmentation algorithms, understands the need for image compression and learn the spatial and frequency domain techniques used for image compression.

CO4: learn different feature extraction techniques employed for image analysis and recognition, and gets an overview on applications of image processing in Machine vision

**Course Contents**

**Digital Image Fundamentals:** Introduction – Origin –Steps in Digital Image Processing – Components; Elements of Visual Perception – Light and Electromagnetic Spectrum – Image Sensing and Acquisition – Image Sampling and Quantization – Relationships between pixels.

**Image Enhancement**: Spatial Domain: Gray level transformations – Histogram processing – Basics of Spatial Filtering–Smoothing and Sharpening Spatial Filtering – Frequency Domain: Introduction to Fourier Transform – Smoothing and Sharpening frequency domain filters – Ideal, Butterworth and Gaussian filters.

**Image Restoration**: Noise models – Mean filters – Order Statistics – Adaptive filters – Band reject – Band pass – Notch – Optimum notch filtering – Inverse Filtering – Constrained Least Square Filtering – Wiener filtering.

**Morphological image processing**: Dilation, Erosion, Opening, Closing, Applications to; Boundary extraction, Region filling, Extraction of connected components.

**Image Compression:** Fundamentals – Image Compression models – Error Free Compression – Variable Length Coding –Bit – Plane Coding – Lossless Predictive Coding – Lossy Compression – Lossy Predictive Coding –Wavelet Coding – Compression Standards – JPEG2000.

**Image Segmentation and Representation:** Segmentation – Detection of Discontinuities – Edge Linking and Boundary detection – Region based segmentation; Representation – Boundary descriptors – Simple Descriptors – Shape numbers –Regional descriptors – Simple and Topological Descriptors – Introduction to Image Processing Toolbox – Practice of Image Processing Toolbox – Case studies– Various Image Processing Techniques. Object recognition: Decision-theoretic methods.

SVM, feature selection methods, feature extraction methods, Maximum Output Information (MOI) for joint selection and classifier training.

**Colour models and Transformations** – Image and Video segmentation - Image and video demonising- Image and Video enhancement- Image and Video compression. Object detection and recognition in image and video - Texture models Image and Video classification models- Object tracking in Video

**Text Books**

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| Digital Image Processing, 3rd Ed., 2007, R. C. Gonzalez, Richard E. Woods, Prentice Hall.<br>Digital Image Processing Using MATLAB, 2nd Ed., 2009, R. C. Gonzalez, Richard E. Woods, Steven L. Eddins, Gatesmark Publishing. |
| **Reference Books** |
| Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press.<br>Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India.<br>Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley.<br>Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker.<br>Computer Vision: Algorithms and Applications, 2011, Rick Szelisk, Springer.<br>Intelligent Video Surveillance Systems, 2013, Jean-Yves Dufour, Wiley.<br>Video Analytics for Business Intelligence, 2012, Caifeng Shan, Fatih Porikli, Tao Xiang, Shaogang Gong, Springer. |

## *AM 627* : *Information Theory and Coding*

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|---|---|---|---|
| Course Code | **AM 627** | | |
| Course Name | **Information Theory and Coding** | | |
| L – T – P - C | **03 – 01- 0 - 4** | | |
| Offered as (Compulsory / Elective): | | **Elective** | |
| Offered in ( SPRING / AUTUMN ) | | **SPRING** | |
| Offered by (Name of Department/ Centre ) | | **School of Computer Engineering & Mathematical Sciences** | |

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| **Course Outcomes:** After completing this course, the students will be able to:<br>CO1: learn the channel performance using Information theory.<br>CO2: Comprehend various error control code properties<br>CO3: Apply linear block codes for error detection and correction<br>CO4: Apply convolution codes for performance analysis & cyclic codes for error detection and correction.<br>CO5: Design BCH & RS codes for Channel performance improvement against burst errors. |
| **Course Contents** |
| **Information Theory:** Uncertainty, Information, Entropy, Discrete Memoryless Channel, Mutual Information, Channel Capacity, Shannon's Theorems, Gaussian Channel, Limits to Communication<br>**Linear Block Codes:** Groups, Fields and Vector Spaces, Construction of Galois Fields of Prime Order, Syndrome Error Detection, Standard Array and Syndrome Decoding, Hamming Codes<br>**Cyclic Codes:** Polynomial Representation of Code words, Generator Polynomial, Systematic Codes, Generator Matrix, Syndrome Calculation and Error Detection, Decoding of Cyclic Codes<br>**Structure and Properties of Convolutional Codes**: Convolutional Encoder Representation, Tree, Trellis, and State Diagrams, Distance Properties of Convolutional Codes, Punctured Convolutional Codes and Rate Compatible Schemes<br>**Decoding of Convolutional Codes**: Maximum Likelihood Detection, The Viterbi Algorithm<br>**Automatic Repeat Request Strategies**: Basic Techniques, Hybrid ARQ<br>**Introduction to Cryptography:** History. Overview of cryptography, Simple classical cryptosystems, Cryptanalysis<br>**Perfect Secrecy:** Information theoretic security**,** One time pad<br>**Secret and Public Key Encryption**: Description of DES, Description of AES (advanced encryption standard), Trapdoor Function, The RSA Algorithm |

| Text Books |
|---|
| Essentials of Error-Control Coding, 2006, Jorge Castiñeira Moreira, Patrick Guy Farrell, John Wiley.<br>Information and Coding Theory, 2000, G. A. Jones and J. M. Jones, Springer.<br>History of Cryptography and Cryptanalysis Codes, Ciphers, and Their Algorithms, 2018, John F. Dooley, Springer. |
| **Reference Books** |
| Number Theory, Elementary Cryptography and Codes, 2009, Maria Welleda Baldoni, Ciro Ciliberto, Giulia Maria Piacentini Cattaneo, Springer.<br>Essentials of Error-Control Coding, 2006, Jorge Castiñeira Moreira, Patrick Guy Farrell, John Wiley & Sons Ltd.<br>Essentials of Error-Control Coding Techniques, 1990, Hideki Imai, Academic Press, Inc.<br>Codes and Cryptography, 1988, Dominic Welsh, Oxford Science Publications.<br>Elements of information theory, $2^{nd}$ Ed., 2006, T. M. Cover, J. A. Thomas, WielyInterscience.<br>Coding and information theory, 1980, R. W. Hamming, Prentice Hall Inc.<br>Entropy and Information Theory, $2^{nd}$ Ed., 2011, Robert M. Gray, Springer, 2011. |

## *AM 628* : *Computational Number Theory and Cryptography*

| Course Code | **AM 628** |
|---|---|
| Course Name | **Computational Number Theory and Cryptography** |
| L – T – P - C | **03 – 01- 0 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

**Course Outcomes**: After completing this course, the students will be able to:
CO1: learn computational methods in Algebra and Number Theory.

CO2: understand fundamental number-theoretic algorithms such as the Euclidean algorithm, the Chinese Remainder algorithm, binary powering, and algorithms for integer arithmetic.

CO3: understand the number-theoretic foundations of modern cryptography and the principles behind their security.

CO4: Understand the mathematical foundations for security of modern cryptography, asymmetric crypto-systems based on hard computational problems from Algebra and Number Theory.

CO5: apply fundamental algorithms for symmetric key and public-key cryptography.

### Course Contents

**Introduction:** Introduction to Cryptosystems, Classical Ciphers, Cryptanalysis of Classical ciphers, LFSR based stream ciphers. Shannon's Theory**,** Diffie-Helman Key Exchange, Rabin Cryptosystem, Knapsack

Ciphers, Digital Signature, Secret Sharing, ElGamal Cryptosystem

**Number Theory:**

**Divisibility:** Representations of Integers, Computer Operations with Integers, Complexity of Integer Operations, Divisibility, Prime Numbers, The Fundamental Theorem of Arithmetic, Sieve of Eratosthenes, The Distribution of Primes, Greatest Common Divisor, Euclidean Algorithm, Mersenne Numbers, Fermat Numbers, Perfect numbers

**Congruence:** Congruences, Congruence Applications, Linear Congruences, The Chinese Remainder Theorem, Theorems of Fermat and Euler- Fermat, Wilson's Theorem, Pseudo Primes, Carmichael Numbers, The Euler Phi-Function, The Sum and Number of Divisors, Quadratic Residue, Quadratic Reciprocity. Legendre and Jacobi Symbols, Computing Legendre symbols, Primitive Roots, Quadratic Reciprocity Law,

**Inter Factorization and Primality Testing Algorithms:** Complexity of Number Theoretic Algorithms, Fermat's Factorization, Kraitchik's Improvement, Trial division, Pollard Rho Algorithm, p-1 method, CFRAC method, quadratic sieve method, elliptic curve method. **Primality testing algorithms:** Fermat test, Miller-Rabin test, Solovay-Strassen test, AKS test.

**Computing discrete logarithms over finite fields:** Baby-step-giant-step method, Pollard rho method, Pohlig-Hellman method, index calculus methods, linear sieve method, Coppersmith's algorithm.

**Representation of finite fields:** Groups, Fields, Finite Fields, Arithmetic in Finite Field, Finding Multiplicative Inverses in finite fields, Prime and extension fields, representation of extension fields, polynomial basis, primitive elements, normal basis, optimal normal basis, irreducible polynomials. Binary Fields and their application in Cryptosystems.

**Elliptic Curve Cryptography:** Introduction to Elliptic Curves, the elliptic curve group, elliptic curves over finite fields, Schoof's point counting algorithm, Discrete Log problem for Elliptic curves, Factorization using Elliptic Curve, Advantage of Elliptic Curve Cryptography over other Public Key Cryptosystems.

**Text Books**

Introduction to Modern Cryptography, 2nd Ed., 2008, J. Katz, Y. Lindell, Chapman & Hall/CRC.
Computational number theory, 2018, Abhijit Das, Chapman and Hall/CRC.
A Course in Number Theory and Cryptography, 2006, N. Koblitz, Springer.
An Introduction to theory of numbers, 2006, I. Niven, H.S. Zuckerman, H.L. Montgomery, John Wiley & Sons, Inc.

**Reference Books**

Elliptic curves: number theory and cryptography, 2003, L. C. Washington, Chapman & Hall/CRC.
Rational Points on Elliptic Curves, 2005, J. Silverman, J. Tate, Springer-Verlag.
Guide to elliptic curve cryptography, 2004, D. Hankerson, A. Menezes, S. Vanstone, Springer-Verlag.
An Introduction to Mathematical Cryptography, 2008, J. Pipher, J. Hoffstein, J. H. Silverman, Springer-Verlag.
Elementary Number Theory, 1998, G. A. Jones, J. M. Jones, Springer-Verlag.
An Introduction to Cryptography, 2001, R. A. Mollin, Chapman & Hall.
Number Theory for Computing, 2nd Ed., 2002, Song Y. Yan, Springer-Verlag.
Introduction to Algorithms, Second Edition, 1994, T. H. Cormen, C. E. Leiserson, R. L. Rivest, Prentice Hall of India.
Elementary Theory of Numbers, 5th Ed., 2004, K. Rosen, Addison Wesley.
. Factorization and Primality Testing, 1989, D. M. Bressoud, Springer-Verlag.
. A computational introduction to number theory and algebra, 2009, V. Shoup, Cambridge University Press.

. Mathematics for computer algebra, 1992, M. Mignotte, Springer-Verlag.
. An introduction to the theory of numbers, 2011, I. Niven, H. S. Zuckerman, H. L. Montgomery, John Wiley.
. Modern computer algebra, 3rd Ed., 2013, J. Von zur Gathen, J. Gerhard, Cambridge University Press.
. Introduction to finite fields and their applications, 2012, R. Lidl, H. Niederreiter, Cambridge University Press.
. Applications of finite fields, 1993, A. J. Menezes, Kluwer Academic Publishers.
. Rational points on elliptic curves, 2015, J. H. Silverman, J. Tate, Springer International Edition.
. Guide to elliptic curve cryptography, 2004, D. R. Hankerson, A. J. Menezes, S. A. Vanstone, Springer-Verlag.
. Public-key cryptography: Theory and practice, 2009, A. Das, C. E. Veni Madhavan, Pearson Education Asia.
. A course in computational algebraic number theory, 1993, H. Cohen, Springer-Verlag.

## *AM 635* : *Finite Elements: Theory and Algorithms*

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|---|---|
| Course Code | **AM 635** |
| Course Name | **Finite Elements: Theory and Algorithms** |
| L – T – P - C | **03 – 01- 0 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:
CO1: Students will independently formulate, implement and use various finite element methods for linear and non-linear PDEs and use fundamental PDE in applications.
CO2: Students will solve the systems of equations resulting from a finite element method in a numerically efficient manner.
CO3: Students will derive common error estimates for finite element methods.
CO4: Students will be able to numerically evaluate the efficiency of the finite element method
CO5: Students will show the existence and uniqueness for analytical and numerical solutions to elliptic PDEs.

**Course Contents**

**Unit I :** Review of Lebesgue Integration Theory, Generalized (weak) derivatives, Sobolev norms and associated spaces, inner-product spaces, Hilbert spaces, Trace Theorems

**Unit II :** Variational Formulation of Elliptic Boundary Value Problems, Reisz Representation Theorem, The Lax -Milgram Theorem, Formulation of Symmetric Variational Problems, Formulation of Nonsymmetric Variational Problems.

**Unit III:** Construction of finite element spaces, Triangular finite elements, two- and three- dimensional finite elements, Rectangular Elements, Interpolation

**Unit IV:** Polynomial Approximation Theory, Error Representation, Interpolation Error, Inverse Estimates, A Discrete Sobolev Inequality.

**Unit V:** Finite element algorithms and implementation for linear elasticity, Mindlin-Reissner plate problem, Systems in fluid mechanics.

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| **Pre-requisites:** Good knowledge of numerical analysis along with basic programming background and/or consent from the instructor. |
| **Text Books** |
| 1. The Finite Element Method for Elliptic Problems, 1978, P. G. Ciarlet, North-Holland,Amsterdam, New York, Oxford.<br>2. Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics,2007, 3rd Ed., Dietrich Braess, Cambridge University Press.<br>3. Numerical Solution of Partial Differential Equations by the Finite Element Method, 2009, C. Johnson, Dover Publications. |
| **Reference Books** |
| 1. The Mathematical Theory of Finite Element Methods, 2008, 3rd Ed., Susanne C. Brenner, Ridgway Scott, Springer-Verlag.<br>2. Finite elements: Theory and Algorithms, 2017, Sashikumaar Ganesan, Lutz Tobiska, Cambridge- IISc Series, Cambridge University Press. |

## *AM 636* **:** *Cloud Computing*

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|---|---|
| Course Code | **AM 636** |
| Course Name | **Cloud Computing** |
| L – T – P - C | **03 – 01- 0 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

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| **Course Outcomes:** After completing this course, the students will be able to:<br>CO1: Articulate the main concepts, key technologies, strengths, limitations of cloud computing and the possible applications for state-of-the-art cloud computing.<br>CO2: Identify the architecture and infrastructure of cloud computing, including cloud delivery and deployment models.<br>CO3: Identify problems, analyze, and evaluate various cloud computing solutions.<br>CO4: Analyze appropriate cloud computing solutions and recommendations according to the applications used. |
| **Course Contents** |
| **Unit I:** Context: Shared/distributed memory computing; Data/task parallel computing; Role of Cloud computing.<br>**Unit II:** Layers in cloud architecture, Software as a Service (SaaS), features of SaaS and benefits, Platform as a Service ( PaaS ), features of PaaS and benefits, Infrastructure as a Service ( IaaS), features of IaaS and benefits, Service providers, challenges and risks in cloud adoption. Public/Private Clouds; |

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| Service-oriented architectures; Mobile, Edge and Fog computing; Multi-clouds.<br>**Unit III:** Application Design Patterns: Workflow and dataflow; Batch, transactional and continuous; Scaling, locality and speedup; Cloud, Mobile and Internet of Things (IoT) applications.<br>**Unit IV:** Execution Models: Synchronous/asynchronous patterns; Scale up/Scale out; Data marshalling/unmarshalling; Load balancing; stateful/stateless applications; Performance metrics; Consistency, Availability and Partitioning (CAP theorem).<br>**Unit V:** Introduction to Simulator, understanding CloudSim simulator, CloudSim Architecture(User code, CloudSim, GridSim, SimJava) Understanding Working platform for CloudSim |
| **Text Books** |
| Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, 2011, Kai Hwang, Jack Dongarra and Geoffrey Fox, Morgan Kaufmann.<br>Cloud computing a practical approach, 2010, Anthony T.Velte , Toby J. Velte Robert Elsenpeter, TATA McGraw-Hill, New Delhi. |
| **Reference Books** |
| Cloud Computing: Web-Based Applications That Change the Way You Work and Collaborate Online, 2008, Michael Miller, Que.<br>Cloud computing for dummies, 2010, Judith Hurwitz, Robin Bloor, Marcia Kaufman, Fern Halper, Wiley Publishing, Inc.<br>Cloud Computing (Principles and Paradigms), 2011, Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley & Sons, Inc. |

## *AM 637* : *Generative AI*

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|---|---|
| Course Code | **AM 637** |
| Course Name | **Generative AI** |
| L – T – P - C | **03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

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| Course Outcomes: After completing this course, the students will be able to:<br>CO1: Understand the concepts and needs of Generative modelling<br>CO2: Learn the concepts of probability and modelling<br>CO3: Learn the recent advancements in the area of deep learning in Generative AI<br>CO4: Handle the different varieties of data-like text, audio and images<br>CO5: Apply the learned concepts to generate the data related to specific applications of text, audio, images. |
| **Course Contents** |
| **Unit I :** Introduction to Generative AI : What is generative AI?, Types of generative models, Applications of generative AI,Probabilistic Models: Introduction to probability theory, Bayesian networks, Markov random fields.<br><br>**Unit II:** Autoencoders : Basics of autoencoders, Variational autoencoders (VAEs), Autoencoder-based |

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| generative models. Generative Adversarial Networks (GANs): Basics of GANs, Training and evaluating GANs, GAN-based generative models<br><br>**Unit III:** Deep Generative Models : Introduction to deep generative models, Deep Boltzmann Machines (DBMs), DeepBelief Networks (DBNs), Adversarial attacks on generative models, Neural Ordinary Differential Equations (ODEs)<br><br>**Unit IV**: Reinforcement Learning for Generative Models : Basics of reinforcement learning, Policy gradients, Reinforcement learning for generative models, and Generative models for unsupervised learning.<br><br>**Unit V**: Applications of Generative AI-Image generation, Text generation, Music generation, Video generation |
| **Text Books** |
| Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press.<br>Generative Deep Learning, 2019, David Foster. O'Reilly. |
| **Reference Books** |
| 1. Probabilistic Graphical Models, 2009, Daphne Koller and Nir Friedman, MIT Press.<br>**2.** Pattern Recognition and Machine Learning, 2006, Christopher M. Bishop, Springer. |

### *AM 638 : Reinforcement Learning*

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|---|---|---|
| Course Code | **AM 638** | |
| Course Name | **Reinforcement Learning** | |
| L – T – P - C | **03 – 01- 0 – 4** | |
| Offered as (Compulsory / Elective): | | **Elective** |
| Offered in ( SPRING / AUTUMN ) | | **SPRING** |
| Offered by (Name of Department/ Centre ) | | **School of Computer Engineering & Mathematical Sciences** |
| Course Outcomes: After completing this course, the students will be able to:<br>CO1: Understand the kind of problems that can be solved using the RL<br>CO2: Build the fundamentals needed for understanding RL<br>CO3: Learn the advance topics in the area of Deep Reinforcement learning<br>CO4: Exposure to the frameworks and libraries for implementing RL<br>CO5: Develop the RL algorithms in the area of Gaming, Robotics and Self driving cars | | |
| **Course Contents**<br>**Unit I** : Introduction to reinforcement learning, Basic concepts and terminology, Markov decision processes (MDPs), Value functions and policies. Dynamic programming and Monte Carlo methods: Policy evaluation and improvement, Value iteration and policy iteration, Monte Carlo methods for policy evaluation | | |

**Unit II**: Temporal difference learning : TD(0) and Sarsa algorithms, Q-learning algorithm, Function approximation with TD learning. Policy gradient methods: Gradient ascent algorithms, REINFORCE algorithm, Actor-critic algorithms.

**Unit III**: Exploration and exploitation:
Epsilon-greedy and softmax policies, Upper confidence bound (UCB) algorithm, Thompson sampling. Deep reinforcement learning: Deep Q-networks (DQN), Double DQN and Dueling DQN, Policy gradient methods with deep neural networks.

**Unit IV:** Multi-agent reinforcement learning Decentralized and centralized policies, Markov games and Nash equilibria Cooperative and competitive multi-agent learning

**Unit V**: Applications of reinforcement learning: Robotics and control, Game playing and strategy, Natural language processing and dialogue systems, Advanced topics in reinforcement learning

**Text Books**

Reinforcement Learning, 2$^{nd}$ Ed., 2018, Richard S Sutton, Andrew G Barto, MIT Press.
Reinforcement Learning and Stochastic Optimization, 2022, Warren B Powell, Wiley.

**Reference Books**

Algorithms for Reinforcement Learning, 1$^{st}$ Ed., 2010, Csaba Szepesvarim Morgan, Claypool Publisher.
Grokking Deep Reinforcement Learning, 2020, Miguel Morales, Manning Publisher.

***AM 639* : *Deep Learning for Computer Vision***

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|---|---|
| Course Code | **AM 639** |
| Course Name | **Deep Learning for Computer Vision** |
| L – T – P - C | **03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre) | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:
CO1: Learn the fundamental principles of deep learning.
CO2: Understand various methods for Deep Learning in computer vision.
CO3: Identify the deep learning algorithms for various types of learning tasks in various domains.
CO4: Implement deep learning algorithms and solve real-world problems.

| Course Contents |
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| **Unit I : Introduction:** Basic introduction on Computer Vision, Feed forward Neural networks, Gradient descent and the back propagation algorithm, Unit saturation, the vanishing gradient problem, and ways to mitigate it.<br>**Unit II:** RelU Heuristics for avoiding bad local minima, Heuristics for faster training, Nestors accelerated gradient descent, Regularization, Dropout. Convolutional Neural Networks: Architectures, convolution / pooling layers, Recurrent Neural Networks: LSTM, GRU, Encoder Decoder architectures.<br>**Unit III:** Deep Unsupervised Learning: Autoencoders, Variational Auto-encoders, Adversarial Generative Networks, Auto-encoder and DBM Attention and memory models. Dynamic memory networks, Applications of Deep Learning to Computer Vision: Image segmentation, object detection, automatic image captioning,<br>**Unit IV:** Image generation with Generative adversarial networks, video-to-text with LSTM models, and Attention models for computer vision tasks. |
| **Text Books** |
| 1 Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press. |
| **Reference Books** |
| 1. The Elements of Statistical Learning, $2^{nd}$ Ed., 2009, T. Hastie, R. Tibshirani, J. Friedman, Springer.<br>2. Probabilistic Graphical Models, 2009, D. Koller, and N. Friedman, MIT Press. |

## *AM 640* : *AI for Medical Image Analysis*

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|---|---|---|
| Course Code | **AM 640** | |
| Course Name | **AI for Medical Image Analysis** | |
| L – T – P - C | **03 – 0- 2 - 4** | |
| Offered as (Compulsory / Elective): | | **Elective** |
| Offered in ( SPRING / AUTUMN ) | | **SPRING** |
| Offered by (Name of Department/ Centre ) | | **School of Computer Engineering & Mathematical Sciences** |
| Course Outcomes: After completing this course, the students will be able to:<br>CO1: Understand medical different medical imaging modalities<br>CO2: Learn the feature extraction schemes specific to imaging modalities<br>CO3: Design the applications in line with the requirement of medical imaging<br>CO4: Handling the intricacies of medical data and how to address the,<br>CO5: Propose and develop a AI solution in Medical Imaging using Open source datasets and custom datasets | | |
| **Course Contents** | | |
| Unit I : Introduction to Medical Imaging and AI-Overview of medical imaging modalities, Enhancement-Fundamental Enhancement Techniques, Adaptive Image Filtering, Enhancement by Multiscale Non-linear operators, Medical image enhancement with Hybrid filters<br>Unit II: Introduction to machine learning and deep learning for medical imaging, Applications of AI in medical imaging.<br>Unit III: Medical Image Segmentation- Principles and Basic Techniques-Segmentation Strategies, Data Knowledge. Image segmentation by fuzzy clustering, Segmentation with Neural Networks.<br>Unit IV: Active Contours and Surfaces- Explicit Active Contours and Surfaces, The levels set model | | |

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| Unit V: Medical Image Classification and Diagnosis, Classification methods for different imaging modalities, Diagnosis using deep learning models, Evaluation metrics for classification and diagnosis algorithms. |
| **Text Books** |
| Handbook of Medical Imaging-Processing and Analysis, 2nd Ed., 2008, Issac N Bankman, Academic Press.<br>Guide to Medical image Analysis, 2012, Klaus D. Toennies, Springer-Verlag London. |
| **Reference Books** |
| Deep Learning for Medical Image Analysis, 2017, S. Kevin Zhou, Hayit Greenspan, Academic Press.<br>Computer Vision: Algorithms and Applications, 2nd Ed., 2022, Richard Szeliski, Springer. |

## *AM 641* : *Accelerated Computing*

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|---|---|
| Course Code | **AM 641** |
| Course Name | **Accelerated Computing** |
| L – T – P - C | **03 – 0- 2 – 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:

CO1: Understand the various computing platforms including GPU and CPU

CO2: Learn about different frameworks for implementation of Accelerated Artificial Intelligence

CO3: Analyse the use of different learning concepts like transfer learning, distributed learning, federated learning etc.

CO4: Apply knowledge representation with accelerated artificial intelligence.

**Course Contents**

**Unit I :** Introduction to System Hardware CPU, RAM, GPU, Interconnects, Storage, Network Controller; Introduction to GPU Accelerators, Introduction to System Software Operating System, Virtualization, Cloud, Introduction to Containers and IDE

**Unit II:** Design principles for building High Performance compute clusters; Implementation details for building High Performance compute clusters for AI, Frameworks for Accelerated Deep Learning Workloads

**Unit III:** Optimizing Deep Learning Training: Automated Mixed Precision, Transfer Learning, Fundamentals of Distributed Computing.

**Unit IV:** Challenges with Distributed Deep Learning, Fundamentals of Accelerating Deployment, Accelerated Data Analytics

**Unit V:** Scale Out with DASK; Web visualizations to GPU accelerated cross-filtering Accelerated ETL Pipeline with SPARK

| Text Books |
|---|
| Accelerating AI with Synthetic Data, 2020, Khaled El Emam, O'Reilly Media, Inc. |
| **Reference Books** |
| 1. Accelerated Optimization for Machine Learning, 1st Ed., 2020 , Zhouchen Lin Huan Li, Springer. |

### *AM 642* : *Computer Vision with Pattern Recognition*

| Course Code | **AM 642** |
|---|---|
| Course Name | **Computer Vision with Pattern Recognition** |
| L – T – P - C | **03 – 0- 2 - 4** |
| Offered as (Compulsory / Elective): | **Elective** |
| Offered in ( SPRING / AUTUMN ) | **SPRING** |
| Offered by (Name of Department/ Centre ) | **School of Computer Engineering & Mathematical Sciences** |

Course Outcomes: After completing this course, the students will be able to:
CO1: Understand the concepts of computer vision with conventional feature engineering
CO2: Learn the different standard architectures of object detection and classification
CO3 : Perform segmentation algorithms in different domains
CO4: Create the datasetss and gets an overview of annotation
CO5: Apply the learned concepts to real world problems in the area of medical imaging, automation, self-driving cars, etc.

Course Contents

Unit I : Introduction and Overview: Course Overview and Motivation; Introduction to Image Formation, Capture and Representation; Linear Filtering, Correlation, Convolution

Unit II: Visual Features and Representations:
Edge, Blobs, Corner Detection; Scale Space and Scale Selection; SIFT, SURF; HoG, LBP, etc

Unit III: Visual Matching: Bag-of-words, VLAD; RANSAC, Hough transform; Pyramid Matching; Optical Flow

Unit IV: Convolutions Neural Networks: Evolution of CNN Architectures: Alexnet, ZFNet, VGG, InceptionNets, ResNets, DenseNets: Recurrent Neural Networks-Review of RNNs; CNN + RNN Models for Video Understanding: Spatio-temporal Models, Action/Activity Recognition

Unit V: Recent Trends: Zero-shot, One-shot, Few-shot Learning; Self-supervised Learning; Reinforcement Learning in Vision; Other Recent Topics and Applications

**Text Books**

Computer Vision: Algorithms and Applications, 2nd Ed., 2022, Richard Szeliski, Springer.
Digital Image Processing, 4th Ed., 2017, Rafael C Gonzalez and Richard E Woods, Pearson.

**Reference Books**

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|---|
| Computer Vision: Models, Learning, and Inferences, 1st Ed., 2012, Simon J D Prince, Cambridge University.<br>M. Pattern Recognition and Machine Learning, 2006, Christopher Bishop, Springer.<br>Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press. |

## *AM 643* : *Database Systems*

<table>
<tr><td>Course Code</td><td colspan="2">AM 643</td></tr>
<tr><td>Course Name</td><td colspan="2">Database Systems</td></tr>
<tr><td>L – T – P - C</td><td colspan="2">03 – 0- 2 – 4</td></tr>
<tr><td colspan="2">Offered as (Compulsory / Elective):</td><td>Compulsory</td></tr>
<tr><td colspan="2">Offered in ( SPRING / AUTUMN )</td><td>SPRING</td></tr>
<tr><td colspan="2">Offered by (Name of Department/ Centre )</td><td>School of Computer Engineering & Mathematical Sciences</td></tr>
<tr><td colspan="3">Course Outcomes: After completing this course, the students will be able to:<br>CO1: Demonstrate the basic elements of a relational database management system<br>CO2: Identify the data models for relevant problems<br>CO3: Design entity relationship and convert entity relationship diagrams into RDBMS and formulate SQL queries on the respect data<br>CO4: Apply database storage structures and access techniques</td></tr>
<tr><td colspan="3">Course Contents<br>Unit I : Data base System Applications, Purpose of Database Systems, View of Data – Data Abstraction Instances and Schemas – data Models – the ER Model – Relational Model – Other Models – Database Languages – DDL – DML – database Access for applications Programs – data base Users and Administrator – Transaction Management – data base Architecture – Storage Manager – the Query Processor Data base design and ER diagrams – ER Model - Entities, Attributes and Entity sets – Relationships and Relationship sets – ER Design Issues – Concept Design – Conceptual Design for University Enterprise. Introduction to the Relational Model – Structure – Database Schema, Keys – Schema Diagrams<br>Unit II: Relational Query Languages, Relational Operations. Relational Algebra – Selection and projection set operations – renaming – Joins – Division – Examples of Algebra overviews – Relational calculus – Tuple relational Calculus – Domain relational calculus. Overview of the SQL Query Language – Basic Structure of SQL Queries, Set Operations, Aggregate Functions – GROUPBY – HAVING, Nested Sub queries, Views, Triggers.<br>Unit III: Normalization – Introduction, Non loss decomposition and functional dependencies, First, Second, and third normal forms – dependency preservation. Higher Normal Forms - Introduction, Multi-valued dependencies and Fourth normal form<br>Unit IV: Transaction Concept- Transaction State- Implementation of Atomicity and Durability – Concurrent – Executions – Serializability- Recoverability – Implementation of Isolation – Testing for serializability- Lock –Based Protocols – Timestamp Based Protocol.<br>Unit V: File organization:– File organization – various kinds of indexes. Query Processing – Measures of query cost - Selection operation – Projection operation, - Join operation</td></tr>
<tr><td colspan="3">Text Books</td></tr>
<tr><td colspan="3">1. Data base System Concepts, 7th Ed., 2019, A. Silberschatz, H. F. Korth, S. Sudarshan, McGraw hill.</td></tr>
</table>

| |
|---|
| 2. Data base Management Systems, 3rd Ed., 2002, Raghurama Krishnan, Johannes Gehrke, TATA McGrawHill. |
| **Reference Books** |
| 1. Fundamentals of Database Systems, 7th Ed., 2017, Elmasri Navathe, Pearson Education.<br>2. An Introduction to Database systems, 8th Ed., 2003, C. J. Date, A. Kannan, S. Swami Nadhan, Pearson. |

***PGC-602* : *Audit Course***

| | | |
|---|---|---|
| Course Code | **PGC-602** | |
| Course Name | **Audit Course** | |
| L – T – P - C | **2 – 0- 0 – 0** | |
| Offered as (Compulsory / Elective): | | **Compulsory** |
| Offered in ( SPRING / AUTUMN ) | | **SPRING** |
| Offered by (Name of Department/ Centre ) | | **PGC/All Departments DIAT** |
| Unit I: English for Research Paper Writing<br>Unit II: Disaster Management<br>Unit II: Sanskrit for Technical Knowledge<br>Unit IV: Value Education<br>Unit V: Constitution of India<br>Unit VI: Pedagogy Studies<br>Unit VII: Stress Management by Yoga<br>Unit VIII: Personality Development through Life Enlightenment Skills | | |

# DEPARTMENT OF APPLIED PHYSICS

## M. Tech. in Sensor Technology

Sensors is one area of science and technology which has witnessed a paradigm shift from conventional bulky components to extremely miniaturized and smart devices. The technological advancements in the area of Electronics, Electrical engineering, along with the advancements in basic sciences in the areas of, nanotechnology, biotechnology and photonics have been responsible for this concomitant growth in the development of current sensors. An interdisciplinary approach that will involve materials engineering, electronics and electrical engineering along with a flavor of chemical engineering and bio-engineering, is now required to understand such sensors. The objective is to make them faster, smaller, smarter and more selective flavour. This domain has, hence, seen a large number of Industries, Institutes and small entrepreneur companies coming up in recent times. The program intends to educate and train bright fresh students in the field of sensor technology to carry out challenging responsibilities in their future careers, and meet the current challenges and foster the opportunities which the globe has to offer. This is an interdisciplinary course concerning broadly Electronics, Instrumentation, Sensors, Optics, Electromagnetism, Nanotechnology and Advanced Materials.

**Eligibility**

To join this course the candidate should possess Masters in science degree or equivalent in Physics, Applied Physics, Optics, Electronic Science, Photonics, Material science, Instrumentation Science OR B. E./ B. Tech (all disciplines)

### PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

**PEO1:** The M Tech in Sensor Technology programme aims at developing skilled human resources in the field of sensor development, control system design, wireless sensor network, artificial intelligence, machine learning etc catering to the emerging multidisciplinary problems faced by defence industry and society.

**PEO2:**With a focus on the DRDO requirements, the students will be trained to use their knowledge for the benefit of society and made aware of their social duty. This will enable them to pursue career in research, academics, and industry.

**PEO3:**At the end of the programme the officer or student should be able to undertake state of the art R&D in Sensor Technology Systemsand competitively work towardsthe development of the latest technology in line with national programmes like Make in India.

### PROGRAMME OUTCOMES (POs)

**PO1:** An ability to independently carry out research /investigation and development work to solve practical problems

**PO2:** An ability to write and present a substantial technical report/document

**PO3:** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor’s program

**PO4:** Having adaptive thinking and adaptability in relation to environmental context and sustainable development
**PO5:** Having a clear understanding of professional and ethical responsibility
**PO6:** Having good cognitive load management skills related to project management and finance

PROGRAMME SPECIFIC OUTCOMES (PSOs)

**On completion of M. Tech. (Sensor Technology) the programme, graduates will be able to**

**PSO1:** The MTech Sensor Technology aims at developing a skilled knowledgeable Human task force in the field of Sensor Technology catering to Defence Research and Development Organization & Tri – services (Army, Navy & Air force), Coast Guard, DGQA, DQA, Defence Public Sector units, in addition to the civilians in general. After completing M Tech course the students develop an ability to carry out independent research in the area of sensors.

**PSO2:** The dissertation work of the MTech students leads to publications in high-impact international journals which trains them in technical documentation and report writing.

**PSO3:** The M Tech Sensor Technology course aims at the development of human resources of high calibre in the field of sensor development, sensor systems, Machine learning, control system and wireless sensors.

## Credit Structure

**SEMESTER I**

| Sl. No. | Course Code | Course | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AP-601 | Principles of Sensing: Material Science and Physics | 3 | 1 | 4 |
| 2 | AP-602 | Sensor Data Acquisition systems | 3 | 1 | 4 |
| 3 | AP -603 | Technology and Packaging of MEMS Systems | 3 | 1 | 4 |
| 4 | AP -604 | Programming for Machine learning | 2 | 2 | 4 |
| 5 | AP - 605 | Sensor Technology Laboratory-I | 3 | 1 | 4 |
| 6 | EE-624 | Digital system design using FPGA | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **19** | 07 | **26** |

**SEMESTER II**

| Sl. No. | Course Code | Course | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AP-606 | Sensors and Actuators -I | 3 | 1 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | AP-607 | Sensors and Actuators -II | 3 | 1 | 4 |
| 3 | AP-608 | Machine learning techniques for sensor data analytics | 2 | 2 | 4 |
| 4 | AP-609 | Sensor Technology Laboratory-II | 3 | 1 | 4 |
| 5 | | Elective I | 3 | 1 | 4 |
| 6 | | Elective – II | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 0 | 0 | 0 |
| | | **Total** | **17** | **07** | **24** |

**SEMESTER III**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AP-681 | M.Tech. Dissertation Phase I | 28 | | 14 |
| | | **Total** | **28** | | **14** |

**SEMESTER IV**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AP-682 | M.Tech. Dissertation Phase II | 28 | | 14 |
| | | **Total** | **28** | | **14** |

**<u>List of Electives:</u>**

| Sr. No. | Course Code | Course |
|---|---|---|
| **Elective I& II** | | |
| 1 | AP 610 | Advanced Sensors |
| 2 | AP 611 | Sensors for Defence |
| 3 | AP 612 | Nanotechnology for Advanced Sensors |
| 4 | AP 651 | Broadband Communication Systems |
| 5 | AP 642 | THz Devices and Applications |
| 6 | EE614 | EMI, EMC, EMP, NEMP design |
| 7 | EE613 | Electronic warfare |
| 8 | CE691 | Wireless sensor network |

**AP-601 - Principles of Sensing: Material Science and Physics**

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts static and dynamic characteristics of sensors and use concepts in common methods for converting a physical parameter into an electrical quantity |
| **CO-2 :** | Analyze the working principle of different materials-based sensors and choose an appropriate sensor comparing different standards and guidelines to make sensitive measurements of physical parameters like pressure, flow, acceleration, etc. |
| **CO-3 :** | Examine the working mechanism of different types of sensors |
| **CO-4 :** | Illustrated the practical implementation of using different materials in sensors and Create analytical design and development solutions for sensors. |
| **CO-5 :** | Summarize different applications of different types of materials for sensors and Locate different types of sensors used in real life applications and paraphrase their importance |

**Syllabus:**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I: | Sensor Classification, Performance and Types, Error Analysis characteristics | 6 |
| Unit II: | Structural, electrical and mechanical and thermal properties | 6 |
| Unit III | Applications of metals and semiconductors<br>Thermal expansion devices, shape memory alloys, thermocouple, positive temperature coefficient resistor, negative temperature coefficient resistor, bolometers, strain gauges | 10 |
| Unit IV | Dielectric, Magnetic and superconducting materials<br>Polarization, frequency response, piezoelectric, pyroelectric, ferroelectric materials, Paramagnetic, diamagnetic, antiferromagnetic, ferromagnetic, ferrimagnetic, superconducting materials | 12 |
| Unit V | Applications of Dielectric, Magnetic and superconducting materials<br>Hall effect, magnetoresistance, SQUID | 6 |
| Unit VI | Introduction to Fiber optic sensors | 6 |

**References Textbooks:**


1. Sensor Materials by P T Moseley and A J Crocker, IOP Publishing Ltd 1996
2. Handbook of Modern Sensors: physics, designs and applications by Jacob Fraden, Springer (2010).
3. Sensor Technology Handbook by John S Wilson, Elsevier, (2005)
4. Transducers and Instrumentation, DVS Murty, 2$^{nd}$Edition2013
5. Material Science and Engineering by Raghavan
6. J. P. Dakin and B Culshaw, Optical Fiber Sensors, Vol. 1 & 2, Artech House, Boston and London,1998.

## AP-602 – Sensor Data Acquisition Systems

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of how sensor data requires further processing |
| **CO-2 :** | Analyze the working principle of Data Acquisition systems |
| **CO-3 :** | Examine the working mechanism of different signal conditioners |
| **CO-4 :** | Illustrate the practical implementation of sensor systems connected to a DAS board and programming of microcontroller platform |
| **CO-5 :** | Summarize various modes of sensor data integration and acquisition for further controls / displays |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | Fundamentals of Data Acquisition: Essentials of computer interfacing – configuration and structure -interface systems-interface bus. | 6 |
| Unit II: | Signal conditioning: Types of signals and signal conditioning, classes of signal conditioning, types of noises (different types) and basics of environmental aspects, shielded and twisted-pair cable, , Different type of signal conditioners- Digital and analog, applications in real systems | 8 |
| Unit III | Data Acquisition boards: A/D Boards, Single-ended vs differential signals, Resolution, dynamic range and accuracy of A/D boards, Sampling rate and the Nyquist theorem, Sampling techniques, D/Aboard. Serial and parallel data communication standards | 12 |
| Unit IV | Data Loggers: Methods of operation, stand-alone loggers/controller hardware, communications hardware interface, Data acquisition using PCMCIA cards. Device communications, Communication system basics for remote sensor data acquisition., Ethernet & LAN systems. | 12 |
| Unit V | Network data communication model for sensor data handling and communication – 7, Communication Protocols Layer Model and TCP/IP Model. Sensor Interface Demos using Arduino Interface and LabView | 8 |

**References Textbooks:**


1. Ramon Pallas-Areny and John G Webster, Sensors and Signal Conditioning, Wiley India Pvt. Ltd., 2 nded.,2012.
2. 2. Maurizio Di Paolo Emilio, Acquisition systems from fundamentals to Applied Design, Springer,2013.
3. 3. Robert H King, "Introduction to Data Acquisition with LabVIEW", McGraw Hill, 2nd ed.,2012.
4. 4. John Park and Steve Mackay, Practical Data Acquisition for Instrumentation and Control', Newness publishers,2003.
5. 5. Maurizio Di Paolo Emilio, Data Acquisition systemss- from fundamentals to Applied Design, Springer,2013. 6. Robert H King

## AP-603 – Technology and Packaging of MEMS systems

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Students to be able to understand concepts involved in MEMS |
| **CO-2 :** | Students to understand the technologies involved in MEMS fabrication and packaging, their advantages and limitations |
| **CO-3 :** | Students to be able to understand working principles in micro sensors and actuators |
| **CO-4 :** | Students to become capable of conceptualizing the design of a microsystem |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Evolution of Microsystems:** Concept & History of Micro systems & MEMS, Benefits of Micro Systems, Comparison between Microsystems & microelectronics, Multidisciplinary nature of microsystems development. | **2** |
| Unit II: | **Scaling Laws in Miniaturization:** Introduction to scaling, geometric scaling, scaling in rigid body dynamics, scaling in electrostatic forces, scaling in electromagnetic Electricity, scaling in fluid mechanics, Scaling in Heat Transfer. | **4** |
| Unit III | **Engineering, Science & Materials for Microsystems**: Atomic structure, Crystal Structures, Bonding in materials, Ionization, Doping in Semiconductors, Diffusion Process, Plasma Physics, Electrochemistry, Silicon as a substrate material for MEMS, Compounds of silicon, Si Piezo resistors, other Piezo electric materials, GaAs, Polymer, Materials used in packaging | **8** |
| Unit IV | **Fabrication of Microsystems**: Photolithography, Ion Implantation, Diffusion, Oxidation, chemical & physical vapor deposition, Epitaxial growth of films, Chemical etching, Plasma etching. | **8** |
| Unit V | **Micromachining processes:** Bulk Micromachining**,** Surface Micromachining, The LIGA Process. | **4** |
| Unit VI | **Working principles of microsystems:** Microsensors: Acoustics wave sensors, Biomedical & Bio sensors, Chemical Sensors, Optical Sensors, Pressure Sensors, Thermal Sensors.<br>MEMS with Microactuators: Microgripper, Micromotors, Micro valves, Micro pumps, Micro accelerometer<br>Microfluidics | **8** |
| Unit VII | **Microsystem packaging:** Levels in microsystem packaging, Interfaces in Microsystem packaging, Essential packaging technologies, 3-d Packaging, assembly of Microsystems. Multi User MEMS Program (MUMPs) | **4** |

| **Lab Assignments** | | **Hrs** |
|---|---|---|
| Lab 1 | To study the etching process in silicon | 4 |
| Lab 2 | Thin film deposition and analysis | 4 |
| Lab 3 | 3D Printing | 4 |

**References Textbooks:**

1] Tai-Ran Hsu, 'MEMS & Microsystem, Design and Manufacture',McGraw Hill, 2012

2] Physics of Semiconductor Devices by S.M. Sze,Wiley Publications(2006)

3] Mark J Jackson, Micro and Nano-manufacturing , Springer; First Edition, (2006)ISBN

4] Zheng Cui,Micro-nanofabrication: Technologies and Applications, Springer First Edition (2006),ISBN-10:3540289224

5] R. Kassing, P. Petkov,W.Kulish, C. Popov., Functional Properties of Nanostructured Materials. Springer (ISBN: 978-1-4020-4595-0 (Print) 978-1-4020-4594-3(Online)

## AP-604 – Programming for Machine learning

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Learn a language, Python, for expressing computations |
| **CO-2 :** | Develop an informal understanding of computational complexity |
| **CO-3 :** | Examine the process of moving from an ambiguous problem statement to a computational formulation of a method for solving the problem |
| **CO-4 :** | Illustrate the useful set of algorithmic and problem reduction techniques |
| **CO-5 :** | Use computational tools (including simple statistical, visualization, and machine learning tools) to model and understand data |

**Syllabus:**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I: | Introduction to Python & Simple Numerical Programs<br>Installing Python and Python IDEs, Basic elements of Python, Variables and assignment, branching programs, strings and input, loops, Simple codes, approximate solutions, Floats, Newton–Raphson | 12 |
| Unit II: | Functions, scoping, and abstraction<br>Functions, Scoping, Using functions to modularize code, Functions as objects, | 6 |
| Unit III | Structured types and mutability<br>Ranges and iterables,Strings, Tuples, Ranges, and Lists, SETS, Dictionaries | 6 |
| Unit IV | Recursion, global variables, modules and files, classes<br>Fibonacci Numbers, Palindromes, Global Variables, modules, files, testing and debugging, Abstract data types and classes, some important complexity classes | 12 |
| Unit V | Object-oriented programming, algorithms, data structures, Plotting<br>Search algorithms, sorting algorithms, Matplotlib | 10 |

**References Textbooks:**

1. Introduction to Computation and Programming Using Python, by John V Guttag, MIT Press

## EE-624 – DIGITAL SYSTEM DESIGN USING FPGAs

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Familiarized with the design of Combinational and Synchronous and Asynchronous Sequential Circuits. Gave an Overview of PLDs and PALs |

| | |
|---|---|
| **CO-2 :** | Covered basic introduction of VHDL and the basic language elements. Various Combinational and Sequential circuits were designed using VHDL |
| **CO-3 :** | In-depth analysis of Faults and testability in digital systems including modelling and detection |
| **CO-4 :** | Interfacing various sensors and reading/writing to/from various file formats. Implementing various modulation schemes |
| **CO-5 :** | Design of a RISC CPU, data and control path components. Introduction to various floating/fractional/fixed-point arithmetic operations. Implementing Data encryption/Decryption system, Error correction, communication modules, BERT |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Digital system design techniques:** Combinational Circuit Design - Synchronous Sequential Circuit Design - Mealy and Moore model - State machine design - Analysis of Synchronous sequential circuit - State equivalence - State Assignment and Reduction - Analysis of Asynchronous Sequential Circuit - flow table reduction – races - state assignment - Design of Asynchronous Sequential Circuit - Designing with PLDs – Overview of PLDs – ROMs - EPROMs – PLA – PAL - Gate Arrays – CPLDs and FPGAs, Designing with ROMs - Programmable Logic Arrays - Programmable Array logic. | 12 |
| Unit II: | **IIVHDL basics and computation module designs:** Introduction to VHDL - Behavioral modeling - Data flow modeling - Structural modeling - Basic language elements – Entity – Architecture - Configurations – Arrays declaration - Subprograms & operator overloading - Packages & libraries – Advanced Features - Model simulation - Realization of combinational and sequential circuits using VHDL – Registers – Flip flops - counters – Shift registers – Multiplexers - sequential machine – Multiplier – Divider, ALU, MAC, CORDIC, Introduction to Synthesis. | 6 |
| Unit III | **Fault modeling, detection and test pattern generation algorithms:** Introduction to testing – Faults in Digital Circuits – Modeling of faults – Logical Fault Models – Fault detection – Fault Location – Fault dominance – Logic simulation – Test generation for combinational logic circuits – Testable combinational logic circuit design - Introduction to Design for Testability - BIST.. | 6 |
| Unit IV | **Digital system design with real-time I/O interface:** Sensors interface - uni-polar & bi-polar A/D converter - D/A converter interface - display devices interface - RS232, USB, Ethernet, VGA interface - RF data link - high voltage switch control - realy/AC/DC motor & buzzer control - PWM signal generation - PS/2 key-board & matrix keypad interface – digital camera interface, arbitrary data/signal generation – sensor data acquisition and writing/reading to/from .xlsx | 12 |

| | | |
|---|---|---|
| | and .doc file - implementation of modulation schemes | |
| Unit V | **Contemporary designs and solutions:** Design of data path components, Control path components - Design of a simple RISC CPU - Debugging using Embedded Logic Analyzers - Audio codec (AC97) interface – Test-bench design - ChipScope Pro Analyzer - introduction to floating/fractional/fixed-point arithmetic operations - Xilinx Sys-Gen tools - MATLAB/VHDL interface with Sys-Gen tools -BERT interface – implementation of DPCM, data encryption/decryption system, EC techniques, communication modules design, DA based computations. | 10 |

**LIST OF EXPERIMENTS:**

| SL No | NAME OF EXPERIMENTS |
|---|---|
| 01. | The Basic FPGA Design Flow<br>To understand use of Xilinx ISE<br>To understand Xilinx Synthesis Technology or XST.<br>Familiarization of Xilinx Vivado Design Tools. |
| 02. | Familiarization of FPGA Boards<br>Xilinx FPGA Boards (Virtex 6,Kintex7)<br>Implementation of Full adder, ALU , Memory and FIFO on FPGA |
| 03. | Fault Detection Logic Implementation on FPGA<br>1. Stuck at Fault 2.Memory BIST |
| 04. | Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analyzers. |

**REFERENCE TEXT BOOKS:**


1. Jesse H. Jenkins, "Designing with FPGAs and CPLDs", Prentice Hall, NJ,1994
2. Fundamentals of Logic Design – Charles H. Roth, 5th ed., Cengage Learning.
3. Kevin Skahill, "VHDL for Programmable Logic", Addison -Wesley, 1996
4. Z. Navabi, "VHDL Analysis and Modeling of Digital Systems", McGRAW-Hill, 1998
5. Digital Circuits and Logic Design – Samuel C. Lee , PHI
6. Smith, "Application Specific Integrated Circuits", Addison-Wesley, 1997
7. P.K. Lala, “Digital Circuit Testing and Testability”, Academic Press, 2002


## AP-605 – Sensor Technology Laboratory-I

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of basic physics behind several sensors |
| **CO-2 :** | Analyze optical, electrical, thermal properties |
| **CO-3 :** | Examine situations where the sensors based on above properties can be used |
| **CO-4 :** | Illustrate implementation of sensor system on LabView |
| **CO-5 :** | Summarize different applications where the sensors systems can be used |

**Syllabus:**

| Units | Syllabus Details |
|---|---|
| Unit I: | Determination of various parameters of optical fiber,<br>Micro and Macro bending for strain detection<br>Michelson Interferometry |
| Unit II: | Hall effect experiment<br>Resistive sensors |
| Unit III | Automation of sensor system,<br>Humidity Sensor,<br>Temperature Sensor |
| Unit IV | Ultrasonic proximity sensor, temperature sensors |
| Unit V | LabVIEW based automation |
| | Sensor Calibration<br>Vibration Sensors<br>GM Counter |

**References Textbooks:**

## AP-606 –Sensors and Actuators - I

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of mechanical and electromechanical sensors |
| **CO-2 :** | Analyze the working principle of magnetic sensors |
| **CO-3 :** | Examine the working mechanism of different types of sensors |
| **CO-4 :** | Illustrated the practical implementation pressure sensing. |
| **CO-5 :** | Summarize different applications of above types of sensors for position, velocity and acceleration measurement |

**Syllabus:**

| Units Divisions | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | Mechanical and electromechanical sensors: Resistive potentiometer, strain gauge, inductive sensor, capacitive sensor | 10 |
| Unit II: | Magnetic sensors: Magneto-resistive, Hall effect sensors, Inductance and eddy current sensors, LVDT, RVDT | 6 |
| Unit III | Pressure measurement: manometer, ring balance manometer, bell type manometer, thin plate diaphragms, bellows, bourdon tube, piezo-resistive and capacitive pressure sensor, optoelectronic pressure sensors, vacuum sensors- pirani gauge, ionization gage, gas drag gauge. | 12 |
| Unit IV | Force and torque measurement: helical spiral springs, cantilever, beams, diaphragm, load cell, torsion bar, flat spiral spring for torque | 6 |
| Unit V | Position and displacement, Velocity and Acceleration sensors: | 12 |

| | | |
|---|---|---|
| | Electromagnetic velocity sensor, Doppler with sound or light or other EM wave, Accelerometer characteristics, capacitive, piezo- resistive, piezoelectric accelerometer, thermal accelerometer, rotor, monolithic and optical gyroscopes and mechanical gyroscopes. | |
| | | |

**References Textbooks:**

## AP-607– Sensors and Actuators - II

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Students to learn the working principles of sensors and actuators |
| **CO-2 :** | Students to be able to understand and carry out applications based selection of sensors and actuators |
| **CO-3 :** | Students to become capable of characterizing a particular given sensor |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | Optical properties, components, sources and detectors: types of sources : source-detector characterstics, Radiometry, Photometry, windows, mirrors, lenses, Fresnel lenses | 4 |
| Unit II: | Light Detectors : Photoconductive detectors, Photo diodes, Avalanche photodiodes, Photoresistors, Photo multipliers, CCDs, Image Intensifiers, Solar Cells, photon counting techniques to count low photon flux, Thermal detectors : Golay Cells, Thermopile Sensors, Pyroelectric Sensors, Bolometers, Active FIR Sensors, Gas Flame detectors | 6 |
| Unit III | Radiation Detectors : Scintillation detectors, Ionization Detectors : Ionization Chambers, Proportional Chambers, Geiger-Muller Counters, Semiconductor Detectors | 4 |
| Unit IV | Temperature Sensors :Thermo resistive Sensors, Thermoelectric Contact Semiconductor Junction Sensors, Optical Temperature Sensors, Acoustic Temperature Sensors, Piezoelectric Temperature Sensors | 6 |
| Unit V | Chemical Sensors : Classification of Chemical Sensing Mechanisms, Direct Sensors : MOX, Chem Fet, Electrochemical, Complex Sensors: Thermal, Pellister Catalytic, Mass detector, Biochemical and enzyme Sensors, Smart chemical sensors, Mass Spectroscopy | 6 |
| Unit VI | Actuation and actuators: Active elements: Piezoelectric, magneto-strictive, photoelectric, thermoelectric, actuator principles, actuators as system components, actuators in mechatronics and adaptronics, electrostatic/Electromagnetic actuators (types of motors) Introduction and classification of motors, PZT actuators, Smart actuators, multilayer actuator. | 8 |

| Lab Assignments | | hrs |
|---|---|---|
| Lab 1 | Comparative experimental study of different Temperature Sensors | 4 |
| Lab 2 | Stepper motor control experiment | 4 |
| Lab 3 | Demo of Radiation detector | 4 |

**References Textbooks:**


1] Handbook of Modern Sensors: Physics, Designs and Applications, Jacob Fradden, Third Edition, Springer

2] Micromachined Transducers Sourcebook," G.T.A. Kovacs,McGraw Hill,1998.

3] Actuators basics and applications, H Janocha,Springer.

4] Sensors and Transducers, D Patranabis PHI Publications, 2nd edition(2013).


## AP-608 – Machine Learning techniques for Sensor Data Analytics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts machine learning |
| **CO-2 :** | Analyze different types of machine learning techniques |
| **CO-3 :** | Examine situations where supervised learning can be used |
| **CO-4 :** | Illustrate implementation of supervised and unsupervised learning. |
| **CO-5 :** | Summarize different applications of machine learning techniques in sensors |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | Introduction: Role of Machine learning techniques in sensor data analytics, Learning from data, Machine learning examples, Simple model for Machine Learning, Types of learning, | 6 |
| Unit II: | Theory of generalization: Feasibility of learning, Hoeffding inequality, complexity of hypothesis set, growth function, VC dimension, Training versus testing | 6 |
| Unit III | Supervised Learning: Perceptron, Linear classification, Linear regression, Logistic regression, Neural Network, Backpropagation algorithm, Support Vector Machines, Radial Basis Functions, K-nearest neighbour, Decision Trees, Bayesian Learning, Deep learning, Feature extraction and dimensionality reduction: Curse of dimensionality, Principal Component analysis, Linear discriminant analysis | 12 |
| Unit IV | Unsupervised Learning: Clustering, K-means clustering, hierarchial clustering | 10 |
| Unit V | Machine Learning issues: Overfitting, Validation, Occam’s razor, Agglomerative Sampling bias, Data Snooping | 10 |

**References Textbooks:**


1. Thomas A. Runkler, "Data Analytics: Models and Algorithms for Intelligent Data Analysis", Springer Vieweg,2012.
2. S. Haykin, “Neural Networks, A Comprehensive Foundation“, Pearson Education Inc.,2004.

3. Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification, 2nd Edition,2001.
4. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer,2006.
5. Y. S. Abu-Mostafa, M. Magdon-Ismail, and Hsuan-Tien Lin, Learning from data,AMLbook.com
6. Y. S. Abu-Mostafa, Learning from data, Caltech lectures(online)
7. S. Sarkar, Introduction to Machine Learning, NPTEL course, IIT Kharagpur(online).

## AP-609 – Sensor Technology Laboratory- II

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the basic concepts of microcomputer |
| **CO-2 :** | Analyze different types of microcomputers |
| **CO-3 :** | Examine situations where they can be used |
| **CO-4 :** | Illustrate implementation of sensor system using Raspberry Pi |
| **CO-5 :** | Summarize different applications of microcomputer in real rife |

**Syllabus:**

| **Units Divisions** | **Syllabus Details** |
|---|---|
| Unit I: | Basic experiments with Raspberry Pi<br>Smart Irrigation System |
| Unit II: | Modulation of the digital signal using Raspberry Pi<br>1. PWM generation<br>2. Changing the PWM parameters |
| Unit III | Interfacing and displaying the sensor on output LCD screen to show temperature and humidity<br>Demonstration of Internet of Things |
| Unit IV | 1. Data collecting and Data logging on a PC using Raspberry Pi<br>2. To control the actuator using RPi Servo motor<br>3. Interconnecting sensor and actuator using RPi |
| Unit V | 1. Operating Joystick using RPi and ATMEGA microcontroller<br>2. Controlling servo motor using joystick through RPi and ATMEGA |
| Unit VI | FPGA based experiments<br>Implementation Gate Circuits<br>Sequential Circuits (Finite State Machine)<br>Counters<br>UART communication with PC |
| **Lab Assignments** | |
| Lab 1 | Mini project from what has been learned in the lab |

**References Textbooks:**

## AP-610 – Advanced Sensors

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | To make students learn the concepts of advanced sensors that are used in various applications. |
| **CO-2 :** | Demonstrate the applications of these sensors practically |
| **CO-3 :** | Perform some real-time applications using advanced sensor system |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Sensor systems for Nuclear applications:** Experimental investigation of interactions of radiation with matter. Principles and mechanisms underlying nuclear radiation detection and measurements; operation of nuclear electronic laboratory instrumentation; application of gas-filled, scintillation and semiconductor laboratory detectors for measurement of alpha, beta, gamma, and neutron radiation. | **8** |
| Unit II: | **Sensors in Automotive Applications:** Introduction to Automotive Engineering, Power train Sensors, Sensors for Chassis management, Sensors for vehicle body management, Sensors for automotive vehicle convenience, Air Bag and Seat Belt Pre tensioner Systems, Passenger Convenience Systems, ModernTrends | **8** |
| Unit III | **Sensors in Biomedical Applications:** Physical Sensors in Biomedicine, Electrochemical Sensors, EEG, EMG & ECG, Detectors in Radiology, Sound in Medicine, Amperometric Biosensor, Potentiometric Biosensor, Optical Biosensor, Immunosensors, Hybrid Biosensor, In Vivo Biosensor and CommercialBiosensor, Demonstration of NMR, PET MRI | **8** |
| Unit IV | **Sensors in Environmental Applications:** Measurement techniques for water quality, Measurement techniques for chemical Pollutants, Waste water treatment, Air pollution; Its sources, Measurement techniques for air quality, Sensors in exhaust gastreatment | **8** |
| Unit V | **Metamaterial based sensors, Wearable and implantable sensors** | **8** |
| Unit VI | Night vision devices, Portable and /or wearable inertial and position, motion and acceleration sensors.Miniaturised and highly sensitive vision camera system, CBW sensors (remote operation or hand-held). | 8 |

**References Textbooks:**


1. Medical Instrumentation; Application and Design; J. G. Webster, Editor, 4th Edition,2015, JohnWiley&Sons,Inc.;NewYork.
2. John Turner, Automotive Sensors, Momentum Press, 1st Edition,2009.
3. Automotive Sensors, BOSCH,2002
4. Techniques of Radiation Dosimetry by K. Mahesh1985
5. Nuclear Radiation Detectors, S.S. Kapoor, V. S. Ramamurthy1986

6. Handbook Of Chemical AndBiological Sensors R.F Taylor, Jerome S. Schultz, 1996 by CRCPress

## AP-611 – Sensors for Defence

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | To make students understand the importance of sensors for various defence applications |
| **CO-2 :** | To interpret the working of a variety of sensors that are useful in Defence |
| **CO-3 :** | Illustrate implementation of sensor in various apparatus that are used in defence |
| **CO-4 :** | Summarize different applications of sensors in defence |
| **CO-5 :** | |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | (Micro) μ radar for personnel use and for unmanned miniaturized vehicles, SAR, GPR principles. | 8 |
| Unit II: | Health monitoring sensors (embedded, continuous or intelligent), Condition monitoring of equipment and munitions.Drug and nutraceutical (nutrition) delivery sensors and systems. Wireless body area network | 10 |
| Unit III | Sonar sensors Ultrasonic sensors, measurements for anemometers, tank or channel level, and speed through air or water, Robot sonars, counter measures, active sonar systems, sonars for military applications, antisubmarine warfare, submarine navigation, intercept sonar. | 10 |
| Unit IV | Extra Low Frequency Electromagnetic (ELFE) sensors**(**sensors for 3-30 Hz, requirements of such sensors, submarine applications, underwater communications, other applications such as pipeline gauges, ham radio, night vision), StarSensors | 10 |
| Unit V | Hyperspectral imaging and multi-sensor data fusion and I-STAR (MW, SW, LW), weapon systems for UAV, smart sensors for long range acquisition and long range laser designation, seekers EO, Laser, IR, UV, cameras miniaturize for DRONE. Emerging technology in defence sensor design and testing (can be covered by experts in the field) | 8 |
| | | |

**References Textbooks:**

1. K. Biggs, M. Burris,M . Stanley, The Complete Guide to Night Vision Paperback, CreateSpace Independent Publishing Platform,2014.
2. Inputs from DRDO scientists working in the relevantfield.
3. Research papers : Wolf, S., J. Davis, and M. Nisenoff. "Superconducting extremely low frequency (ELF) magnetic field sensors for submarine communications." *IEEE Transactions on Communications* 22.4 (1974):549-554.
4. Constable, Steven, and Leonard J. Srnka. "An introduction to marine controlled-source electromagnetic methods for hydrocarbon exploration." *Geophysics* 72.2 (2007): WA3- WA12.
5. McKerrow, P. J. "Robot perception with ultrasonic sensors using data fusion." *Systems, Man and Cybernetics, 1995. Intelligent Systems for the 21st Century., IEEE International Conference on*. Vol 2.

IEEE,1995.
6. Staszewski, Wieslaw, ChrBoller, and Geoffrey R. Tomlinson, eds. *Health monitoring of aerospace structures: smart sensor technologies and signal processing*. John Wiley & Sons, 2004

## AP-612– Nanotechnology for Advanced Sensors

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret basic concepts of nanotechnology |
| **CO-2 :** | Analyze growth of nanostructures |
| **CO-3 :** | Examine different types of nanostructures and their characterization |
| **CO-4 :** | Illustrate implementation of nanostructures for exploring different properties |
| **CO-5 :** | Summarize different applications nanostrucutures for sensors |

**Syllabus:**

| Units Divisions | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | Implications of nano size on physical and chemical properties: Density of States, 2D, 1D, 0D, Quantum size effect, large surface to volume ratio, surface functionalization, Physical Chemistry of solid surfaces, crystal structures, surface energy, chemical potential, | 8 |
| Unit II: | Fundamentals of nucleation and growth: Electrostatic Stabilization Surface charge density, Electric potential at the proximity of solid surface, Van der Waals attraction potential, Interactions between two particles: DLVO theory, Solvent and polymer, Interactions between polymer layers, Mixed steric and electric interactions | 8 |
| Unit III | Nanoscale Phenomenon: Nanoparticles, nano-clusters, nanotubes, nanowires and nanodots. Electronic structure: quantum dots, quantum wires and quantum wells, confinement of electrons energy quantization, semiconductor nanocrystals, carbon nanotubes, quantum wells. | 8 |
| Unit IV | Characterization and properties of nanomaterials: Structural Characterization, X-ray diffraction (XRD), Small angle X-ray scattering (SAXS), Scanning electron 8microscopy (SEM), Transmission electron m8icroscopy (TEM), Scanning probe microscopy (SPM), Surface plasmon resonance | 8 |
| Unit V | Nano Sensors: Metal nanoparticle-based Sensors, Quantum Dot, Nanowire-based Sensors, Carbon Nanotubes-based Sensors, Sensors Based on Nanostructures of Metal Oxide, Mass-Sensitive Nanosensors, Arrays of Nanomaterial-based Sensors, e-nose | 8 |

**References Textbooks:**

1. Nanostructures & nanomaterials Synthesis, Properties & Applications, Guozhong Cao, Imperial College Press(2004).
2. Introduction to Nanotechnology, Charles Poole Jr and Frank J Owens, Wiley India, New Delhi(2006)
3. Nanophysics and Nanotechnology, Edward L Wolf, Wiley-VCH, Verlag(2006)

4. Ramsden Jeremy, Nanotechnology, an Introduction. Elsevier(2011).
5. Florinel-Gabriel Banica,Chemical Sensors and Biosensors: Fundamentals and Applications, John Wiley and Sons(2012)

## PGC-601 – Research Methodology and IPR

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understanding the fundamentals of research and its methodology |
| **CO-2 :** | Choose the appropriate research design and develop appropriate 3 hypotheses for a research project |
| **CO-3 :** | Knowledge of manuscript preparation, patents and Intellectual property |
| **CO-4 :** | Technology transfer and application of IPR in various domains |

**Syllabus:**

| **Units Divisions** | **Syllabus Details** |
|---|---|
| Unit I: | Meaning of research problem, Sources of the research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of the research problem.Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations |
| Unit II: | Effective literature studies approach, analysis Plagiarism, Research ethics, |
| Unit III | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee |
| Unit IV | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process ofPatenting and Development: technological research, innovation, patenting, development.International Scenario: International cooperation on Intellectual Property. Procedure forgrants of patents, Patenting under PCT. |
| Unit V | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications |
| Unit VI | New Developments in IPR: Administration of Patent System. New developmentsin IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |

**References Textbooks:**

1. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for science & engineering students’”
2. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
3. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for beginners”
4. Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd,2007.
5. Mayall, “Industrial Design”, McGraw Hill, 1992.
6. Niebel, “Product Design”, McGraw Hill, 1974.
7. Asimov, “Introduction to Design”, Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”, 2016.

9. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

## PGC-602 – Audit I and II

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | |
| **CO-2 :** | |
| **CO-3 :** | |
| **CO-4 :** | |
| **CO-5 :** | |

**Syllabus:**

| Units Divisions | Syllabus Details |
|---|---|
| Unit I: | English for Research Paper Writing |
| Unit II: | Disaster Management |
| Unit III | Sanskrit for Technical Knowledge |
| Unit IV | Value Education |
| Unit V | Constitution of India |
| Unit VI | Pedagogy Studies |
| Unit VII | Stress Management by Yoga |
| Unit VIII | Personality Development through Life Enlightenment Skills |

## M. Tech. in Lasers and Electro-optics

One of the greatest scientific discoveries of the twentieth century that has led to technological advancement touching all aspects of human life is the LASER. Applications of lasers range from medical applications, communications, and industrial applications to military applications. An understanding of laser technology is essential for an engineer working in many of the present-day cutting-edge technologies. The aim of this program is to train the students in the field of lasers, fiber optics, electro-optics, and photonics that would enable them to meet the challenges in this rapidly developing field.

**Stakeholders:**

(i) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments

(ii) Graduates in the relevant field of science/technology from recognized Universities across the country.

**Eligibility for Students:**

The candidate should possess Master degree or equivalent in Physics, Applied Physics, Engineering Physics, Electronic Science, Photonics, Optics, Material Science, Instrumentation Science or any equivalent branch

**OR**

B. E./ B. Tech (Any discipline)

**Organization:** The M. Tech. programme is of four-semester duration. In each of the first two semesters there are six theory courses and one laboratory course. There will be three continuous evaluation examinations and a final semester examination for every course. Half yearly evaluation of the project takes place at the end of the third semester. At the end of the final semester, the student submits a dissertation and makes a presentation about the work carried out by him/her on the project, which is evaluated by the Internal and External examiners. Course syllabus is updated periodically to keep pace with the contemporary technological advancement.

## PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

**PEO1:** The M Tech in Lasers and Electro-Optics programme aims at developing skilled human resources in the field of Optics, lasers and Electro-optics. It will ensure the understanding of applied optics, physics and engineering laser technology, fiber optics, semiconductor photonic devices, laser systems and its various applications, catering to the emerging multidisciplinary problems faced by defence industry and civilization.

**PEO2:** With a focus on the DRDO requirements, the students will be trained to use their knowledge for the benefit of society and made aware of their social duty. This will enable them to pursue career in research, academics and industry.

**PEO3:** At the end of the programme the officer or student should be able to undertake state of the art R&D in lasers and electro-optic systems and competitively work towards development of the latest technology in line with national programmes like Make in India.

## PROGRAMME OUTCOMES (POs)

**PO1:** An ability to independently carry out research /investigation and development work to solve practical problems

**PO2:** An ability to write and present a substantial technical report/document

**PO3:** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor's program

**PO4:** Having adaptive thinking and adaptability in relation to environmental context and sustainable development

**PO5:** Having a clear understanding of professional and ethical responsibility

**PO6:** Having a good cognitive load management skill related to project management and finance

## PROGRAMME SPECIFIC OUTCOMES (PSOs)

**On completion of M. Tech. (Lasers and Electro-Optics) programme, graduates will be able to**

**PSO1:** The M. Tech in Lasers and Electro-Optics aims at developing a skilled knowledgeable Human task force in the field of Lasers and Electro-Optics serving the needs of the Defence Research and Development Organization & Tri – services (Army, Navy & Air force), Coast Guard, DGQA, DQA, Defence Public Sector units, in addition to the civilians in general. After completing M. Tech. course, the students develop an ability to carry out independent research in the area of optical devices.

**PSO2:** The dissertation work of the M. Tech. students leads to publications in high impact international journals which trains them in technical documentation and report writing.

**PSO3:** The goal of the M. Tech. in Lasers and Electro-Optics course is to generate highly competent human resources in the areas of laser development, electro-optic systems, fibre optics, applied optics, and computational photonics.

## Credit Structure

**Semester I**

| Sl No | Course Code | Course Name | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | P/T (in Hr) | |
| 1 | AP 621 | Fundamentals of Laser and Laser Systems | 3 | 1 | 4 |
| 2 | AP 622 | Optical Electronics | 3 | 1 | 4 |
| 3 | AP 623 | Introduction to Fiber Optics | 3 | 1 | 4 |
| 4 | AP 624 | Semiconductor Photonic devices | 3 | 1 | 4 |
| 5 | AP 625 | Quantum mechanics for Engineers | 3 | 1 | 4 |
| 6 | AP 701 | Laser & Electro-Optics Laboratory – I | 0 | 8 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **TOTAL** | **17** | **13** | **26** |

**Semester II**

| Sl No | Course Code | Course Name | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | P/T (in Hr) | |
| 1 | AP 631 | Laser Applications | 3 | 1 | 4 |
| 2 | AP 632 | Computational Photonics | 3 | 1 | 4 |
| 3 | AP 702 | Laser & Electro-Optics Laboratory – II | 0 | **8** | 4 |
| 4 | AP 6XX | Elective – I | 3 | 1 | 4 |
| 5 | AP 6XX | Elective – II | 3 | 1 | 4 |
| 6 | AP 6XX | Elective – III | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | **TOTAL** | **17** | **13** | **24** |

**SEMESTER III**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AP-681 | M. Tech. Dissertation Phase I | 28 | | 14 |
| | | **Total** | **28** | | **14** |

**SEMESTER IV**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | AP-682 | M. Tech. Dissertation Phase II | 28 | | 14 |
| | | **Total** | **28** | | **14** |

**List of Electives**

**AP-621 – Fundamentals of Laser and Laser Systems**

| Sr. No. | Course Code | Course |
|---|---|---|
| **Elective I,II & III** | | |
| 1 | AP 641 | High Power Lasers |
| 2 | AP 642 | Terahertz Devices and Applications |
| 3 | AP 643 | Free Space Optical Communication |
| 4 | AP 644 | Nanophotonics |
| 5 | AP 645 | Non-linear and Quantum Optics |
| 6 | AP 646 | Integrated Optics and Silicon Photonics |

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of laser technology |
| **CO-2** | Analyze the working principle of lasers |
| **CO-3** | Examine the laser radiation beams |
| **CO-4** | Illustrate and construct the practical laser systems |
| **CO-5** | Summarize different types of laser systems and its working principals |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | Light-matter interaction: Interaction of radiation with atomic systems, Einstein's coefficients, spontaneous emission, stimulated emission, Linewidth of the laser, line broadening | 6 |
| Unit II: | Lasers Oscillation: Theory of laser oscillation; Threshold condition, Rate equation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output power, Spectral distribution, Spatial distribution and polarization, Hole burning, Properties of laser beam, Pumping techniques. | 12 |
| Unit III | Laser Resonators and Gaussian Beams: The Ray Matrix, Resonator Stability, Paraxial Wave Equation, Gaussian Beams, ABCD Law for Gaussian Beams, Gaussian Beam Modes, Hermite–Gaussian and Laguerre–Gaussian Beams, Resonators for He–Ne Lasers, Diffraction, Diffraction Theory of Resonators, Beam Quality, Resonators for High-Power Lasers. | 10 |
| Unit IV | Laser Systems 1: Ruby Lasers, Neodymium-Based Lasers, Titanium Sapphire Laser, He–Ne Laser, Argon Ion Laser, $CO_2$ laser, Excimer Laser and Fiber Lasers & Amplifiers. | 9 |
| Unit V | Laser Systems 2: Semiconductor Lasers, Optical Gain in Semiconductors, Quantum Well Lasers, Quantum Dot Laser, and Quantum Cascade Laser | 9 |

**References Textbooks:**

1. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
2. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
3. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988
4. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
5. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).

## AP-622 – Optical Electronics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of optical electronics |
| **CO-2** | Analyze the working principle of ME Theory, EO, MO and AO effects |
| **CO-3** | Examine the working mechanism of different types of Optical components, EO, MO and AO effects |
| **CO-4** | Illustrate the practical use of Optical components, EO, MO and AO effects |
| **CO-5** | Summarize different applications of optical electronics devices |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Electromagnetic fields and Anisotropic media:** Wave equation, Plane waves, Reflection and Refraction of plane waves, Fresnel Formula, Wave propagation in stratified medium, propagation of Electromagnetic waves in Uniaxial and biaxial crystals, the dielectric constant tensor and the 'index ellipsoid' | **9** |
| Unit II: | **Polarisation of light and Basic optical components:** Electromagnetic theory of light, Dielectric media, Monochromatic EM waves, Absorption and dispersion, Polarisation of light, Jones Calculus, Poincare sphere. Polarisers, Quarter, Half, and Full waveplates, Beam splitters: polarizing and non-polarizing, wavelength filters, dichroic mirrors, Lenses. | **12** |
| Unit III | **Electro-optics:** Basic principles: Pockel and Kerr effects, Electro-optic devices: modulators, switches, and scanners, E.O. effect in liquid crystals; LCDs and SLMs, Applications. | **9** |
| Unit IV | **Acousto-optics:** Strain waves in solids and liquids, the strain-optic tensor; theory of Raman-Nath and Bragg diffraction; small-angle and large-angle Bragg diffraction. Accousto-optic devices: Modulators, deflectors, scanners, interconnections, and acoustooptictunable filters. | **10** |
| Unit V | **Magneto-optics**: Principles, Faraday effect, Gyrotropic permittivity, Kerr rotation and Kerr ellipticity, Applications. | **6** |

**References Textbooks:**

1. A. K. Ghatak& K. Thyagarajan, Optical Electronics, Cambridge University Press,1989. References
2. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006.
3. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
4. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000.

5. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
6. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988.
7. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.

## AP-623 – Introduction to Fiber Optics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understand the basics concepts of Fiber Optic Communication |
| **CO-2** | Understand all the sub-components of Fiber Optics |
| **CO-3** | Examine the working mechanism of Fiber Optics |
| **CO-4** | Illustrate the practical implementation of Fiber Optic Communication |
| **CO-5** | Summarize different applications of Fiber Optic Communication |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Optical Fibers:** Light Propagation in Optical Fibers, Optical fiber Modes and Configurations, Mode Theory for Circular waveguides, SM and GI Fibers, Fiber Materials, PhC fibers, Fiber fabrication.<br>**Optical Fibers Characteristics:** Fiber Attenuation, Absorption losses, scattering losses, Radiation losses, Bending losses, Measurement of losses, Dispersion in fibers, Effect of dispersion in the communication link, Dispersion reduction, and compensation techniques. | **12** |
| Unit II: | **Power Launching and Coupling:** Source to Fiber launching and Launching Schemes for Coupling Improvements. Fiber to Fiber joints, Laser coupling to SM fiber, Fiber splicing, Optical Fiber Connector.<br>**Optical Receivers:** Basic Concepts, Common Photodetectors, Receiver Design, Receiver Noise, Coherent Detection, Receiver Sensitivity, Sensitivity Degradation, Receiver bandwidth, and Performance | **9** |
| Unit III | **Fiber Amplifier:** Optical Amplification in rare-earth-doped fibers, Types of Fiber Amplifiers, EDFA, Amplifier Noise, Optical SNR, System Application, Raman Amplifiers, Wideband Optical Amplifier | **9** |
| Unit IV | **Optical Fiber Sensors:** Introduction, Classification and Types of Optical Fiber Sensors, Sensor Modulation techniques, Fiber Bragg Grating Sensors: Principle and Applications. | **9** |
| Unit V | **Overview of Optical Fiber Communication:** Lightwave communications, Optical Spectrum Bands, and Visible Units, Network Information rate and WDM concepts. Key Elements of fiber optics system, Standards for Optical fiber communications. | **9** |

**References Textbooks:**

1. A.K. Ghatak & K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press 1998
2. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008
3. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998

4. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998
5. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988

## AP-624 – Semiconductor Photonic devices

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understand the basics of Semiconductor Physics |
| **CO-2** | Interpret all the optical properties and processes in semiconductors |
| **CO-3** | Examine the working mechanism of different kinds of LEDs and LASERs |
| **CO-4** | Illustrate the implementation of Modulation and Switching Devices |
| **CO-5** | Explain different types of photodiodes and photodetectors |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Review of Semiconductor Physics:** Energy Bands, Density of States, Fermi-level, PN Junction, Homo and Hetero Junction, Quantum Wells. Semiconductor Optoelectronic materials, Electron-hole pairs | **9** |
| Unit II: | **Light Emitting Diodes:** The electroluminescence Process, LED materials, Device configuration and Efficiency, LED structures, LED performance characteristics, Frequency response and Modulation bandwidth. LEDs for display and Lighting. | **9** |
| Unit III | **Semiconductor Lasers:**Junction Laser Operating Principles, Threshold Current, Heterojunction Laser, Distributed Feedback Lasers and Distributed Bragg Reflector, Ring Lasers: Single and Double, Master Oscillator Power Amplifier. VCSELS and Laser Diode Arrays. Advanced Semiconductor Laser: Quantum Well and Quantum Cascade Laser, Laser Modulation Bandwidth. | **9** |
| Unit IV | **Modulation and Switching Devices:** Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator. | **9** |
| Unit V | **Photodetectors:** Types of photodetectors, Photoconductors, Junction photodiode, PIN photodiode and APD, Quantum Well IR Detectors, High Speed Measurements, Detectors for long wavelength operation, Wavelength selective detection, Coherent detection. CCDs and PICs. | **9** |

**References Textbooks:**

1. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).
2. G. Ghione, Semiconductor Devices for High-Speed Optoelectronics, Cambridge University Press (2009)
3. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communication, Oxford University Press (2007), 6$^{th}$ Ed., Ch.15-17.
4. G. Keiser, Optical Fiber Communications, McGraw-Hill Inc., 3$^{rd}$ Ed. (2000), Ch.4, 6.
5. J. Singh, Semiconductor Optoelectronics: Physics and Technology, McGraw-Hill Inc. (1995).

6. J. M. Senior, Optical Fiber Communication: Principles and Practice, Prentice Hall of India, 2nd Ed. (1994), Ch.6-8.
7. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17, and 18.
8. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021).

## AP-625 – Quantum mechanics for Engineers

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understand the basic concepts of quantum mechanics Physics |
| **CO-2** | Interpret the physical meaning of formulation in quantum mechanics |
| **CO-3** | Examine different 1D problems in quantum mechanics |
| **CO-4** | Illustrate the implementation to 1 electron atoms |
| **CO-5** | Explain Quantum mechanics to Lasers |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | Introduction: Thermal radiation, Plank's postulates, The Schrödinger equation, Statistical interpretation, probability, normalization, momentum, the uncertainty principle | **9** |
| Unit II: | Time Independent Schrödinger: stationary states, infinite square well, harmonic oscillator, free particle, delta function potential, finite square well | **9** |
| Unit III | Formalism: Hilbert's space, observables, eigen function of Hermitian operator, statistical interpretation, Dirac notation | **9** |
| Unit IV | One electron atoms: solution of Schrödinger equation in 3D, eigen values, quantum numbers, and degeneracy, orbital angular | **9** |
| Unit V | Quantum statistics: indistinguishability and quantum statistics, quantum distribution functions, Boltzmann distribution as an approximation to quantum distributions, The Lasers | **9** |

**References Textbooks:**

1. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing
2. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing
3. Quantum Mechanics by B H Bransden and C J Joachain Pearson Publishing
4. Zettili, Nouredine. "Quantum mechanics: concepts and applications." John Wiley and Sons, Ltd., Publishing 2nd Ed. (2009).

## AP-631 – Laser Applications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarize to a variety of applications on lasers |
| **CO-2** | Interpret how laser-based metrological techniques work |
| **CO-3** | Understand laser spectroscopy applications |
| **CO-4** | Investigate various methods of how a laser can be used for defence applications |

| | |
|---|---|
| **CO-5** | Summarize different applications of lasers |

**Syllabus:**

| Units | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Laser Metrology: Laser** for measurement of distance, length, velocity, acceleration; rotation sensing; RLG and FOG. | **6** |
| Unit II | **Laser Spectroscopy:** IR absorption Spectroscopy, Laser Raman spectroscopy, Laser induced breakdown spectroscopy (LIBS), laser-induced fluorescence (LIF), Tunable diode laser spectroscopy (TDLS), Terahertz spectroscopy, Photoacoustic spectroscopy, Instrumentation in laser spectroscopy, Isotope Separation & Enrichment. Bio-Medical Application of Lasers | **12** |
| Unit III | **Holography:** Holographic interferometry and applications; Holography for non – destructive testing – Holographic components | **6** |
| Unit IV | **Industrial Application of Laser:** Laser cutting, Laser welding, Laser drilling, Laser marking, Photolithography, Laser-based unmanned ground vehicles | **9** |
| Unit V | **Defence Applications:** Low power laser applications including Laser Range finders-LRF (DPSSL, Eye Safe & High PRF) & Laser Target Designators; Dazzlers, Laser Warning receivers, Infrared counter measures, Laser Guidance; Laser-based navigation; Laser-based imaging; Laser-based remote sensing: Laser radar, laser radar seekers, LIDAR basic concept and applications | **12** |

**References Textbooks:**

1. J.F. Ready, Industrial Applications of Lasers. Academic Press, 1997 2nd Edition
2. G.K. Ackermann & J. Eichler, Holography: A practical approach, John Wiley & sons, 2008
3. H. Wichel, Laser Beam Propagation in the Atmosphere, SPIE Press 1990
4. K. Bharat, Laser Safety Tools and Training, CRC Press 2009
5. K. Nagothu, New Paradigms for Underwater Communication, ProQuest 2009

## AP-632 – Computational Photonics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of Simulation and Modelling methodology |
| **CO-2** | Analyse the modelling results of photonics devices |
| **CO-3** | Examine the working photonics devices with different methods |
| **CO-4** | Demonstrate the practical implementation |
| **CO-5** | Understand the nanofabrication |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Mode Solver Method:** Theory of fully vectorial mode solvers in 2D and 3D structures, low-index polymer waveguides, high-index silicon (SOI) and GaAs/AlGaAs waveguides, buried, etched (rib, | **12** |

| | | |
|---|---|---|
| | ridge), and diffused geometries commonly used in opto-electronics slot waveguides, slanted-wall and graded structures, plasmonic and microwave waveguides, | |
| Unit II: | **Beam Propagation Method:** Theory and working of beam propagation method, Tutorials on MMI couplers, optical gratings, co-directional couplers or polarization converters. | **9** |
| Unit III | **FDTD Method:** Theory and working of FDTD method, Tutorials on photonics band gap simulation: 2D and 3D of different crystal lattices. | **9** |
| Unit IV | **Fiber Optics Modeling:** Simulation and modeling of single mode and multimode optical fiber using mode solver, FBG and Chirped FBG synthesis, photonic crystal fiber simulation | **9** |
| Unit V | **Nanodesign:** Mask designing for nanofabrication of different device geometry | **6** |

**References Textbooks:**


1. S. Sujecki, Photonics Modelling and Design, CRC Press, 2015.
2. K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000.
3. A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method. Norwood, MA: Artech House, 1995.


## AP-641 – High Power Lasers

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of HPL technology |
| **CO-2** | Analyze the working principle of different types of HPLs |
| **CO-3** | Examine the working mechanism of High Power Fiber Lasers |
| **CO-4** | Demonstrate the practical implementation of HPLs |
| **CO-5** | Understand the Safety & legislations related to HPL |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **High Power Lasers Source:** Criteria for High Power Capability, High Power Laser Resonators and Beam Quality Considerations, High Power Lasers: HF, DF, COIL, $CO_2$ Gas Dynamic Laser, Alkali Laser, High Power Solid State Laser, Free electron laser (FEL), HPL beam combining techniques, Thermal management. | **9** |
| Unit II: | **High Power Fiber Laser and Amplifiers:** Introduction, Materials, Fiber design, Fiber laser components, High Power Pulse Fiber Lasers, High Power cw Fiber Laser Systems, High Energy ns and fs Fiber Laser Systems, Mode-Locked fs Fiber Lasers, Single Frequency Fiber Lasers, Beam Combining. | **9** |
| Unit III | **Beam Director Technology**: Design considerations for beam director, threat alerting system, target acquisition & tracking system, laser beam pointing, target sightline stabilization, system | **9** |

| | | |
|---|---|---|
| | processor & boresight functions, HPL beam control, battle damage assessment, Effects of atmosphere on HPL beam propagation; Adaptive optics | |
| Unit IV | Applications to protect against military threats: laser protection from missiles, laser to address threat of new nuclear weapons, protecting assets from directed energy lasers, lidar protects from chemical/biological weapons | **9** |
| Unit V | **Safety aspects of laser & legislation:** Effective laser safety, laser safety standards; hazard classification of lasers, maximum permissible exposure (MPE), hazard distances, zones, calculation of NOHD; Potential hazard to personnel: eye anatomy & hazards, hazards to skin, other potential hazards(non-beam hazards; common causes of laser incidents; safety operating guidelines/procedures; field testing & planning, range laser safety officer; Legislation: Protocol IV . | **12** |

**References Textbooks:**


1. High Power Lasers–Directed Energy Weapons Impact on Defence and Security, A. Mallik, DRDO MONOGRAPHS/SPECIAL PUBLICATIONS SERIES, 2012
2. H. Injeyan and G. Goodno, High Power Laser Handbook, McGraw-Hill Professional; 1 edition (April 25, 2011)
3. AK Jha, Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, Wiley, 2000
4. Ter-Mikirtychev and Vartan, Fundamentals of fiber lasers and fiber amplifiers, Springer Series in Optical Sciences, Vol. 181, 2014.
5. B. Zohuri, Directed Energy Weapons Technologies, CRC Press, 1 ed., 2012.
6. V VApollonov, High-Power Optics: Lasers and Applications, Springer International Publishing, Switzerland, 2015
7. Alastair D. McAulay, MILITARY LASER TECHNOLOGY FOR DEFENSE: Technology for Revolutionizing 21st Century Warfare, John Wiley & Sons, Singapore, 2011


## AP-642 – Terahertz Devices and Applications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of terahertz technology |
| **CO-2** | Analyze the working principle of different types of terahertz signal sources |
| **CO-3** | Examine the working mechanism of different types of terahertz detectors |
| **CO-4** | Illustrate the practical implementation of fabrication of components and circuits for terahertz systems |
| **CO-5** | Summarize different applications of terahertz technologyfor imaging, sensing and communications |

**Syllabus:**

| Units | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Basics of Terahertz Technology:** Electromagnetic radiation and propagation fundamentals, Introduction to terahertz technology, | **9** |

| | | |
|---|---|---|
| | Background, Terahertz gap, Key technological issues for terahertz technology, Advantages and limitations of terahertz waves, Material properties at mm and sub-mm frequencies | |
| Unit II | **Terahertz Sources:** Terahertz sources based on electronics: Diodes, transistors, resonant tunnelling diodes, vacuum electronics; Terahertz sources based on photonics: Non-linear crystals, quantum cascade lasers, plasma-based source; Terahertz sources based on optoelectronics: Photomixer, photoconductive antenna and its types; Noises at terahertz frequencies in different sources | **9** |
| Unit III | **Terahertz Detectors:** Terahertz detectors based on electronics: HOT electron bolometer, Heterodyne SIS receivers: Theory and design, Superconducting tuning circuitries, HEB heterodyne receivers: Theory and design, Terahertz MMICs: Theory and design, Terahertz detectors based on photonics | **9** |
| Unit IV | **Terahertz Components:** Terahertz components: Metamaterials and plastic fibers, HEMT cryogenic amplifiers: Theory and design, Antennas, Filters, Waveguides, Beam Splitter, Beam Combiner, Polarizer, Mirrors, Isolator, Circulator, Cameras, Fabrication Technologies, Metamaterial THz devices, Spintronic THz components. | **9** |
| Unit V | **Terahertz Applications:** Terahertz applications: Time domain Colinear and Non-colinear terahertz spectroscopy, Optical-pump-THz-probe Spectroscopy, Terahertz Imaging, Terahertz sensing and analysis, Terahertz wireless communication, Terahertz remote-sensing, 3D terahertz tomography system, Industrial applications, Space Communication, Cutting-edge terahertz technologies | **9** |

**References Textbooks:**


1. A. Rostami, H. Rasooli, H. Baghban, Terahertz Technology: Fundamentals and Applications, Germany, Springer, 2011.
2. R. E. Miles, P. Harrison, D. Lippens, Terahertz Sources and Systems “, Dordrecht: Kluwer, Springer, 2000.
3. K. Sakai, Terahertz Optoelectronics, Springer, 2004.
4. H.-J. Song, T. Nagatsuma, Handbook of Terahertz Technologies, Devices and applications, Pan Stanford Publishing Pte. Ltd., 2015.
5. D. Saeedkia, Handbook of Terahertz Technology for Imaging, Sensing and Communications, Woodhead Publishing, 2013.


## AP-643 – Free Space Optical Communications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of Free Space Optical Communication |
| **CO-2** | Understand all the sub-components |
| **CO-3** | Examine the working mechanism of FSOC |
| **CO-4** | Illustrate the practical implementation of FSOC |
| **CO-5** | Summarize different applications of FSOC such as VLC/UWOC |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Introduction FSOC/OWC,** Basic Link configuration of FSOC, various application areas of FSOC, Indoor Channel modelling, various link configurations, Artificial light interference effects in indoor channel. | **9** |
| Unit II: | **Channel Modelling -Outdoor channel,** Atmospheric channel loss related issues, Atmospheric turbulence effects, Measurement of $C_n^2$, Various atmospheric turbulence models, Effects of atmospheric turbulence on laser beam propagation, Realization of atmospheric effects on OWC test beds | **9** |
| Unit III | **Modulation Techniques:** Importance of modulation in FSO, various modulation formats, selection criteria for modulation, basic modulation schemes OOK,PPM, PIM, DH-PIM, BPSK etc. and error propagation<br>**FSO link Performance under atmospheric turbulence:** performance of FSO link in various modulation formats, comparison across the modulation formats, the turbulence-induced penalty in FSO link, Link budget analysis, Power budget analysis | **12** |
| Unit IV | **Mitigation techniques:** introduction, aperture averaging, various diversity techniques, spatial diversity, time diversity coding techniques, adaptive optics and other techniques. | **9** |
| Unit V | **Laser beam Tracking, pointing & acquisition:** Acquisition and Tracking systems, System description, Acquisition methodology, tracking and pointing control system, RF cross-link system design, link equation | **9** |

**References Textbooks:**


1. Arun K. Majumdar, Free-Space Laser Communications Principles and Advances. Springer Publications
2. Hemani Kaushal, Free Space Optical Communication. Springer Publication
3. J. Franz and V.K. Jai, Optical Communication Systems. Narosa Publications
4. Morris Katzman, Laser Satellite Communications. Prentice Hall Inc 1991
5. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K. Jha


## AP-644 – Nanophotonics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarization to the concept of Metamaterials |
| **CO-2** | Illustration of Optical Properties in Metamaterials |
| **CO-3** | Examine Surface Plasmon Resonance |
| **CO-4** | Analyze Photonic Bandgap Crystals in different dimensions |
| **CO-5** | Understanding the Importance of Silicon Photonics and Its Applications |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I | Basics of Nanophotonics: Photons and electrons, Quantum confinement effects, 2D, 1D, 0D structures, their growth and properties | **9** |
| Unit II: | **Metamaterials:** Definition of Metamaterials (MTMs) and Left-Handed (LH) MTMs, **Fundamentals of LH MTMs** Left-Handedness from Maxwell's Equations, Entropy Conditions in Dispersive Media, Boundary Conditions, Reversal of Doppler Effect, Reversal of Vavilov-ˇCerenkov Radiation, Reversal of Snell's Law: Negative Refraction, Focusing by a "Flat LH Lens" | **9** |
| Unit III: | **Metamaterial in Optics:** Optical Properties of Metal-Dielectric Composites, Optical Magnetism, Negative-refractive Index, Perfect lens and Cloaking objects. | **9** |
| Unit IV | **Surface Plasmon Resonance:** Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation od surface plsmons, surface Plasmon properties, SPR spectroscopy | **9** |
| Unit V | **Photonic band gap crystals:** Photonics Band-Gap: Introduction to Photonics crystal, Photonic Band Structures, One dimensional, Photonic crystal: Origin of Photonics Band Gap, Size of the band gap, Evanescent Modes in Photonics Band gaps, Two-dimensional Photonic crystal: Two-dimensional Bloch States, Square Lattices (Dielectric Columns and Veins), Three-dimensional Photonic crystal: Three-dimensional lattices, Designing photonics crystal for application: A Mirror, A Waveguide and A Cavity. | **12** |

**References Textbooks:**


1. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, Christophe Caloz,Tatsuo Itoh, John Wiley and Sons,2006
2. Optical Metamaterials, Fundamentals and Applications, Wenshan Cai Vladimir Shalaev, Springer, 2010.
3. John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade,Photonic Crystal: Molding Light Flow of Light, Princeton University Press, 2008.
4. Graham T. Reed and Andrew P. Knights, Silicon Photonics: An Introduction, JohnWiley and Sons Ltd, 2004
5. Metamaterials: Physics and Engineering Explorations, Nader Engheta Richard W. Ziolkowski, Wiley and Sons,2006
6. Negative-Refraction Metamaterials Fundamental Principles and Applications, G. I. Eleftheriades K. G. Balmain,Wiley and Sons,2005


## AP-645 – Nonlinear and Quantum Optics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of nonlinear process |
| **CO-2** | Analyse the optical response of NLO devices |
| **CO-3** | Examine the working principal of different NLO devices |

| | |
|---|---|
| **CO-4** | Illustrate the application of NLO for ultrashort pulse generation |
| **CO-5** | Understand the quantum optics |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Nonlinear optics basics**: Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients | **9** |
| Unit II: | **Second order nonlinear effects**: Second harmonic generation, Phase matching condition, Various phase matching techniques, Characterization of second order nonlinear optical materials, Periodically poled materials and their applications in nonlinear optical devices. Sum and difference frequency generation, Optical parametric amplification (OPA) and oscillation (OPO), Analysis of OPA and OPO; practical device configurations and applications. | **9** |
| Unit III | **Third order and Higher order effects**: Third harmonic generation, Four wave mixing and Self-phase-modulation Optical Kerr effect, Self-focusing, Optical Solitons; Optical phase conjugation and Optical bistability. Stimulated Raman Scattering and Stimulated Brilluoin Scattering. | **9** |
| Unit IV | **Ultrafast Optics**: Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Nonlinear Schrödinger equation, Supercontinuum generation. | **6** |
| Unit V | **Quantum Optics**: Review of Quantum Mechanics basics, Quantization of electromagnetic fields, Number states, Coherent states and squeezed states of light and their properties, Beam splitters and interferometers, spontaneous parametric down conversion, concept of quantum entanglement, application of optical parametric processes to generate squeezed states of light and entangled states, applications of quantum optics. | **12** |

**References Textbooks:**


1. A. Yariv and P. Yeh, Optical waves in crystals: propagation and control of laser radiation, Wiley, New York, 2002.
2. Peter E. Powers, Fundamentals of Nonlinear Optics, CRC Press, 2011.
3. A. Yariv, Quantum Electronics, John Wiley, 1989.
4. Y. R. Shen, The Principles of Non-linear Optics, John Wiley & Sons, 2003
5. R. W. Boyd, Nonlinear Optics, Academic Press, 2008.
6. H.M. Moya-Cessa and F. Soto-Eguibar, Introduction to Quantum Optics (Rinton Press 2011).
7. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, 2nd ed..John Wiley, 2007.
8. A. M. Weiner, Ultrafast Optics, Wiley Books, 2008
9. Gerry, Christopher; Knight, Peter, Introduction to Quantum Optics. Cambridge University Press, 2004.
10. L. Mandel, E. Wolf, Optical Coherence and Quantum Optics (Cambridge 1995).
11. D. F. Walls and G. J. Milburn, Quantum Optics (Springer 1994).

## AP-646 – Integrated Optics and Silicon Photonics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarization to the concept of Optical Waveguides |
| **CO-2** | Analysis of Guided Wave Interaction |
| **CO-3** | Understanding of Planner and Channel Waveguide Devices |
| **CO-4** | Illustrate the Silicon-on-Insulator (SOI) Photonic devices |
| **CO-5** | Advanced demonstration of Silicon Photonic Devices |

**Syllabus:**

| **Units Divisions** | **Syllabus Details** | **Hours** |
|---|---|---|
| Unit I: | Optical waveguides: Introduction to optical waveguides Differences between optical and microwave waveguides, Planar and channel waveguides, General characteristics of guided waves, Formation of optical waveguides on LiNb03, GaAs, InP, Si substrates. Electromagnetic analysis of modes in optical waveguides; The asymmetric planar waveguide, TE and TM modes in planar waveguides. Rectangular and channel waveguides; modal solutions using the effective index and perturbation methods. | 12 |
| Unit II: | **Guided-wave interactions**: Coupled mode analysis of coupled waveguide structures., Examples of coupled mode analysis - the grating reflection filter, and the directional coupler. | **6** |
| Unit III | Planar and Channel waveguide devices: Excitation and detection of planar guided waves, Diffraction, focusing, and collimation in planar waveguides, Diffraction devices, The Star coupler, Passive waveguide components; The power divider, Wavelength filters/multiplexers, Waveguide reflectors, Resonators, The optical time delay line. Segmented waveguides; electro-optic andacousto-optic waveguide devices. Directional couplers, optical switch; phase andamplitude modulators, Y-junction, power splitters, Arrayed waveguide devices.Tapered couplers, nonlinear effects in integrated optical waveguides. | 12 |
| Unit IV | **Silicon-on-Insulator (SOI) Photonics:** Introduction, Silicon-on-Insulator waveguides, Effective Index Method of Analysis, Large Single-mode Rib Waveguides, Refractive Index and Loss Coefficient in Optical Waveguides, Coupling to the Optical Circuit; Grating Couplers, Butt Coupling and End-fire Coupling. Optical Modulation Mechanisms in Silicon, fabrication of Silicon Waveguide Devices. | **9** |
| Unit V | **Photonic Devices:** Optical Phase Modulators and Variable Optical Attenuators, MachZehnder Interferometer, Waveguide Bend, Waveguide-to-Waveguide Coupler, Arrayed Waveguide Grating (AWG), Waveguide Couplers for Small-dimension Waveguides, Advantage and Disadvantage of Silicon Photonics. Silicon **Light-emitting Devices:** Erbium Doping, Low-dimensional Structures, Dislocation-engineered Emitters | **9** |

**References Textbooks:**

1. William S. C. Chang, Fundamentals of Guided-wave optoelectronics devices, Cambrige University Press,2009
2. G. T. Reed and A. P. Knights, Silicon Photonics An Introduction, John Wiley & Sons, 2004
3. T. Tamir, Ed. Integrated Optics, Springer, 2nd Ed., 1983.
4. R. Hunsperger, Integrated Optics: Theory and Technology" 6th Ed., Springer - 2009.
5. H. Nishihara, M. Haruna, and T. Suhara "Optical Integrated Circuits", McGraw-Hill, 1988.
6. K Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2005.
7. *Ghatak* .A.K., and K. *Thyagarajan* ,Optical Electronics, Cambridge, 1989.

## PGC-601 – Research Methodology and IPR

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the fundamentals of research and its methodology |
| **CO-2** | Choose the appropriate research design and develop appropriate 3 hypotheses for a research project |
| **CO-3** | Knowledge of manuscript preparation, patents and Intellectual property |
| **CO-4** | Technology transfer and application of IPR in various domains |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | Meaning of research problem, Sources of the research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of the research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations | **9** |
| Unit II: | Effective literature studies approach, analysis Plagiarism, Research ethics | **6** |
| Unit III | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee | **6** |
| Unit IV | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. | **9** |
| Unit V | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications | **9** |
| Unit VI | New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. | 9 |

**References Textbooks:**

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
a. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
3. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
4. Mayall, "Industrial Design", McGraw Hill, 1992.
5. Niebel, "Product Design", McGraw Hill, 1974.
6. Asimov, "Introduction to Design", Prentice Hall, 1962.
7. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.
8. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

## AP 701 Laser & Electro-Optics Laboratory – I

**Pre-requisite: Laser safety tutorials/video demonstration of Laser safety followed by written test**

1. Michelson Interferometer: Setting up Michelson interferometer using a highly monochromatic laser source, evaluation of laser wavelength by fringe counting.
2. Beam Width, Divergence and $M^2$ measurement of He-Ne/Diode Laser with and without collimation lens.
3. Determination of the Electrical and Optical Characteristics of LED and Laser diode.
4. Designing of Optical Window, Concave and Convex Lens
5. Detection of polarisation states using polarisation components like polarizers, waveplates etc.
6. Analysis of various light source spectra using OSA.
7. Determination of the refractive index profile of a multimode and single mode fiber by the transmitted near field scanning technique and measurement of NA.
8. Macro and Microbending loss in optical fibers and its application
9. Measurement of Photodiode characteristics
10. Study of Fraunhofer diffraction pattern of a rectangular and circular aperture.
11. Fiber optic link design
12. Measurement of attenuation and dispersion in optical fibers
13. Fiber to Fiber splicing and splicing loss measurement.
14. Setting up of Mach-Zender interferometer
15. Measurement of Photoluminiscence of an active materials using PL measurement setup.
16. Design of driver circuit for LED and Laser diode
17. Characterization of Erbium Doped Fiber Amplifier
18. Pulse width measurement of different laser using auto-correlator.
19. Holography
20. One Mini project (**compulsory for all**)

Note: Every student should perform a minimum of 15 experiments from the above list.

## AP 702 Laser & Electro-Optics Laboratory – II

1. Characterization of Fiber Bragg grating
2. Phase Sensitive detection technique using lock-in amplifier.
3. Power budget analysis using Optical Time Domain Reflectometer (OTDR)
4. Study of Time Division Multiplexing of digital signals

5. Study of a Wavelength Division Multiplexing(WDM) in optical fiber link
6. Study of Add/drop multiplexer
7. Study of Bit error rate and Eye pattern analysis
8. Setting up a Free space Laser Communication experiment link
9. Study of Electro-optic effect (Pockel and Kerr)
10. Measurement of third order nonlinear optical coefficient using Z-scan
11. Design of a fiber optic sensor
12. Line coding and decoding, voice coding
13. Measurement of insertion loss of an isolator, coupler and multiplexer
14. Beat length measurement in birefringent fibers.
15. Laser Raman Spectroscopy Experiments
16. $M^2$ measurement of different lasers
17. Measure the effect of the relative motion by using SAGNAC Interferometer
18. Mini project (**compulsory for all**)

    **Note**: Every student should perform a minimum of 15 experiments from the above list.

# SCHOOL OF QUANTUM TECHNOLOGY

## M. Tech. in Quantum Computing
## (Spl: Quantum Communication & Sensing)

**About:** Quantum technology is an emerging field of physics and engineering, which relies on the principles of quantum physics. It is about creating practical applications—such as quantum computing, quantum sensors, quantum cryptography, quantum simulation, quantum metrology, and quantum imaging—based on properties of quantum mechanics, especially quantum entanglement, quantum superposition, and quantum tunneling. The idea of starting a quantum technology program is keeping in mind the need for high-quality human resources for India. It will be one of the world's leading academic organizations engaged in quantum technologies.

**Eligibility:** The candidate should possess a Master/Integrated degree or equivalent in Physics, Applied Physics, Electronic Science, Photonics
(OR)
B.E. / B.Tech / BSc. (Eng.) or equivalent in any branch

**Stakeholders:**

i. Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments
ii. Graduates in the relevant field of science/technology from recognized Universities across the country.

**Organization:** The M. Tech. Program is of four-semester duration. In each of the first two semesters, there are five classroom teaching classes and one experimental laboratory. There will be continuous evaluation examinations, three internal examinations, and a final semester examination for every course. A half-yearly evaluation of the project takes place at the end of the third semester. At the end of the last semester, the student submits a thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners.

### SEMESTER I

| Sl. No. | Course Code | Course | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | **QT601** | Introduction to optics and photonics | 4 | 0 | 4 |
| 2 | **QT602** | Introduction to Quantum Mechanics | 4 | 0 | 4 |
| 3 | **QT603** | Introduction to Quantum Computing | 4 | 0 | 4 |
| 4 | **QT604** | Quantum information theory | 4 | 0 | 4 |
| 5 | **QT605** | Digital System Design and DSP using FPGA. Control systems, and Lock-in amplifiers. FPGA implementation for quantum computation systems, QKD & post-processing | 3 | 2 | 4 |
| 6 | **QT610** | Quantum Technology Laboratory-1 | 0 | 8 | 4 |
| 7 | **PGC-601** | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **21** | **10** | **26** |

## SEMESTER II

| Sl. No. | Course Code | Course | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | **QT 606** | Advanced Quantum communications | 4 | 0 | 4 |
| 2 | **QT 607** | Quantum Metrology and Sensing | 4 | 0 | 4 |
| 3 | **QT 608** | Quantum Computing II | 4 | 0 | 4 |
| 4 | **QT 611** | Quantum Technology Laboratory-2 | 0 | 8 | 4 |
| 5 | | Elective I | 4 | 0 | 4 |
| 6 | | Elective – II | 4 | 0 | 4 |
| 7 | **PGC-602** | Audit Course | 2 | 0 | 0 |
| | | **Total** | **22** | **8** | **24** |

**List of Electives**

| Sl No | Course Code | Course |
|---|---|---|
| **Elective I & II** | | |
| 1 | **QT 621** | Classical and Quantum Cryptography |
| 2 | **QT 622** | Nonlinear and Quantum Optics |
| 3 | **QT 623** | Machine Learning |

## SEMESTER III

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | **QT 651** | M.Tech Dissertation Phase – I | 28 ** | | 14 |
| | | **Total** | **28** | | **14** |

** Contact hours/week

## SEMESTER IV

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | **QT 652** | M.Tech Dissertation Phase – II | 28 ** | | 14 |
| | | **Total** | **28** | | **14** |

** Contact hours/week

## PROGRAM OUTCOMES

| | |
|---|---|
| **PO1** | To accustomed and gain sufficient knowledge in all verticals of Quantum technology (Quantum computing, Quantum communications, and Quantum sensing) |

| | |
|---|---|
| **PO2** | An ability to independently carry out research and development work to handle actual problems utilizing quantum resources |
| **PO3** | Mastery over the area of specialization at a level higher than their previous degree to meet the requirements of emerging Quantum-based laboratories and companies |
| **PO4** | Next-generation workforce in Quantum technology |

## PROGRAM SPECIFIC OUTCOMES

| | |
|---|---|
| **PSO1** | Practical implementation of the knowledge of basic and advanced optics, electronics, quantum technologies, and quantum algorithm tools to integrate into the systems to enhance their performance and solve complex problems in nature. |
| **PSO2** | Fluent in design and model systems for Quantum communications and Quantum sensing using appropriate technology and software tools. |
| **PSO3** | Able to handle and develop quantum technologies towards quantum-enabled society |

## QT 601: INTRODUCTION TO OPTICS AND PHOTONICS

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | **Ray optics and Maxwell's equations:** Maxwell's equations and solution to Maxwell's equation. Paraxial waves, ray optics and ABCD matrices. Propagation of EM waves in free-space and material media. Helmholtz Equation, electric constant and refractive index. Vector and Scalar Potentials and Gauge invariance. Polarisers, Quarter, Half, and Full waveplates, Beam splitters: polarizing and non-polarizing, wavelength filters, dichroic mirrors, Lenses |
| **Unit II** | **Wave optics**: Basic postulates of wave optics, Monochromatic waves, plane waves, spherical waves, paraxial waves. Helmholtz equation. Interference of waves. The polarization of light, Stokes vector, Jones Calculus. |
| **Unit III** | **Gaussian and special beams**: Complex amplitude of Gaussian beam, Parameters of Gaussian beam, transmission of Gaussian beams through optical components. Hermite-Gauss and Laguerre Gauss beams, nondiffracting beams |
| **Unit IV** | **Fourier Optics**: Propagation of light in free space, Fourier transform using a lens, Fraunhofer and Fresnel diffraction. |
| **Unit V** | **Lasers:** Resonator theory, Basic laser theory, Laser oscillators and amplifiers, Coherence, Diode laser, DPSS lasers, Distributed Fiber Laser and VECSELS, Generation on nanosecond and femtosecond pulses, Group velocity and Pulse Dispersion |
| **Unit VI** | **Imaging resolution:** Limits on resolvability (abbe diffraction limits and beat the limits of classical diffraction, classical techniques, NSOM, EIT, super-resolution, entangled photons) |
| **Unit VII** | **Wave guides and Optical Fibers**: Light Propagation in Optical Fibers, Optical fiber Modes and Configurations, Mode Theory for Circular waveguides, Single Mode, Multi-mode and Polarization Maintaining Fibers. Fiber Attenuation, |

| | |
|---|---|
| | Absorption losses, Scattering losses, Radiation losses, Bending losses, Dispersion in fibers, Effect of dispersion in communication link |

***References***


1. B E A Saleh and M C Teich, Fundamentals of Photonics, John Wiley and Sons, 3rd edition, 2019.
2. E. Hecht, Optics, Pearson Education India, 2012
3. D. H. Goldstein, Polarized Light, 3rd edition, Taylor and Francis group, 2011
4. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
5. A. K. Ghatak and K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press (1998).


**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Understanding the fundamentals of ray optics, wave optics, and Gaussian optics. |
| **CO-2** | Mathematical description of light propagation through various optical mediums. |
| **CO-3** | Basics of laser technology and their propagation through waveguides and fibers. |
| **CO-4** | Introduction to waveguides and imaging |

## QT 602: QUANTUM MECHANICS

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | **Basic introduction to Quantum Mechanics:** Wave-particle duality and matter waves. The double slit experiment. The Stern-Gerlach experiment. The Schrödinger equation, square integrable functions and wavefunctions. Particle in an infinite potential well and bound states. Quantum Tunneling. Position and momentum eigenstates. |
| **Unit II** | **Linear algebra and complex vectors spaces:** Hilbert space. State vectors. Basis sets and the Gram-Schmidt orthogonalization. Unitary operators, operator adjoints and self-adjoint operators (Hermitian operators). Eigenvalues and eigenstates. Eigen basis and spectral decomposition of operators. The Hamiltonian operator. Position, momentum and energy eigenstates. The density operator. Complete set of commuting operators and Observables in quantum mechanics. |
| **Unit III** | **Quantum Measurements:** Projective measurements rank one projectors. Positive Operator Valued Measures. Expectation values and Variance. The Heisenberg uncertainty relations. Pauli's exclusion principle, Fermi and Bose particles. |
| **Unit IV** | **Harmonic Oscillator, Angular momentum and other problems:** The Linear Quantum Harmonic Oscillator. Creation, annihilation operators and number operators their properties. Spin- half quantum systems and Pauli operators. The Angular Momentum problem. Time evolution of quantum systems: The Heisenberg, Schrödinger and Interaction pictures. Time evolution of density operators and the Born formula. Approximation methods. |

***References***


1. Quantum Mechanics, Claude Cohen-Tannoudj, B. Diu and F. Laloë, Volume-I, WILEY-VCH, New

York
2. Joachim Stoke, Dieter Suter, Quantum Computing: A *Short* Course from Theory to Experiment, WILEY-VCH GmbH & Co, 2004.
3. L.I Schiff, Quantum Mechanics, McGraw-Hill, 1968.
4. The Principles of Quantum Mechanics, Clarendon Press, Oxford, 1958.
5. David J. Griffiths, Introduction to Quantum Mechanics, Cambridge University Press, 2017
6. Kurt Gottfried, Quantum Mechanics: Fundamentals, Springer (2Ed.), 2003

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | The transition from classical mechanics to quantum mechanics. |
| **CO-2** | Foundations of linear algebra and complex vector spaces for quantum mechanics. |
| **CO-3** | Fundamentals of quantum mechanics principles. |
| **CO-4** | Understanding of quantum harmonic oscillator and angular momentum. |

## QT 603: INTRODUCTION TO QUANTUM COMPUTING

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | **Introduction:** Introduction to Quantum computing, prehistory of quantum computing, Requirements for quantum computers (DiVincenzo criteria), Quantum Bits, Qubit measurements, qubit evolution, mixed states and density operators, Tensor product and compound quantum systems, two qubits and multiple qubits systems. Quantum operation on a multiqubit systems, Quantum entanglement, No-cloning theorem, Super-dense coding, Quantum Teleportation. |
| **Unit II** | **Quantum Gates:** Classical Logic gates, Irreversible gates, Universal gates, reversible gates, universal reversible gates, Quantum logic gates, single qubit gates, Rotation gates, multiqubit gates, controlled quantum gates, Universal quantum gates, quantum circuit identities. |
| **Unit III** | **Quantum Algorithms:** Quantum Parallelism, Phase kick-back, Deutsch's problem, Deutsch-Jozsa algorithm, Quantum Fourier transform, Quantum Phase estimation, Grover's search algorithm, Simon's problem, Shor's algorithm. |

***<u>References</u>***

1. Joachim Stoke, Dieter Suter, Quantum Computing: A Short Course from Theory to Experiment, WILEY-VCH GmbH & Co, 2004
2. Chris Bernhardt, Quantum Computing for Everyone, The MIT Press, 2019
3. Nielsen, Michael A.; Chuang, Isaac L., Quantum Computation and Quantum Information Cambridge: Cambridge University Press, 2012
4. Philip Kaye, Raymond La Flamme and Michele Mosca. An Introduction to quantum Computing, Oxford. University Press.

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Introduction to single-partite and multipartite quantum states. |
| **CO-2** | Basics of quantum gates to multiqubit systems. |

| | |
|---|---|
| **CO-3** | Requirements and Physical realization of quantum computers |
| **CO-4** | Understanding of quantum algorithms and quantum error correction codes. |

## QT 604: QUANTUM INFORMATION THEORY

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | **The Quantum bit:** The two-state system as the unit of information- The Qbit and ebit. Pure and mixed states. Bloch sphere and Poincare sphere representation of qubits. |
| **Unit II** | **Classical Information theory:** Convex functions and Jensen's inequality. Shannon Entropy, mutual entropy and mutual information. Joint and conditional entropy. Data compression and codes. Kolmogorov complexity. Classical channels and Shannon coding theorems. Entropic inequalities. |
| **Unit III** | **Quantum entropy:** Properties of Entropy. Conditional entropy. Quantum mutual information. Additivity sub additivity and strong subadditivity. The Holevo bound. A comparison between classical and quantum information theory. |
| **Unit IV** | **Separable and Entangled states:** Von-Neumann entropy. The Bell-state and maximally entangled states. Quantification of Entanglement: Entanglement of formation, Concurrence and entanglement monogamy. Separability of composite states. Entangled states, product states and separable systems. von Neumann entropy and negativity. The Peres-Horodecki theorem. Local unitary operations and classical communication. Quantification of entanglement. Maximally entangled mixed states. The Werner state. Local unitary operations on Bell states. |
| **Unit V** | **Quantum decoherence and quantum operations:** Fidelity and trace distance measure between quantum states. Quantum systems coupled to environments. Bit flip, Phase Flip and depolarization channels. Amplitude and phase damping. Illustrations in the case of polarization qubits. Quantum state and process tomography with practical illustrations. The operator-sum representation and measurements. |

***References***


1. Nielsen, Michael A.; Chuang, Isaac L., Quantum Computation and Quantum Information Cambridge: Cambridge University Press, 2012
2. Benenti, Casati, Strini, Principles of quantum computation and Information, World Scientific.


**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Introduction to classical information theory and the concept of entropy for classical random variables. |
| **CO-2** | Understanding the von Neumann entropy and the comparison between classical and quantum information theory. |
| **CO-3** | Mathematical description of separable and entangled quantum systems. |
| **CO-4** | The conception of a qualitative and quantitative measure of entanglement. |

# QT 605: HIGH PERFORMANCE DSP USING FPGA

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | **Introduction to high performance digital computations:** Digital system design, signal processing, fixed and floating point computations, standards for high resolution computing, Design with Vivado design suite (IP, SysGen for DSP and image processing, model composer, embedded development, AI and ML tools), testing with high speed logical analyser, advanced features of modern FPGAs (Kintex-7, Virtex-7, Zynq-7000, Artix-7, Kintex UltraScale, Kintex UltraScale+,Virtex UltraScale, Virtex UltraScale+, Zynq UltraScale+ and RFSoC etc.,), external memory interface, designs with advanced VHDL, advanced design with the PlanAhead analysis/design-tools, debugging techniques using the ChipScope Pro tools, FPGA power optimization. |
| **Unit II** | **System implementation using hybrid Simulink-programming tools:** Introduction to SysGen tools, integration of MATLAB & Simulink with SysGen platform, Model composer algorithms, integrated mixed language based design, high level synthesis, MATLAB & simulink, C and LabVIEW based HLS designs, massive parallel computations, designs with advanced XDC and STA, debugging techniques using Vivado logic Analyzer, designing with the Xilinx analog mixed signal solution. |
| **Unit III** | **IP core library and design managements:** IP core design flow, IP core subsystems and integrations, parallelism, full/partial reconfiguration, flexible DSP blocks and multipliers, processor cores, embedded block RAM, embedded designs, standard communication interfaces, mixed signals based design, Multi-Rate Systems, MAC-Based FIR, Distributed Arithmetic and Multipliers Realization, FIFO, creating and managing reusable IPs, designs using Xilinx IP with Third-Party Synthesis Tools, Programming and Debugging Embedded Processors, SoC Processor Design, Embedded MicroBlaze Processor. |
| **Unit IV** | **Algorithm implementations using DSP tools:** Ultra fast algorithm design methodology, reconfigurable FPGA-based DSP Systems, real-time DSP System on Chip (SoC), Graphical Representation of DSP Algorithms, FIR/IIR filters, Adaptive filters, CORDIC algorithm implementations, multirate signal processing, FT/T_F analysis, spectral estimation and analysis, optimum and estimation techniques, image and speech processing, implementations of advanced transforms, Wavelet based designs. |
| **Unit V** | **Contemporary applications and solutions:** Video and image processing, database and data analysis, control systems, high-speed, wired, wireless communications, network accelerations, test and M/m systems, HT generations/ detections, AI and machine learning algorithm implementations, 5G adaptive beamforming, RF transceiver modules interface, software driven DDS/SDR platform interface, Gbps Ethernet/optical-fiber dynamic switching, Designing an Integrated PCI Express System, IoE designs, soft controller designs. |

***References***


1. Michael P, Digital Signal Processing 101: Everything You Need to Know to Get Started, 2010, Elsevier.
2. Steve K, Advanced FPGA Design: Architecture, Implementation, and Optimization, 2007, IEEE.
3. Sanjay Churiwala, Designing with Xilinx® FPGAs: Using Vivado, 2017, Springer.
4. Roger Woods et al., FPGA-based Implementation of Signal Processing Systems, 2017, Wiley.
5. Donald G. Bailey, Design for Embedded Image Processing on FPGAs, 2011, IEEE.
6. Uwe Meyer-Baese Digital Signal Processing with Field Programmable Gate Arrays, 2013, Springer.
7. Nasser Kehtarnavaz, Digital Signal Processing Laboratory: LabVIEW-Based FPGA Implementation, 2010, Brown Walker Press.
8. https://www.xilinx.com/support.html#knowledgebase.


**LIST OF EXPERIMENTS (in QT 605):**

| Sl. No. | Name of experiments |
|---|---|
| 01. | The Basic Design Flow of DSP Implementation in FPGA.<br>To understand use of Xilinx System Generator.<br>To understand Xilinx Synthesis Technology or XST.<br>Familiarization of Simulink, Signal Processing Toolbox, Signal Processing Block-set. |
| 02. | Implementation of Dual Port RAMS, Addressable Shift Register, FIFO And ROM in FPGA.<br>Familiarization with Memory Blocks implementation in FPGA.<br>To Understand FGPGA Hardware.<br>Familiarization of XUP board (Vertex-5). |
| 03. | Implementation of M Code Adder in FPGA<br>This exercise provides an introduction to the integration of M Code into a System Generator System.<br>To understand the functionality of a basic 2-input adder is interpreted from the M-code. |
| 04. | Generation of Simulink System Period<br>To understand Simulink system periods, and confirm the meaning of this parameter from the simulation results. |

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Introduction to basics of FPGA systems |
| **CO-2** | Linking FPGA with various graphical programming |
| **CO-3** | Various algorithms and implementations on FPGA |
| **CO-4** | Future application of FPGA systems |

**QT 610: QUANTUM TECHNOLOGY LABORATORY-I**

**SYLLABUS:**

| Sl. No. | Name of experiments |
|---|---|
| 01. | Study of Optical lens and lens systems |
| 02. | Fibre splicing and OTDR measurement |

| | |
|---|---|
| 03. | Study of Polarizer, Polarizing and Non-polarizing BS, QW, HW, FW Plates |
| 04. | Polarization properties of laser with and without QW, HW and FW Plates |
| 05. | Fourier Optics |
| 06. | Characterization Diode laser system |
| 07. | Laser beam-divergence and $M^2$ measurement |
| 08. | Setting up Michelson interferometer |
| 09. | Setting up Mach-Zehnder interferometer |
| 10. | Determination of the refractive index profile of a multimode and single mode fibre by the transmitted near field scanning technique and measurement of NA. |
| 11. | Measurement of attenuation and dispersion in optical fibres |
| 12. | WDM Mux, Demux and add drop multiplexing |
| 13. | Fibre amplifier |
| 14. | Particle nature of photons |
| 15. | Demonstration of BB84 protocol |
| 16. | Quantum random number generation |

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Understanding and Hands on experience on optical elements and Fibers. |
| **CO-2** | Construction of various optical interferometers |
| **CO-3** | Introduction to Quantum phenomena. |

## PGC-601: RESEARCH METHODOLOGY AND IPR

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations |
| **Unit II** | Effective literature studies approaches, analysis Plagiarism, Research ethics, |
| **Unit III** | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee |
| **Unit IV** | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. |
| **Unit V** | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications |
| **Unit VI** | New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |

***References Textbooks***

10. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for

11. science & engineering students'"
12. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
13. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
14. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
15. Mayall, "Industrial Design", McGraw Hill, 1992.
16. Niebel, "Product Design", McGraw Hill, 1974.
17. Asimov, "Introduction to Design", Prentice Hall, 1962.
18. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
19. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Understanding the fundamentals of research and its methodology |
| **CO-2** | Choose the appropriate research design and develop appropriate research hypothesis for a research project |
| **CO-3** | Knowledge of manuscript preparation, patents and Intellectual property |
| **CO-4** | Technology transfer and application of IPR in various domains |

## QT 606: ADVANCED QUANTUM COMMUNICATIONS

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | Elements of classical cryptography (basic understanding), RSA public and private key distribution, Block ciphers, American encryption standards (AES), Authentication and Wegman-Carter protocol, Universal hashing techniques |
| **Unit II** | Shennon and Reni entropy, BB84 protocol, Difference between free- space and fibre-based QKD systems, Quantum teleportation and swapping, Post-processing of QKD data, Error correction and cascade protocol |
| **Unit III** | Attack strategies on QKD protocols, QKD systems, Plug and play systems, Differential phase shift key (DPS), Time bin qubits & phase based techniques, The decoy state protocol, Measurement device independent QKD |
| **Unit IV** | Current trends in free-space and satellite QKD, QKD networks, Basic techniques of quantum optics and quantum technology |

***References***

1. Nielsen, Michael A.; Chuang, Isaac L., Quantum Computation and Quantum Information Cambridge: Cambridge University Press, 2012
2. Benenti, Casati, Strini, Principles of quantum computation and Information, World Scientific

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Advanced classical cryptography technics and their applications. |
| **CO-2** | Limitations of classical cryptography and the necessity of QKD protocols. |
| **CO-3** | Introduction to various QKD protocols and their realization |
| **CO-4** | Present trends in QKD |

## QT 607: QUANTUM METROLOGY AND SENSING

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | Time dependent perturbation theory, applications like fine structure constant, hyper-fine splitting, Zeeman effect, Introduction to atom-light interactions, Rabi model, Optical cavities, Introduction to laser and their applications to metrology |
| **Unit II** | Fisher information, Cramer-Rao bound (classical and quantum), Standard quantum limit (shot-noise limit) and Heisenberg limit (squeezed light), Ghost imaging (quantum enhanced imaging), Quantum illumination, Quantum reading, Quantum RADAR, Super-resolution with OAM beams and vector beams |
| **Unit III** | Cold atoms, Gravimeters and time-stamping based on atom interferometery, Joshpson junction and NV color centers in diamonds for sensing, Lock-in detection, spectroscopy, Doppler-limit and Doppler-free spectroscopy |
| **Unit IV** | Frequency standards, Frequency combs, atomic clocks, SQUID techniques |

***<u>Textbook/ References</u>***

1. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, 2nd ed..John Wiley, 2007
2. A. Yariv, Quantum Electronics, John Wiley.
3. Research papers/Articles as required

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Introduction to atomic, molecular and optical physics |
| **CO-2** | Quantum principles and their applications to information and imaging. |
| **CO-3** | Quantum sensing using cold atoms |
| **CO-4** | Introduction to frequency standards |

## QT 608: QUANTUM COMPUTING II

**SYLLABUS:**

**Prerequisite: Quantum computing I**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | Quantum noise and error correction codes: Noise and the Di-vincenzo criteria. The classical error correction model. The classical three bit code. Quantum error correction. Three and nine bitcodes and the stabilizer codes. |
| **Unit II** | **Quantum computing with Qiskit:** Qubits; multi-qubits systems. Quantum operation on a multi-qubit systems, Reversible Gates; Quantum Gates; |
| **Unit III** | **Implementation of Quantum Algorithms with Qiskit:** Quantum Parallelism, Phase kick-back, Deutsch's problem, Deutsch-Jozsa algorithm, Quantum Fourier transform, Quantum Phase estimation, Grover's search algorithm, Simon's problem, Shor's algorithm. |
| **Unit IV** | **Physical realization of qubits:** introduction to Super conducting qubits and ion traps models, Linear optical quantum computing, Single qubit gates, Computational complexities: brief introduction, models , How to compute quantum volume using free-accessible quantum sources from IBM. |

***<u>Reference Books</u>***

1. Michael A. Nielsen and Isaac L. Chuang, Quantum computation and quantum information, Cambridge University Press 2010
2. Thomas H. Cormen Charles E. Leiserson Ronald L. Rivest Clifford Stein, Introduction to Algorithms, Second Edition, The MIT Press, Cambridge, Massachusetts

***Reference papers***

1. Robert S. Smith, Michael J. Curtis, William J. Zeng. A Practical Quantum Instruction Set Architecture. arXiv:1608.03355. 2016.
2. Eric C. Peterson, Gavin E. Crooks, Robert S. Smith. Fixed-Depth Two-Qubit Circuits and the Monodromy Polytope. arXiv:1904.10541. 2019.
3. Robert S. Smith. Someone Shouts |01000> !Who's Excited?. arXiv:1711.02086.2017.
4. Christopher M. Dawson, Michael A. Nielson. The Solovay–Kitaev Algorithm. Quantum Information and Computation. 2005.
5. Klaus Mølmer, Anders Sørensen. Multi-particle entanglement of hot trapped ions. Physical Review Letters 82. 1999.
6. Vivek V. Shende, Igor L. Markov. On the CNOT-cost of TOFFOLI gates. Quan- tum Information and Computation. 2009.
7. Vivek V. Shende, Stephen S. Bullock, Igor L. Markov. Synthesis of Quantum Logic Circuits. IEEE Transactions on Computer-Aided Design, vol. 25, no. 6. 2006.

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Introduction to classical deterministic and probabilistic quantum systems; and the leap from classical mechanics to quantum mechanics. |
| **CO-2** | Conception of physical realization of qubits. |
| **CO-3** | Implementation of various quantum algorithms using QISKIT - IBM Quantum experience. |

**QT 611: QUANTUM TECHNOLOGY LABORATORY-II**

**SYLLABUS:**

| **Sl. No.** | **Name of experiments** |
|---|---|
| 01. | Demonstration of Quantum Zeno effect |
| 02. | Tomographic single photon state reconstruction |
| 03. | Demonstration of wave nature of photons |
| 04. | Setting up Quantum eraser system |
| 05. | Test of wave particle dualism |
| 06. | Visible light interference |
| 07. | Measurement of wavelength of single photons |
| 08. | Coherence length measurement of single photons |
| 09. | Interaction-free measurement |
| 10. | Test of Bell's inequality (CHSH) violation |
| 11. | Non-classical polarization correlations |
| 12. | Tomographic state reconstruction |
| 13. | Demonstration of QKD (BBM protocol) |
| 14. | Ekert protocol – test |
| 15. | Hong-Ou-Mandel two-photon interferometers |

| | |
|---|---|
| 16. | Hong-Ou-Mandel interference + Hanbury-Brown & Twiss interference FPGA based electronics and post-processing protocols for QKD |

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Demonstration of heralded single photon and the entangled photons sources. |
| **CO-2** | Construction of various single photon interferometers for the understanding of foundations of quantum mechanics. |
| **CO-3** | Hands-on experience on the characterization of single and entangled photon sources. |
| **CO-4** | Demonstration of QKD protocols using entangled photon set up. |

## QT 621: CLASSICAL AND QUANTUM CRYPTOGRAPHY

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | **Introduction to Post Quantum Cryptography:** What Is Post-Quantum Cryptography? Comparison to Quantum Cryptography. Introduction to Mathematics of Cryptography. Classical Cryptography. |
| **Unit II** | **Hash Based Digital Signature Schemes:** Hash Based One-Time Signature Schemes, Merkle's Tree Authentication Scheme, One-Time Key-Pair Generation Using an PRNG, Authentication Path Computation, Tree Chaining, Security In Merkle Signature Scheme. |
| **Unit III** | **Code-Based Cryptography:** Introduction to Code-Based Cryptography, Codes and Structures, McEliece Cryptosystem. |
| **Unit IV** | **Lattice Based Cryptography:** Introduction, Preliminaries of Linear Alzebra, Finding Short Vectors, Public Key Encryption Schemes, Digital Signature Schemes, Other Cryptographic Primitives. |
| **Unit V** | **Multivariate Public Key Cryptography:** Introduction, the Basics of Multivariate PKCS, Examples of Multivariate PKCS, Basic Construction and Variations. |

***Text Book***

1. Post-Quantum Cryptography by Daniel J. Bernstein, Johannes, Buchmann, Erik Dahmen, Springer. ISBN: 978-3-540-88701-0.

***Reference Books/Papers***

1. Regev, O. 2009. School of Computer Science Tel Aviv University. Lattices in Computer Science 0368.4282. Lectures- 1, 2, 6.5.
2. Schneier, B. 1996. Applied Cryptography. John Wiley & Sons, Inc. ISBN: 0471128457
3. Research papers/Articles as required

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Understanding the Mathematical description of cryptography |
| **CO-2** | Introduction to classical cryptography |
| **CO-3** | Modeling of public key cryptosystems |
| **CO-4** | Understanding the fundamentals of Post-quantum cryptography |

## QT 622: NONLINEAR AND QUANTUM OPTICS

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | **Nonlinear optics:** Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients. Second harmonic generation |
| **Unit II** | **Nonlinear Optics:** Phase matching condition, Various phase matching techniques, Periodically poled materials and their applications in non-linear optical devices, Sum and difference frequency generation, Optical parametric amplification (OPA) and oscillation (OPO) |
| **Unit III** | **Nonlinear Optics:** Third harmonic generation, four wave mixing and Self phase-modulation Optical Kerr effect, Self-focusing, Optical bistability, Stimulated Raman Scattering and Stimulated Brilluoin Scattering, Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Supercontinuum generation |
| **Unit IV** | **Quantum Optics:** Field quantization, Correlation functions, photon statistics, shot noise of the photodetectors, Poissonian and sub-Poissonain light, Photon bunching and antibunching, HBT experiment |
| **Unit V** | **Quantum Optics:** single photon sources, Coherent states and squeezed states, Phasor diagram, generation and detection of squeezed light, Quantum noise, Phase space representation and Wigner function. |

***Text/References***


1. R. W. Boyd, Nonlinear Optics, Academic Press, 2008
2. Peter E. Powers, Fundamentals of Nonlinear Optics, CRC Press, 2011.
3. Mark Fox, Quantum Optics: An Introduction, Oxford master series in physics, 2007
4. A guide to experiments in Quantum Optics, Hans-A Bachor, T. C. Ralph, 3rd edition, Wiley, 2019


**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Introduction to nonlinear optics and their applications |
| **CO-2** | Understanding of various second order nonlinear optical processes and critical and quasi-phase matching techniques |
| **CO-3** | Conception of various third and higher order nonlinear effects |
| **CO-4** | Introduction to field quantization and quantum optics |
| **CO-5** | Introduction to various quantum states of light |

## QT 623: MACHINE LEARNING

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | **Introduction** - Well-posed learning problems, Designing a learning system, Perspectives and issues in machine learning<br>**Concept learning and the general to specific ordering** – Introduction, A concept learning task, Concept learning as search, Find-S: finding a maximally specific hypothesis, Version spaces and the candidate elimination algorithm, Remarks on version |

| | |
|---|---|
| | spaces and candidate elimination, Inductive bias |
| **Unit II** | **Decision Tree learning** – Introduction, Decision tree representation, Appropriate problems for decision tree learning, The basic decision tree learning algorithm, Hypothesis space search in decision tree learning, Inductive bias in decision tree learning, Issues in decision tree learning<br>**Evaluation Hypotheses** – Motivation, Estimation hypothesis accuracy, Basics of sampling theory, A general approach for deriving confidence intervals, Difference in error of two hypotheses, Comparing learning algorithms |
| **Unit III** | **Bayesian learning** – Introduction, Bayes theorem, Bayes theorem and concept learning, Maximum likelihood and least squared error hypotheses, Maximum likelihood hypotheses for predicting probabilities, Minimum description length principle, Bayes optimal classifier, Gibs algorithm, Naïve Bayes classifier, An example learning to classify text, Bayesian belief networks The EM algorithm<br>**Computational learning theory** – Introduction, Probability learning an approximately correct hypothesis, Sample complexity for Finite Hypothesis Space, Sample Complexity for infinite Hypothesis Spaces, the mistake bound model of learning - Instance-Based Learning-Introduction, k -Nearest Neighbour Learning, Locally Weighted Regression, Radial Basis Functions, Case-Based Reasoning, Remarks on Lazy and Eager Learning |
| **Unit IV** | **Genetic Algorithms** – Motivation, Genetic Algorithms, an illustrative Example, Hypothesis Space Search, Genetic Programming, Models of Evolution and Learning, Parallelizing Genetic Algorithms<br>**Learning Sets of Rules** – Introduction, Sequential Covering Algorithms, Learning Rule Sets: Summary, Learning First Order Rules, Learning Sets of First Order Rules: FOIL, Induction as Inverted Deduction, Inverting Resolution |
| **Unit V** | **Analytical Learning** - Introduction, Learning with Perfect Domain Theories: Prolog-EBG Remarks on Explanation-Based Learning, Explanation-Based Learning of Search Control Knowledge<br>**Combining Inductive and Analytical Learning** – Motivation, Inductive-Analytical Approaches to Learning, Using Prior Knowledge to Initialize the Hypothesis, Using Prior Knowledge to Alter the Search Objective, Using Prior Knowledge to Augment Search Operators, |
| **Unit VI** | **Reinforcement Learning** – Introduction, the Learning Task, Q Learning, Non-Deterministic, Rewards and Actions, Temporal Difference Learning, Generalizing from Examples, Relationship to Dynamic Programming. |

***Text / References***

1. Machine Learning – Tom M. Mitchell, - MGH
2. Machine Learning: An Algorithmic Perspective, Stephen Marsland, Taylor & Francis (CRC)
3. Machine Learning Methods in the Environmental Sciences, Neural Networks, William W Hsieh, Cambridge Univ Press.
4. Richard o. Duda, Peter E. Hart and David G. Stork, pattern classification, John Wiley & Sons Inc., 2001.
5. Chris Bishop, Neural Networks for Pattern Recognition, Oxford University Press, 1995

**COURSE OUTCOMES:**

| | |
|---|---|
| **CO-1** | Introduction to learning systems |
| **CO-2** | Computational learning theory and its applications |
| **CO-3** | Brief overview of various optimization algorithms |
| **CO-4** | Introduction to Analytical learning and reinforcement learning |

## PGC-602: AUDIT COURSE

**SYLLABUS:**

| Unit | Syllabus Details |
|---|---|
| **Unit I** | English for Research Paper Writing |
| **Unit II** | Disaster Management |
| **Unit III** | Sanskrit for Technical Knowledge |
| **Unit IV** | Value Education |
| **Unit V** | Constitution of India |
| **Unit VI** | Pedagogy Studies |
| **Unit VII** | Stress Management by Yoga |
| **Unit VIII** | Personality Development through Life Enlightenment Skills |

# DEPARTMENT OF TECHNOLOGY MANAGEMENT

## M.TECH. IN TECHNOLOGY MANAGEMENT

**SEMESTER I**

| Sl. No. | Course Code | Course | Contact Hours / week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | TM601 | Introduction to Technology Management | 3 | 1 | 4 |
| 2 | TM602 | R&D Management | 3 | 1 | 4 |
| 3 | TM603 | Project Management | 3 | 1 | 4 |
| 4 | TM604 | Strategic Management for Technology | 3 | 1 | 4 |
| 5 | TM605 | Management of Innovation and Intellectual Property | 3 | 1 | 4 |
| 6 | TM615 | Human Resource Management for Technology intensive organisations | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

**SEMESTER II**

| Sl. No. | Course Code | Course | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | TM610 | Leadership & Organisational Behaviour | 3 | 1 | 4 |
| 2 | TM612 | Quality Management | 3 | 1 | 4 |
| 3 | AM634 | Applied statistics for Management | 3 | 1 | 4 |
| 4 | TM617 | Logistics and Supply Chain Management | 3 | 1 | 4 |
| 5 | | Elective – III | 3 | 1 | 4 |
| 6 | | Elective – IV | 3 | 1 | 4 |
| 7 | PGC-602 | Audit Course | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

**SEMESTER III**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | NT-651 | M.Tech. Dissertation Phase I | 28 | | 14 |
| | | **Total** | **28** | | **14** |

**SEMESTER IV**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | NT-652 | M.Tech. Dissertation Phase II | 28 | | 14 |
| | | **Total** | **28** | | **14** |

**List of Electives:**

| Sl. No. | Course Code | Course Name |
|---|---|---|
| **Elective I, II, III, IV, V & VI** | | |
| **ELECTIVES FROM DEPARTMENT (Semester 2)** | | |
| 1 | TM607 | Management of Manufacturing and Integration |
| 2 | TM608 | Knowledge Management |
| 3 | TM609 | System Engineering for Managers |
| 4 | TM611 | Software Projects Management |
| 5 | TM613 | Value Engineering |
| 6 | TM614 | Design Management |
| 7 | TM616 | Introduction to variables of Nation Building |
| 8 | TM618 | Operations Management |
| 9 | TM619 | Advanced Project Management Techniques |
| 10 | TM620 | Accounting and Finance for Technologists |
| 11 | TM621 | Artificial Intelligence (AI) for Managers |
| **ELECTIVES FROM OTHER DEPARTMENT** | | |
| 11 | | Open Electives from other departments |
| * 1 Credit in Theory/Tutorial means 1 contact hour and 1 credit in practice/Project Thesis means 2 contact hours in a week | | |

**Program Outcomes (POs)**

**PO1:** To develop an ability to identify, understand, analyze the management issues in an organization.

**PO2:** To be able to perform statistical research for better management solution/decision.
**PO3:** To give managerial as well as academic interpretations based on management by facts and put it into formal documentations. To achieve excellence in management decisions.

**Program Specific Outcomes (PSOs)**

**PSO1**: To learn the basics and advances in Technology management perspective. To emphasize the need for adequate knowledge and competence in Technology. To overcome the time & cost overruns of various defence related projects.
**PSO2**: Proper utilization of human resources and their intellectual abilities for betterment in projects, R&D and strategy formation decisions.
**PSO3**: To learn various management cases through problem solving approach inclined to corporate decisions.

## SEMESTER 1 : INTRODUCTION TO TECHNOLOGY MANAGEMENT (TM601)

| **Course Outcomes** | |
|---|---|
| **CO -1** | Understand the issue around Technology management, Technology Cycle and wealth creation through technological development. |
| **CO -2** | Identify the technology decisions for push-pull, assessments, strategy. |
| **CO -3** | Understanding the process of Technology planning, forecasting, road-mapping, transfer, acquisition, exploitation. |
| **CO -4** | To analyze Key current technological issues for organizations sustenance and transferring technology lab to land. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Introduction to technology, History of managing tech in India, Managing in today's high tech environment and mgmt. Tech – scope and focus, The Role of Technology in the Creation of Wealth, Critical Factors In Managing Technology, Management of Technology: The New Paradigms, Technology Life Cycles, Tech life cycle and product life cycles, Tech maturation and tech substitution, Integrating tech and strategic planning, Core competencies for tech development |
| **Unit II** | Understanding the Dynamics of Technology & Product development Environment, Technology Search Mechanisms, Technology Assessment Models, Technology selection criteria, In-sourcing & Out-sourcing decisions in Technology development, Competitiveness, Business Strategy and Technology Strategy |
| **Unit III** | Technology Planning, Acquisition and Exploitation of Technology, Managing risk in high technology, Transfer of tech from lab to land. Technology Transfer, Manufacturing and Service Industries, Design of Organizations, Changing Game of Management, Case Studies (How the World Does It). |

**Text Books:**


1. Tareek Khalil and Ravi Shankar, Management of Technology: the key to Competitiveness and Wealth Creation, Second Edition, McGraw-Hill Publishing Company Ltd, New Delhi (2012).
2. Thahaman H.J., Management of Technology, New Jersey: John Wiley & Sons, 2005.

3. Bringing Technology and Innovation into the Boardroom: Strategy, Innovation and Competences for Business Value Thomas Durand, Ove Granstand, Cornelius Herstatt, Arie Nagel, David Probert, Breffni Tomlin and Hugo Tschirky.
4. Roadmapping for Strategy and Innovation - Aligning technology and markets in a dynamic world (Phaal, R; Probert, D; Farrukh, C.) ISBN 978-1-902546-82-7
5. Management of Technology and Innovation Competing Through Technological Excellence , Second Edition P N Rastogi , Sage publications

**Reference Books:**

1. BETZ Frederick, Strategic Technology Management, New York: McGraw Hill, 1994.
2. Steele, Lowell W. Managing technology: the strategic view. New York: McGraw-Hill, 1989.
3. Turn the Ship Around!: A True Story of Turning Followers into Leaders (Hardcover) by L. David Marquet
4. Technopoly: The Surrender of Culture to Technology by Neil Postman

**SEMESTER 1 : R & D MANAGEMENT (TM 602)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | To learn about leading R&D professionals; To gain insights about building effective R&D teams; To understand issues related to design of performance management and compensation management practices of R&D departments and organizations |
| **CO -2** | To learn about strategic management and issues related to commercialization of innovation (products, services) designed by R&D departments; To learn about innovative organizational design and issues related to knowledge management architectures |
| **CO -3** | To understand issues related to management of R&D projects (i.e., managing projects that are inherently risky and uncertain) |
| **CO -4** | To familiarize participants with basics of accounting and managing finances for risky and uncertain projects; and to gain a holistic understanding of issues related to management of creative talent within organizations |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Introduction to R&D function, The Strategic Aspects of R&D Management, Project Planning and Budgeting, R & D Road mapping, Project Selection, Project Evaluation. R&D- Marketing interface, Emerging Perspectives in Industrial R&D, External Technology Acquisition |
| **Unit II** | Human Resource Management in R&D, HR Planning, Attraction and Retention of Talent in R&D, Creativity in R&D Organizations, Interpersonal Relationships, Teams and Team building, Reward System, Performance Appraisal system and Career Management System |
| **Unit III** | New Product Development: What is New Product Development and why is it so important, The new Product Development Process Principles of Success, Phases of New Product Development, Idea Generation, Opportunity identification/selection Techniques, The New Product Process: The Stage-Gate, Frameworks for stakeholder involvement in NPD, Concurrent Engineering, Brand/value creation, Product Launch. |

**Text Books:**

1. Hawthrone E.P., Management of Technology, McGraw-Hill, 1978.
2. Akhilesh KB, R&D Management, Springer, 2013
3. The Reflective Practitioner D.A. Schone Basic Books, NY, 1982
4. R&D Tactics H.R. Kaufman Front Range Research, Fort Collins, 1989

**Reference Books:**

1. Beattle C.J. & Reader R.D., Quantitative Management in R&D, Chapman and Hall, 1971.
2. Gibson J.E., Managing Research and Development, Wiley & Sons Inc., New York, 1983
3. Vittorio Chiesa, R&D Strategy and Organisation Managing Technical Change in Dynamic Contexts, Imperial CollegePress

**SEMESTER 1 : PROJECT MANAGEMENT (TM 603)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | To recognize key factors in projects and project stages, cycle and responsibilities. |
| **CO -2** | To identify risk associated with project, its dynamics and team requirements for successfulness. |
| **CO -3** | To align the project activities through project network techniques and scheduling and its cost-time tradeoffs. |
| **CO -4** | Assessing the budget allocation/ financing issues, project handling and implementations through various case studies |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Project Systems Management: a life cycle approach, stage-gate model, project characteristics; project life cycle phases: conception, definition, planning and organising, implementation and project clean up, Management of projects. Organization Strategy and Project Selection. Project feasibility analysis, The project manager: role and responsibilities, Tools and techniques for project management, Environmental impact analysis of a project. |
| **Unit II** | Managing Risks, Network techniques for project management-PERT and CPM Accounting for risk, uncertainty and fuzziness. Time cost tradeoffs and crashing procedures. Multi project planning and scheduling with limited resources. |
| **Unit III** | Projects financing, performance budgeting and control. Project materials management. Pricing, estimating, and Contract Administration and Management, Building and Bid evaluation and analysis. Project implementation and monitoring, Project management information and control systems. Project systems management performance indices. Software Packages application for Project Systems Management. Case studies |

**Text Books:**

1. Iyer, P.P., Engineering Project Management with Case Studies, Vikas Publishing, New Delhi, 2009.
2. J.R., and Mantel, S.J. Jr., Project Management: A Managerial Approach, John Wiley and Sons, NY, 1995.
3. P Gopalakrishnan & V E Ramamoorthy, Textbook of Project Management, Trinity Press

**Reference Books:**

1. John M. Nicholas and Herman Steyn, Project Management for Business, Engineering, and Technology: Principles and Practices (Third Edition), Elsevier (2008).
2. Clifford F. Gray, Erik W. Larson and Gautam V. Desai, Project management: The Managerial Process (Sixth Edition), Mc Graw Hill Education (2014).
3. Project Management Institute, USA. A Guide to the Project Management Body of Knowledge. Newton Square, PA. 1996.
4. Project Management Absolute Beginner's Guide ,Author: Greg Horine
5. Project Management for Non-Project Managers , Jack Ferraro
6. Project Management Case Studies , Harold Kerzner
7. Making Things Happen: Mastering Project Management, Scott Berkun
8. The Lazy Project Manager: How To Be Twice As Productive And Still Leave The Office Early , Peter Taylor

## SEMESTER 1 : STRATEGIC MANAGEMENT FOR TECHNOLOGY (TM604)

| **Course Outcomes** | |
|---|---|
| **CO -1** | Describe the practical and integrative model of strategic management process that defines basic activities in strategic management |
| **CO -2** | Demonstrate the knowledge and abilities in formulating strategies and strategic plans |
| **CO -3** | Analyze the competitive situation and strategic dilemma in dealing with dynamic global business environment in terms of rapidly changing market trends and technological advancement |
| **CO -4** | Evaluate challenges faced by managers in implementing and evaluating strategies based on the nature of business, industry, and cultural differences |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Strategic Management Process; Challenge of Globalization; Strategic Planning in India; Corporate Governance; Board of Directors; Role and functions of Top Management, Environmental scanning: Industry Analysis, Internal Scanning: Organizational Analysis |
| **Unit II** | Strategy Formulation: Situation Analysis and Business Strategy, Corporate Strategy, Functional Strategy, Strategy Implementation and Control, Strategic Alternatives; Diversification, Mergers and Acquisitions. |
| **Unit III** | Case Studies in Strategic Management: Strategic initiatives of Govt. of India, FDI in defence, start-ups, “Make in India” for document of cutting edge technology coming from abroad-offset policies, Freedom to operate, strategic aspects of Technology Management. |

**Texts Books:**

1. R. Srinivasan, Strategic Management – The Indian Context, Prentice-Hall of India, 3rd Edition, 2008
2. Burgelman, Christensen, and Wheelwright Strategic Management of Technology and Innovation by, TMH
3. David Baker, The Strategic Management of Technology, Woodhead Publishing Limited.

4. *Edward B. Roberts, Strategic Management of Technology: Global Benchmarking, Leopold Classic Library*

**Reference Books:**

1. Azhar Kazmi, Business Policy and Strategic Management, 2e. Tata McGraw Hill Education.
2. R. Srinivasan, Case Studies in Marketing – The Indian Context, Prentice-Hall of India, 4th Edition, 2002
3. Frederick Betz, Strategic Technology Management, McGraw-Hill Inc., US
4.Pierre Dussauge, Stuart Hart, Bernard Ramanantsoa, Strategic Technology Management, Wiley

## SEMESTER 1: MANAGEMENT OF INNOVATION AND INTELLECTUAL PROPERTY (TM605)

| **Course Outcomes** | |
|---|---|
| **CO -1** | Different types of IP, Commercialization of IP, Intellectual property |
| **CO -2** | Industrial design, how to register at the right time, and privacy, Innovation management, geographical indication, and the trade secret |
| **CO -3** | Patent and who is the owner of the patent, as well as patent filling techniques |
| **CO -4** | Copyright, its ownership, and registering a creative work, Trademark involved and registration |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | *Organizational and technological innovation* : role of organizational design and processes in managing inventions and innovations, introduction to intellectual property rights, strategic role of intellectual property protection in technological innovations case studies, role of open source, the use of patent information, the R&D value chain, stage gates , differences in priority with the R&D value chain |
| **Unit II** | *The Process of Technological Innovation*, Need for innovation in business: measuring innovative performance, Characteristics of innovative work environment, Stimulating Innovation, Promoting break through innovation, Open innovation and Knowledge Markets |
| **Unit III** | *Innovative inventions*: Commercial potential, management of processes to enhance innovative patents and technological know-how transfer, incubators, assessing patent value implications on managing the R&D value chain for corporate R&D, designing innovation and intellectual property divisions, and information technology support systems in managing innovation and intellectual property |

**Texts/References:**

1. Trott, P., Innovation Management and New Product Development, Financial Times, Pitman Publishing, GB, 1998.
2. Joe Tidd & John R. Bessant , Managing Innovation: Integrating Technological, Market and Organizational Change, 7th Edition, Wiley
3. Shlomo Maital, Innovation Management: Strategies, Concepts and Tools for Growth and Profit, Sage Publishers

4. Anurag K. Agarwal, Business And Intellectual Property, Penguin Random House
5. Dr. Mathew Thomas,Understanding Intellectual Property, Eastern book company
6. https://www.amazon.com/How-Innovation-Works-Flourishes-Freedom/dp/0062916599

## SEMESTER 1: HUMAN RESOURCE MANAGEMENT FOR TECHNOLOGY INTENSIVE ORGANISATIONS (TM 615)

| **Course Outcomes** | |
|---|---|
| **CO -1** | Critically assess existing theory and practice in the field of HRM, Develop an ability to undertake qualitative and quantitative research, Apply knowledge about qualitative and quantitative research to an independently constructed piece of work |
| **CO -2** | Respond positively to problems in unfamiliar contexts, Identify and apply new ideas, methods and ways of thinking, Demonstrate competence in communicating and exchanging ideas in a group context |
| **CO -3** | Be able to advance well-reasoned and factually supported arguments in both written work and oral presentations, Work effectively with colleagues with diverse skills, experience levels and way of thinking |
| **CO -4** | Be able to evaluate HRM related social, cultural, ethical and environmental responsibilities and issues in a global context |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Introduction, Personnel Management & HRM, elements & model, functions, challenges; Balanced Scorecard: history, perspectives, BSC & Strategy, Competency Management: Concept, need, competence & competency, framework. |
| **Unit II** | Cross Culture: nature, Hofstede’s cultural dimensions, strategy; HR Audit: need, concept, strategy, structure, role of HRD audit, functions, methodology; Human capital and performance: elements, significance, measurement, reporting. |
| **Unit III** | Management of change: The nature of change, Eight steps to successful change, Change management and organizational structure, Change strategies, Change resistance, Effective communication, Effective leadership, Emotional Intelligence. |

**Text Books:**

1. Aswathappa, Human Resource Management: Text and Cases.
2. V. S. P. Rao, Human Resource Management, 2010.
3. Palmer et al. (2009): Managing Organizational Change: A Multiple Perspectives Approach, McGraw-Hill
4. Bridges (2009): Managing Transitions: Making the Most of Change, Da Capo Press

**References Books:**

1. Gary Dessler, Human Resource Management 12 Edition (Old Edition), 2011.
2. Dessler/Varkkey, Human Resourse Management 14e(4 Color), Pearson, 2015
3. P. Jyothi & D.N. Venkatesh, Human Resource Management (Oxford Higher Education), 2012.
4. Kotter (1996): Leading Change, Harvard Business School Press

5. Linstead et al. (2009): Management and Organization: A Critical Text, Palgrave

**SEMESTER 2 : LEADERSHIP & ORGANISATIONAL BEHAVIOUR (TM610)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | Describe the field of organizational behavior and discuss its relevance to the workplace, Discuss the impact that diversity of race, gender, ability, religion, and age has on the workplace |
| **CO -2** | Describe the methods of encouraging ethical behavior and the laws encouraging good corporate practices, Discuss the impact organizational culture has on individuals and the workplace |
| **CO -3** | Strategies to improve motivation in the workplace, importance of managing stress and emotions in the workplace, appropriate methods and styles of communication in the workplace |
| **CO -4** | Strategies for managing conflict and negotiation in the workplace, process and techniques of individual and group decision-making, Recognize good and poor leadership and the varieties of leadership, impact organizational change has on individuals and the workplace |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Organisation: context, structure, processes, Theories of organisation, organisation and its environment, organisational analysis: Individual and Group, Organisational change and development. |
| **Unit II** | Functions of Human Resource Management, Recruitment, Selection, Performance Management, Reward and Compensation Management, Training and development, administration wage and salary, labour legislations and Industrial Relations. |
| **Unit III** | Basics of Human Behaviour, Leadership, Competing for the future through leadership management, career management and leadership pipeline, succession planning and change management. |

**Text Books:**

1. Paul Hersey, Kenneth H Blanchard & Dewey Johnson, Management of Organisational Behavior PHI
2. John W Newstrom & Keith Davis, Organizational Behavior: Human Behavior at work, Tata McGraw Hill
3. Fred Luthans, Organizational Behavior, McGraw Hill
4. K. Aswathappa , Organisational Behavior
5. Newstrom, J. W , Organizational Behavior: Human Behavior At Work.TMH
6. Sekaran, Uma, Organisational Behaviour: Text & Cases TMH
7. Aswathappa, K , Organisational Behaviour: Text, Cases, Games. Himalaya

**References Books:**

1. Paul Hersey & Kenneth H Blanchard, Management of Organisational Behavior: utilizing Human behaviour, PHI
2. Stephen P Robbins, Organizational Behavior: Concepts, controversies and applications, PHI

**SEMESTER 2 : QUALITY MANAGEMENT (TM 612)**

| Course Outcomes | |
|---|---|
| **CO -1** | To learn quality related issue and quality philosophies |
| **CO -2** | Usefulness of tools and techniques of seven quality control. |
| **CO -3** | Application of Quality six sigma approach with DMAIC phases, FMEA and QFD for benchmarking. |
| **CO -4** | Strategies for achieving incremental quality process through innovative problem solving approach and maintaining quality standards. |

| Unit | Syllabus |
|---|---|
| **Unit I** | **Introduction to TQM and Six Sigma**: Customer Orientation, Continuous Improvement, Quality, Productivity and Flexibility, Approaches and philosophies of TQM, Quality Awards, Strategic Quality Management, TQM and corporate culture, Total Quality Control; Basic Analytical tools-Check Sheets; Histograms; Pareto charts, Cause and Effect diagrams; Flow charts, Quality assurance, OC curve. |
| **Unit II** | **Statistical Process Control; Advanced Analytical tools**: Statistical Design of Experiments; Taguchi Approach; Cost of Quality; Reliability and failure analysis. FMEA, Six Sigma tools and techniques for DMAIC phases, Quality Function Deployment. |
| **Unit III** | **Quality Teams, Employee practices in TQM organisations**: Leadership, delegation; empowerment and motivation; role of communication in Total Quality, Quality Circles; Total Employee Involvement; Problem Solving in TQM- Brain storming; Nominal Group Technique Team process; Kaizen and Innovation; Measurement and audit for TQM; Quality Information Systems, ISO 9000 series of Quality Standards; TQM and Six Sigma case studies implementation. |

**Text Books:**


1. O.N. Pandey Bhupesh Aneja, Quality Management, Katson Books.
2. Besterfield, Total Quality Management, 4th edition, Pearson.
3. R. Panneerselvam, p. Sivasankaran, Quality Management, PHI Publication.


**Reference Books:**


1. James R. Evans & William M. Lindsay, Managing for Quality and Performance Excellence, Seventh Edition, Cengage learning (2008)
2. John S Oakland, TQM: Text with Cases, Taylor and Francis Culley, William C. Environmental and quality systems integration, CRC Press Company (2004)
3. V. K. Khanna, PremVrat, B. S. Sahay and Ravi Shankar (2008): Total Quality Management: Planning Design and Implementation, New Age International Publication, New Delhi.

**SEMESTER 2 : APPLIED STATISTICS FOR MANAGEMENT (AM634)**

| Course Outcomes | |
|---|---|
| **CO -1** | Describe and discuss the key terminology, concepts tools and techniques used in business statistical analysis |
| **CO -2** | Critically evaluate the underlying assumptions of analysis tools |
| **CO -3** | Understand and critically discuss the issues surrounding sampling and significance |
| **CO -4** | Discuss critically the uses and limitations of statistical analysis |
| **CO -5** | Solve a range of problems using the techniques covered |
| **CO -6** | Conduct basic statistical analysis of data. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | *Nature and role of statistics for management:* Types of data, data measurement scales, Descriptive Statistics: Measures of Central Tendency, Measures of Dispersion, Introduction to probability theory. Probability Theory: Preliminary concepts in Probability, Basic Theorems and rules for dependent/independent events, Random Variable, Probability distributions, Sampling Techniques, Sampling distributions. |
| **Unit II** | *Hypothesis testing*: Z-test, t-test, Basic Two-Level Factorial Experiments, Additional Tools for Design and Analysis of Two Level Factorials, Correlation and Regression analysis, Multiple and Partial Correlation, ANOVA, Chi-square tests. |
| **Unit III** | Factor Analysis, Time Series Analysis and Business Forecasting, Non-Parametric Methods, SPSS and their use for statistical modeling, applications and case studies in data analysis,Excel,Minitab,R. |

**Text Books:**

1. Levin Richard, I., Rubin David, S., Sanjay Rastogi and Masood Husain, S., Statistics for Management, Seventh Edition, Pearson Education India (2012).
2. S C Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons (2014)
3. Andy Field, Discovering Statistics Using SPSS, Third Edition, Sage Publications Ltd, London (2009)

**Reference Books:**

1. Lawson, J. and Erjavec, J., Modern Statistics for Engineering and Quality Improvement, First Edition, Duxbury Press (2000).
2. Anderson, Sweeney, Williams Camm and Cochran, Statistics for Business and Economics, Twelfth Edition, Cengage Learning (2014)

**SEMESTER 2 : LOGISTICS AND SUPPLY CHAIN MANAGEMENT (TM617)**

| Course Outcomes | |
|---|---|
| **CO -1** | Understand the concept of Logistics, supply chain flows and drivers |
| **CO -2** | Learn Supply chain integration and process view for supply chain strategies. |
| **CO -3** | Advanced tools for managing supply chains through VMI, EDI, E-commers, centralized-decentralized process. |

| | |
|---|---|
| **CO -4** | Outsourcing, bidding, negotiation, procurement procedures through case studies of various companies. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | *Introduction to Logistics and supply chain management (LSCM***)**: Concept and objectives of logistics management and supply chain management (SCM), Flow in supply chain, Decision phases in supply chain, Push-pull supply chains, Supply chain integration, Process view of a supply chain, Lead time management, Cold chains, Reverse logistics, Uncertainties in supply chain, supply chain drivers. Demand management in SCM; *Sourcing and Procurement:* Vendor development, Outsourcing benefit, Vendor evaluation and rating, supply contracts, competitive bidding and Negotiation, E-Procurement, Vendor managed inventory (VMI); *Purchasing:* Objectives, Relations with other departments, centralised and decentralised purchasing, Purchasing procedure in government organisations in India, Types of orders, Tender buying, purchasing department records, Computer-based systems/EDI, Stores management. |
| **Unit II** | *Inventory Management in SCM:* Introduction of inventory system, EOQ model, ABC-VED Analysis, Service-level management, Risk pooling and postponement strategies, Lean, Agile and Leagile supply chain, Designing lean supply chain; *Distribution Management in Supply Chain:* Different distribution strategies in supply chain, warehousing and cross- locking, Network planning and design, 3PL and 4PL |
| **Unit III** | *Managing Information flow in supply chain:* Bullwhip effect- cause and remedy. Role of Information technology in SCM; *Performance management in a supply chain:* Balance scorecard and SCOR Framework. Sustainable and low-carbon supply chains. Sustainable freight transportation. Supply chain risk management. |

**Text Books:**

1. Simchi-Levi, D., Kaminsky, P., Simchi-Levi, E., and Ravi Shankar, Designing & Managing the Supply Chain: Concepts, Strategies & Case Studies, Third Edition, McGraw-Hill Publishing Company Ltd, New Delhi (2008)
2. Richard B. Chase, Ravi Shankar, and F. Robert Jacobs: Operations & Supply Chain Management (14th Edition), McGraw-Hill Publishing Company Ltd, New Delhi (2014)

**Reference Books:**

1. Chopra, S., Meindl, P. and Kalra DV, Supply chain Management: Strategy, Planning and Operations. Sixth Edition, Pearson Education (2016)
2. Tersine, R.J. Principles of Inventory and Materials Management, $4^{th}$ edition, Prentice-Hall Inc., New Jersey, (1994)

## ELECTIVES FROM DEPARTMENT
## MANAGEMENT OF MANUFACTURING AND INTEGRATION (TM 607)

| **Course Outcomes** | |
|---|---|
| **CO -1** | To compete for the future through human resource management and organizational behavior concepts. |
| **CO -2** | To acquire knowledge of changing role of Managerial leadership leads to managing high risk in handling technology and building high performance teams. |
| **CO -3** | To understand the critical-to-quality concepts to increase overall productivity. To learn quality related issue and quality philosophies. |
| **CO -4** | To drive the economy for R&D activities through strategic aspects.<br>To provide the strategies to mitigate cost and time overrun. |
| **CO -5** | To study the role of management of manufacturing and integration for working towards industry 4.0. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Introduction to Manufacturing, Concepts of Total Quality Management (TQM) and Six Sigma, Benchmarking and Business Process reengineering, The continuous process improvement cycle. |
| **Unit II** | Lean Manufacturing, Design for Manufacturing. Rapid Prototyping, 3D printing, IT for Manufacturing: Digital and Smart Factory, Virtual Product Creation, Interface between R&D and Manufacturing, Product Lifecycle Management, Concurrent and Simultaneous Engineering, cellular manufacturing system, design planning and implementation. |
| **Unit III** | Flexible Manufacturing System: Automation of Manufacturing Processes – an overview, Flexible Automation, Integrated Manufacturing Modelling and FMS, Hardware Components, Control Components, System Planning and Design Problems, Production Planning, Process Planning, Scheduling, Economic and Technological Aspects, Automation / Mechatronics / Robotics, Manufacturing 4.0 |

**Text Books**:

1. Partik Jonsson and Stig-Arne Mattsson, "Manufacturing, planning and control", McGraw-Hill, 2011
2. K. L. S. Sharma, "Overview of Industrial Process Automation", Elsevier, 2011.
3. Kuldeep Sareen and Chandandeep Grewal, "CAD/CAM", S. Chand and Company Ltd., 2009
4. H. D. Ramachandra, "Mechatronics", Sudha Publication, 2006

**References Books**:

1. Michael Grieves, "Product lifecycle management", McGraw-Hill, 2006
2. Tien-Chien Chang, Richard A. Wysk and Hsu-Pin Wang, "Computer-Aided Manufacturing", Pearson, 2009
3. Mark W. Spong, Seth Hutchinson and M. Vidyasagar, "Robot Modelling and control", Wiley, 2006
4. Mikell P. Groover, "Principles of modern manufacturing", Wiley, 2014
5. Chris Anderson, "Makers: The New Industrial Revolution", Cornerstone Digital, 2013

**KNOWLEDGE MANAGEMENT (TM 608)**

| Course Outcomes | |
|---|---|
| **CO -1** | Understand Apply complex theories and practice of knowledge and intellectual capital management |
| **CO -2** | Understand Apply theories to a wide range of scenarios |
| **CO -3** | Formulate action plans for knowledge intensive organisations |
| **CO -4** | Distinguish aspects of industrial era management that may be inappropriate for knowledge intensive organisations and provide alternatives |
| **CO -5** | Understand Formulate a framework for thinking about knowledge intensive organisations |
| **CO -6** | Understand, describe and work with intangibles |

| Unit | Syllabus |
|---|---|
| **Unit I** | Data Information Knowledge wisdom, Knowledge cycle, Basics of Knowledge Management: Knowledge capture, storage, use and reuse learning organisations. |
| **Unit II** | Intellectual capital and its measurements, Performance management systems in Knowledge Management, Knowledge transfer in organisations, knowledge mapping, knowledge ownership, knowledge losses, knowledge management for new product development, Human aspects of knowledge management, design and implementation of effective knowledge management systems |
| **Unit III** | Knowledge Management in the Fourth Industrial Revolution, Theoretical and Practical Considerations in Cyber Physical Production Systems, the future of Knowledge Management |

**Text Books:**

1. Harvard Business Review on Knowledge Management by Peter Ferdinand Drucker, David Garvin, Dorothy Leonard, Susan Straus, John Seely Brown
2. Sudhir Warier , Knowledge Mangement, Vikas publishing House
3. Knowledge Retention: Strategies And Solutions – Jay Liebowitz
4. Knowledge Management – Paul Gamble & John Blackwell
5. The Power Of KM: Harnessing The Extraordinary Value Of Knowledge Management – Brent N. Hunter
6. Knowledge Management in Theory and Practice – Kimiz Dalkir
7. Knowledge Management – Shelda Debowski
8. Knowledge Management: Concepts and Best Practices by Kai Mertins (Editor), Peter Heisig (Editor), Jens Vorbeck (Editor)

**References Books:**

1. If Only We Knew What We Know: The Transfer of Internal Knowledge and Best Practice by Carla O'dell, C. Jackson Grayson
2. The Selfish Gene , Richard Dawkin
3. The Reality of Magic, Richard Dawkin
4. The Blind watchmaker, Richard Dawkin

5. The greatest show on Earth, Richard Dawkin
6. The extended phenotype, Richard Dawkin

**SYSTEMS ENGINEERING FOR MANAGERS (TM 609)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | Understand engineering design and product lifecycles in the context of the professional career Explain how system engineering methodologies make for an orderly design process |
| **CO -2** | Elaborate on how intended use guides the development of socio-technical systems, Develop and evaluate systems requirements |
| **CO -3** | Analyse and decompose system requirements into functions and design requirements, Plan the design process |
| **CO -4** | Create a system design concept that can be verified against the requirements, Weigh the strengths and weaknesses of system thinking and service thinking, Outline how product-service systems can be designed to support in-service systems |
| **CO -5** | Demonstrate professional skills including participation in and running meetings; effective team membership and leadership; preparation of professional standard documentation based on templates from a business management system. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | SYSTEMS ENGINEERING AND THE WORLD OF MODERN SYSTEMS<br>What Is Systems Engineering?<br>Origins of Systems Engineering<br>The Power of Systems Engineering<br>Examples of Systems Requiring Systems Engineering |
| **Unit II** | STRUCTURE OF COMPLEX SYSTEMS<br>System Building Blocks and Interfaces<br>Hierarchy of Complex Systems<br>System Building Blocks<br>The System Environment<br>Interfaces and Interactions<br>Complexity in Modern Systems<br>Examples of Complex Systems |
| **Unit III** | THE SYSTEM DEVELOPMENT PROCESS<br>Systems Engineering through the System Life Cycle<br>System Life Cycle<br>Evolutionary Characteristics of the Development Process<br>The Systems Engineering Method<br>Testing throughout System Development<br>Development process examples |
| **Unit IV** | SYSTEMS ENGINEERING MANAGEMENT<br>Managing System Development and Risks<br>WBS<br>SEMP<br>Risk Management |

**Text Books:**

1. B.Dennis M.Buede, The Engineering Design of Systems: Models and Methods, John Wiley& Sons,2011
2. A.Kossiakoff, W.N.Sweet,S.J.Seymour & S.M.Biemer,Systems Engineering: Principles and Practice,Wiley,2011
3. D.J.E.Kasser,A Framework for Understanding Systems Engineering, Book/Surge Publishing,2007

**References Books:**

1. George,A. Hazelrigg, Systems Engineering: An Approach to Information-Based Design, Prentice Hall NJ, 1996.
2. Benjamin, A., Blanchard, and Walter,J. Fabrycky, Systems Engineering and Analysis, 3rd Ed., Prentice Hall International Series, Industrial & Systems Engg., 1998
3. B.S.Blanchard, Systems Engineering Management,Wiley,1998

**SOFTWARE PROJECTS MANAGEMENT (TM611)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | Get an overview of Software project management, its evaluation, management and approach. Learn the concept of Agile Project Management. |
| **CO -2** | Calculate the software effort estimation through various methods. |
| **CO -3** | Determine the Project management scheduling through activities, Risk associated and resource association. |
| **CO -4** | Monitoring and control of overall project for assessing the project successfulness. |
| **CO -5** | Understanding software quality and reliability concept and its certification. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | *Introduction to Software Project Management*: Software projects versus other types of project, Activities Covered by software project management, Some ways of categorizing software projects, Stakeholders, Project success and failure.; *Project Evaluation and Programing Management*: Project portfolio management, Evaluation of individual projects, Cost-benefits Evaluations techniques, Risk Evaluation, Programme management, managing the Allocation of Resources within programmes, Aids to programme management; *An overview of Project Planning:* Introduction Step wise project planning; *Selection of an Appropriate Project Approach*: Build or Buy?, Choosing Methodologies and Technologies , Software processes and process Models , Choices of process Models , Structure versus speed of Delivery , The waterfall Model , The Spiral Model , Software prototyping , Other Ways of Categorizing Prototypes ,incremental Delivery , Atern/ Dynamic systems development methods , Rapid application development , Agile methods , Extreme programming (XP), Scrum , Managing Iterative processes , Selecting the most appropriate process Model. |
| **Unit II** | *Software Effort Estimation*: The basis for software estimating, Software effort estimation techniques , Bottom up estimating, the top-down Approach and parametric models ,Expert Judgement , estimating by analogy ,Albrecht function point analysis, COSMIC full function points , COCOMO II : A parametric productivity Model , cost estimation; .*Activity Planning*: Sequencing and Scheduling Activities, Network |

| | |
|---|---|
| | planning Models, Formulating a Network Model, Identifying the Critical path; *Risk Management***:** Categories of risk, Risk identification , Risk assessment , Risk planning, Risk management , Evaluating risks to the schedule , Monte carlo simulation; *Resource Allocation:* The nature of Resources ,Identifying Resource Requirements, Scheduling resources , Counting the cost ,Being specific , Cost schedules |
| **Unit III** | *Monitoring And Control***:** Creating the framework, visualizing progress, cost monitoring, earned value analysis, prioritizing monitoring, Getting the project Back to target, Software Configuration management (SCM); *Managing Contracts***:** Stages in contract placement, typical terms of a contract, Contract management, Acceptance; *Working In Teams***:** Becoming a team, Decision making , Organization and team strictures , Dispersed and virtual teams , Communication plans; *Software Quality***:** Defining software Quality, ISO 9126, Product and process metrics, , Quality management systems, process capability models , techniques to Help Enhance software Quality , software reliability. |

**Text Books:**


1. Ravi Chopra, Software Project Management, Katson Books.
2. Sanjay Mohapatra, Software Project Management, Cengage Learning.
3. Rishabh Anand, Software Project Management, Katson Books.


**References Books**:


1. Pankaj Jalote:Software Project Management in Practice, Pearson
2. Bob Hughes, Mike Cotterell, Rajib Mall: SOFTWARE PROJECT MANAGEMENT (5th edition),-McGraw Hill Education. 2016
3. Taylor James:Managing Information Technology Projects: Applying Project Management Strategies To Software, Hardware, And Integration Initiatives 1st Edition, AMACOM
4. Gunther Ruhe &Claes Wohlin:Software Project Management in a Changing World, Springer
5. Hughes, Software Project Management, 5th edition, SIE Publication.
6. Royce, Software Project Management: A Unified Framework, 1e, Pearson Publication.


**VALUE ENGINEERING (TM 613)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | Reference to acquire the basic concept of value engineering and value analysis. |
| **CO -2** | It gives functional approach to value improvement and various techniques of the job plan. |
| **CO -3** | Illustrations and In depth concept of life cycle costing and its methods.0 |
| **CO -4** | Enriching value to the system through cognition and creativity and its usefulness. |
| **CO -5** | Evaluation of various value enrichment alternatives and making decision through matrix. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Introduction to Value Engineering and Value Analysis, Methodology of V.E., Quantitative definition of value, Use value and prestige value, Estimation of product quality/performance, Classification of functions, functional cost and functional worth, Effect of value improvement on profitability. |

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|---|---|
| **Unit II** | Introduction to V.E. job plan / Functional approach to value improvement, Various phases and techniques of the job plan, Life Cycle Costing for managing the total value of a product, Cash flow diagrams, Concepts in LCC, Present Value concept, Annuity cost concept, Net Present Value, Pay Back period, Internal rate of return on investment (IRR), Continuous discounting, Examples and illustrations. |
| **Unit III** | Creative thinking and creative judgment, False material, labor and overhead saving, System reliability, Reliability elements in series and in parallel, Decision Matrix, Evaluation of value alternatives, Estimation of weights and efficiencies, Sensitivity analysis, Utility transformation functions, Fast diagramming, Critical path of functions, DARSIRI method of value analysis. |

**Text Books:**

1. Anil Kumar Mukhopadhyaya, Value Engineering: Concepts, Techniques and Applications, Sage Publication.
2. Zimmerman L., Value Engineering Paperback – 2010.

**References Books:**

1. Del l. Younker, Value Engineering: Analysis And Methodology,
2. J. Paul Guyer, Value Engineering (Engineering Sound Bites) Kindle Edition

**DESIGN MANAGEMENT (TM 614)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | Understand the various issues in philosophical and psychological perspectives. |
| **CO -2** | Developing design perceptions and its effect on competitiveness. |
| **CO -3** | Learn data elicitation techniques and various analysis useful for design management. |
| **CO -4** | Understanding the design thinking, value analysis and value engineering. |
| **CO -5** | Various applications of computer in design management. Exploring the knowledge on prototyping, entrepreneur and IPR. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Introduction; Designer's view; Philosophical and psychological issues in design; Fostering creativity and innovation; cognition: Action selection, memory, decision making; Perception: Auditory & Visual, errors. Design and Competitiveness: Oligopoly, Monopoly |
| **Unit II** | Requirement elicitation and analysis: QFD, HOQ; Anthropometrics, Human factors & Ergonomics; Environmental design; Industrial design management; basics of work study: time study, motion study; Economic analysis: Break even analysis, profit, Taguchi function |
| **Unit III** | Collaboration and conflict management; concept of value analysis and value engineering- design perspective; role of computer in design; rapid prototyping; designer as an entrepreneur, designer's knowledge on Intellectual Property Rights |

**Text Books:**

1. Oakley, M. (Ed), Design Management – A Handbook of Issues and Methods, Blackwell Publication.
2. Kathryn Best, Design Management: Managing Design Strategy, Process and Implementation
3. Brigitte Borja de Mozota, Design Management: Using Design to Build Brand Value and Corporate Innovation

**References Books:**

1. Michel Farr, Design Management.
2. Rachel Cooper, Sabine Junginger and Thomas Lockwood, Design Management.

**INTRODUCTION TO VARIABLES OF NATION BUILDING (TM 616)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | Evolution, basic concept and structure of National service scheme. |
| **CO -2** | Problem solving and decision making approach for improvement of life competencies. |
| **CO -3** | This guides for entrepreneurship development ways and means. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | *Introduction and Basic Concepts of National Service Scheme (NSS)*: History, philosophy, aims & objectives of NSS, Emblem, flag, motto, song, badge etc., Organizational structure, roles and responsibilities of various NSS functionaries. |
| **Unit II** | *Life competencies & Disaster Management*: Definition and importance of life competencies, Communication, Inter Personal, Problem-solving and decision-making, Introduction to Disaster Management, classification of disasters, Role of youth in Disaster Management |
| **Unit III** | *Entrepreneurship Development:* Definition & Meaning, Qualities of good entrepreneur, Steps/ways in opening an enterprise, Role of financial and support service Institutions. |

**Text Books:**

1. Disaster Management, Harsh k Gupta
2. Management of natural disasters in developing countries, H N Srivastava
3. Entrepreneurship Development, S Anil Kumar

**References Books:**

1. Chhatrapati Shahu – The Pillar of Social Democracy, Ed. P.B. Salukhe.
2. National Service scheme Manual, Govt. of India.
3. Training Programme on National programme scheme, TISS.
4. Orientation courses for N.S.S. programme officers, TISS.
5. Case material as Training Aid for field workers, Gurmeet Hans

**OPERATIONS MANAGEMENT (TM618)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | Understanding production and operations systems for manufacturing industry. |
| **CO -2** | Learning various tools and techniques for facilities planning and design. |

| | |
|---|---|
| **CO -3** | Various techniques for productions and management of inventory concept. |
| **CO -4** | Learning the concept of work study, time study, quality engineering, SPC and Maintenance concepts. |
| **CO -5** | Exploring world class manufacturing facilities and their practices as case study. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Managing operations; planning and design of production and operations systems. Service characteristics. Facilities planning location, layout and movement of materials. Line balancing. Analytical tools and techniques for facilities planning and design. |
| **Unit II** | Production forecasting. Aggregate planning and operations scheduling, Production Planning and Control. Purchasing, Materials Management and Inventory control and JIT Material Requirements Planning. MRPII, ERP, Optimization techniques applications. |
| **Unit III** | Work Study, Value Engineering, Total quality &statistical process control. Maintenance management and equipment policies. Network planning and control. Line of Balance, World class manufacturing and factories of the future, Case studies. |

**Text Books:**

1. Operations Management: Theory and Practices, B. Mahadevan; 3rd edition, Pearson.
2. Production and Operations Management; R. Paneerselvam, 3rd edition, PHI.

**Reference Books:**

1. Richard B. Chase, Ravi Shankar, and F. Robert Jacobs: Operations & Supply Chain Management (14th Edition), McGraw-Hill Publishing Company Ltd, New Delhi (2014)
2. Operations Management; J. Heizer and B. Render; 11th edition, Pearson.
3. Operations Management; Russell and Taylor; 7th edition, Wiley.

## ADVANCED PROJECT MANAGEMENT TECHNIQUES (TM619)

| **Course Outcomes** | |
|---|---|
| **CO -1** | To get awareness of various advanced project management concepts. |
| **CO -2** | Exploring software project management and tools and techniques for managing projects. |
| **CO -3** | Design and Development of product process and intricacies in project phases. |
| **CO -4** | The process of collaboration for product development and integration process. |
| **CO -5** | Various case studies and projects from different industries as applications of project management concept. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Advanced concepts in Project Management: Agile PM, Capability Maturity Model (CMM), Earned Value Analysis (EVA) and Earned Duration Analysis (EDA) |
| **Unit II** | Software Project Management: Software testing and quality Management, Effort estimating and scheduling, Project Monitoring and control, Reviews, Risk Management, |

| | |
|---|---|
| | Tools for software project such as MS project |
| **Unit III** | Applications and case studies in Project Management, Management of multiple projects |
| **Unit IV** | Collaborative Product Development: Integrated Product Design, User Experience Design, Internal & External Collaborations, Integrated Process & Product Development. |

**Text Books:**


1. Ravi Chopra, Software Project Management, Katson Books.
2. Sanjay Mohapatra, Software Project Management, Cengage Learning.
3. Rishabh Anand, Software Project Management, Katson Books.


**References Books**:


1. John M. Nicholas and Herman Steyn, Project Management for Business, Engineering, and Technology: Principles and Practices (Third Edition), Elsevier (2008).
2. Pankaj Jalote:Software Project Management in Practice, Pearson
3. Bob Hughes, Mike Cotterell, Rajib Mall: SOFTWARE PROJECT MANAGEMENT ($5^{th}$ edition),- McGraw Hill Education. 2016
4. Taylor James: Managing Information Technology Projects: Applying Project Management Strategies To Software, Hardware, And Integration Initiatives 1st Edition, AMACOM


**ACCOUNTING AND FINANCE FOR TECHNOLOGISTS (TM 620)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | Understand the basic concepts of accounting and finance. Understanding the process of financing the projects, feasibility and funding. |
| **CO -2** | Acquire the knowledge on social cost benefit analysis, ROI, capita, audit and profit concepts. |
| **CO -3** | Focusing on contracts, cost escalation and its consequence. |
| **CO -4** | Determine Planning and budgeting for projects and its implication on it. |
| **CO -5** | Risk analysis of accounting and financing while import and export of product and projects and its case studies. |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Introduction to accounting, accountability, transparency, responsibility; Basic accounting concepts and financial statements, sources and use of finance, Basics of Project finance in Public domain, feasibility study, Asset Funding. |
| **Unit II** | Social cost benefit analysis; Return on Investment, Cost of Capital, Audit and control; Cost concepts and profit centers and responsibility accounting; costing and profitability analysis; Good costs vs. Bad costs. |
| **Unit III** | Basics of contracts, Cost escalation clause in contracts and consequences, Planning and budgeting; Basic concepts of working capital, Basics of financing of imports, exchange rate risk in capital expenditure decisions |

**Text Books:**

1. Anthony, Robert N (1984): Management accounting, Text and Cases, Richard D. Irwin, Inc.illionois
2. Ernest, W. Walker (1976): Essentials of Financing Management, Prentice Hall, New Delhi.
3. Gestenberg, Charles W. (1962): Financial Organisation and Management of Business Asia Publishing, Sultan Chand and Sons
4. Pandey, I.M. (1983): Financial Management, Vikas Publishing House Pvt. Ltd., New Delhi.
5. Jain S P ,Narang K L , Cost and Management Accounting, Kalyani Publishers
6. Khan a, Jain, Financial Management, Tata McGraw Hill
7. Dr. V K Goyal, Finanacial Accounting, Excel Books

**Reference Books:**

1. Van, Home James C. (1971): Fundamentals of Financial Management Prentice Hall Inc. Englewood Cliffs, New Jersey.
2. Vyas, J.N. (1983): Financing and Industrial, N.K. Vyas, Family trust, Ahmedabad.
3. Walker, Ernest, W (1976): Essentials of Financing Management,¬ Prentice Hall of India Ltd., New Delhi.

**ARTIFICIAL INTELLIGENCE (AI) FOR MANAGERS (TM621)**

| **Course Outcomes** | |
|---|---|
| **CO -1** | Develop a core understanding of AI & ML concepts and its business applications across sectors |
| **CO -2** | Gain exposure to the latest algorithms, tools, techniques, and frameworks used in AI & ML for solving real-world business challenges |
| **CO -3** | Explore the impact of these technologies on business outcomes across functions and domains |
| **CO -4** | Understand data and how AI & ML can be leveraged to create a data-driven organisation |
| **CO -5** | Gain hands-on learning in identifying, defining, designing, implementing & monitoring AI& ML Projects |

| **Unit** | **Syllabus** |
|---|---|
| **Unit I** | Information Systems, Introduction, Management of Information Systems, Types of Information Systems, Role of Data mining, Designing & Induction Challenges |
| **Unit II** | Artificial Intelligence Concepts, Different Types of AI – Narrow AI, General AI, Super AI, Building Blocks of AI, Basic Terminologies in AI&ML, Difference between AI, ML, DL, RL, BDA; ***Fields of AI*** – Computer Vision, Speech Analytics, Natural Language Processing<br>***AI Learning Models*** – Supervised, Unsupervised, Reinforcement |
| **Unit III** | Basics of contracts, Cost escalation clause in contracts and consequences, Planning and budgeting; Basic concepts of working capital, Basics of financing of imports, exchange rate risk in capital expenditure decisions<br>***(A) Data and Algorithm***<br>Problems and required Algorithms |

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|---|---|
| | Artificial Neural Network<br>Big Data Analytics and AI<br>***(B) Develop AI & ML Models without writing code***<br>***(C ) AI Applications***<br>i. Computer Vision<br>ii. Natural Language Processing<br>**iii.** Voice AI |
| **Unit IV** | Developing Use Cases; Common Mis-conceptions about AI&ML<br>Case studies/Tutorial on Application of AI for Management Decision |

**Text Books:**

1. Artificial Intelligence: A Modern Approach, Prentice-Hall, Third Edition (2009) Stuart Russell & Peter Norvig
2. Applied artificial intelligence: a handbook for business leaders by Mariya Yao, Adelyn Zhou, Marlene Jia
3. Artificial Intelligence and Machine Learning by Finlay, Steven
4. Artificial Intelligence Basics A Non-Technical Introduction by Tom Taulli

**Reference Books:**

1. AI for People and Business: A Framework for Better Human Experiences and Business Success 1st Edition by Alex Castrounis
2. Machine Learning For Absolute Beginners: A Plain English Introduction (Second Edition) (Machine Learning From Scratch Book by Oliver Theobald
3. Fundamentals of Machine Learning for Predictive Data Analytics Algorithms, Worked Examples, and Case Studies By John D. Kelleher, Brian Mac Namee and Aoife D'Arcy
4. Artificial Intelligence and Machine Learning for Business: A No-Nonsense Guide to Data Driven Technologies by Steven Finlay
5. Artificial Intelligence: What Everyone Needs to Know by Jerry Kaplan
6. The Future of Leadership: Rise of Automation, Robotics and Artificial Intelligence by Brigette Tasha Hyacinth

**PGC-601 – RESEARCH METHODOLOGY AND IPR**

| | |
|---|---|
| **CO-1** | Understanding the fundamentals of research and its methodology |
| **CO-2** | Choose the appropriate research design and develop appropriate research hypothesis for a research project |
| **CO-3** | Knowledge of manuscript preparation, patents and Intellectual property |
| **CO-4** | Technology transfer and application of IPR in various domains |

| Unit | Syllabus Details |
|---|---|
| **Unit I** | Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations |
| **Unit II** | Effective literature studies approaches, analysis Plagiarism, Research ethics, |

| | |
|---|---|
| **Unit III** | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and<br>assessment by a review committee |
| **Unit IV** | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. |
| **Unit V** | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.<br>Patent information and databases. Geographical Indications |
| **Unit VI** | New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |

**References Textbooks:**


1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
5. Mayall, "Industrial Design", McGraw Hill, 1992.
6. Niebel, "Product Design", McGraw Hill, 1974.
7. Asimov, "Introduction to Design", Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
9. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008


**PGC-602: AUDIT COURSE**

| | |
|---|---|
| **CO-1** | Understand that how to improve your writing skills and level of readability.<br>Learn about what to write in each section. Understand the skills needed when writing a Title. Ensure the good quality of paper at very first-time submission. |
| **CO-2** | Understanding foundations of hazards, disasters and associated natural/social phenomena.<br>Familiarity with disaster management theory (cycle, phases) |
| **CO-3** | Understanding basic Sanskrit language<br>Ancient Sanskrit literature about science & technology can be understood<br>Being a logical language will help to develop logic in students<br>Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.<br>Discuss the intellectual origins of the framework of argument that informed the conceptualization of social reforms leading to revolution in India. |
| **CO-4** | Students will gain deeper understanding about the purpose of their life. Students will understand and start applying the essential steps to become good leaders. Students will emerge as responsible citizens with clear conviction to practice values and ethics in life |
| **CO-5** | Demonstrate a broad and coherent body of knowledge with depth in the underlying principles |

| | |
|---|---|
| | and concepts. Integrate knowledge of the diversity of cultures and peoples. Use the collaborative learning into a course in a way that aligns with students learning objectives and intended outcomes.<br>Critically analyse the classroom teaching learning and the ability to observe classroom behaviour. |
| **CO-6** | Use practical tools for stress management in educational environments;<br>Foster resilience and cope with stressful situations at the workplace to increase their well-being;<br>Improve their emotional intelligence to better deal with stress;<br>Understand the best relaxation techniques for educators and students |
| **CO-7** | p inter personal skills and be an effective goal-oriented team player.<br>p professionals with idealistic, practical and moral values.<br>p communication and problem-solving skills.<br>neer attitude and understand its influence on behavior |

| Unit | Syllabus Details |
|---|---|
| **Unit I** | **English for Research Paper Writing**<br>Planning and preparation, identifying research problem, research questions, structuring paragraph, developing a persuasive style in writing, objectivity, avoiding ambiguity etc.<br>Methodology, literature review/survey, writing introduction, result discussion, analyzing findings, conclusion and various sections. |
| **Unit II** | **Disaster Management**<br>Introduction: Concepts and definitions: Disaster, hazard, vulnerability, resilience, risks, frequency and details, capacity, impact, prevention, mitigation.<br>Disaster Risk Reduction (DRR)<br>Disaster management: Applications and case studies |
| **Unit III** | **Sanskrit for Technical Knowledge**<br>Alphabets in Sanskrit,<br>Past/Present/Future Tense,<br>Simple Sentences<br>Technical information about Sanskrit Literature<br>Technical concepts of Engineering-Electrical, Mechanical,<br>Architecture, Mathematics |
| **Unit IV** | **Value Education**<br>Values and self-development<br>Personality and Behavior Development<br>Character and Competence |
| **Unit V** | **Constitution of India**<br>History of Making of the Indian Constitution<br>Philosophy of the Indian Constitution<br>Contours of Constitutional Rights & Duties<br>Organs of Governance<br>Local Administration<br>Election Commission |

| | |
|---|---|
| **Unit VI** | **Pedagogy Studies**<br>Introduction and Methodology : Aims and rationale, Policy background, Conceptual framework and terminology<br>Thematic overview: Pedagogical practices are being used by teachers<br>in formal and informal classrooms in developing countries.<br>Evidence on the effectiveness of pedagogical practices :Professional development: alignment with classroom practices and<br>follow-up support |
| **Unit VII** | **Stress Management by Yoga**<br>Definitions of Eight parts of yoga.( Ashtanga )<br>Yam and Niyam. Do`s and Don't's in life.<br>Asan and Pranayam |
| **Unit VIII** | **Personality Development through Life Enlightenment Skills**<br>Holistic development of personality<br>Approach to day to day work and duties |

**Text Books:**


1. Goldbort R *Writing for Science*, Yale University Press (available on Google books): 2006
2. Day R: *How to write and Publish a Scientific Paper*, Cambridge University Press :2006
3. Adrian Wallwork, *English for Writing Research Papers*, Springer New York, 2011
4. Chakroborty, S.K. "Values and Ethics for organizations Theory and practice", Oxford University Press, New Delhi
5. Tushar Bhattacharya, "Disaster Science and Management", McGraw Hill India Education Pvt. Ltd., 2012.
6. Pradeep Sahni, "Disaster Mitigation: Experiences and Reflections", Prentice Hall,2004.
7. Singhal J.P. "Disaster Management", Laxmi Publications, 2010.
8. Donald Hyndman & David Hyndman, "Natural Hazards & Disasters", Cengage Learning, 2010.
9. Singh B.K., Handbook of Disaster Management: Techniques & Guidelines, Rajat Publication, 2008.
10. Govt. of India: Disaster Management Act, Government of India, New Delhi, 2005.
11. 'Yogic Asanas for Group Training-Part-I":Janardan Swami Yogabhyasi Mandal, Nagpur
12. "Rajayoga or conquering the Internal Nature" by Swami Vivekananda, Advaita Ashrama (Publication Department), Kolkata


**Reference books:**


1. S.C. Parja & Vikram Kate. *Writing and Publishing a Scientific Research Paper*. Springer: 2017.
2. Highman N, *Handbook of Writing for the Mathematical Sciences*, Highman's Book: 1998.
3. "Abhyaspustakam" – Dr.Vishwas, Samskrita-Bharti Publication, New Delhi
4. "Teach Yourself Sanskrit" Prathama Deeksha-VempatiKutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
5. "India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi.
6. The Constitution of India, 1950 (Bare Act), Government Publication.

7. Dr. S. N. Busi, Dr. B. R. Ambedkar framing of Indian Constitution, 1st Edition, 2015.
8. M. P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis, 2014.
9. D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015
10. Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, Compare, 31 (2):245-261.
11. Agrawal M (2004) Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies, 36 (3): 361-379.
12. Alexander RJ (2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.

# DEPARTMENT OF ELECTRONICS ENGINEERING

## M. Tech. in Electronics and Communication Engineering
## (Signal Processing and Communication)

### Semester I

| Sl. No | Course Code | Course Title | Contact Hours/ Week | | *Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1. | EE601 | Microwave Engineering | 3 | 1 | 4 |
| 2. | EE602 | Digital Signal Processing | 3 | 1 | 4 |
| 3. | EE603 | Wireless and Mobile Communication | 3 | 1 | 4 |
| 4. | EE604 | Radar System Design | 3 | 1 | 4 |
| 5. | EE624 | Digital System Design using FPGA | 3 | 1 | 4 |
| 6. | AM607 | Mathematics for Engineers | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | Total | 20 | 6 | 26 |

### Semester II

| Sl. No | Course Code | Course Title | Contact Hours/ Week | | *Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE606 | Statistical Signal Processing | 3 | 1 | 4 |
| 2 | EE607 | Detection and Estimation Theory | 3 | 1 | 4 |
| 3 | | Departmental Elective I | 3 | 1 | 4 |
| 4 | | Departmental Elective II | 3 | 1 | 4 |
| 5 | | Elective – III | 3 | 1 | 4 |
| 6 | | Elective – IV | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | Total | 20 | 6 | 24 |

* Four week industrial practice school during summer vacation for scholarship students (optional).

### Semester III

| Sl. No | Course Code | Course Title | Contact Hours /week | | *Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE651 | M.Tech. Dissertation Phase I | 28** | | 14 |
| | | Total | 28 | | 14 |

### Semester IV

| Sl. No | Course Code | Course Title | Contact Hours /week | | *Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE652 | M.Tech. Dissertation Phase II | 28** | | 14 |
| | | Total | 28 | | 14 |

*****1 Credit in Theory/Tutorial means 1 contact hour and 1 credit practice/Project Thesis means 2 contact hours in a week.

****Contact Hours/ week**

**M. Tech. in Electronics and Communication Engineering**
**(Radar and Communication)**

**Semester I**

| Sl. No | Course Code | Course Title | Contact Hours/ Week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1. | EE601 | Microwave Engineering | 3 | 1 | 4 |
| 2. | EE602 | Digital Signal Processing | 3 | 1 | 4 |
| 3. | EE603 | Wireless and Mobile Communication | 3 | 1 | 4 |
| 4. | EE604 | Radar System Design | 3 | 1 | 4 |
| 5. | EE624 | Digital System Design using FPGA | 3 | 1 | 4 |
| 6. | AM607 | Mathematics for Engineers | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | Total | 20 | 6 | 26 |

**Semester II**

| Sl. No | Course Code | Course Title | Contact Hours/ Week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE610 | Radar Signal Processing | 3 | 1 | 4 |
| 2 | EE611 | Array Signal Processing | 3 | 1 | 4 |
| 3 | | Departmental Elective I | 3 | 1 | 4 |
| 4 | | Departmental Elective II | 3 | 1 | 4 |
| 5. | | Elective – III | 3 | 1 | 4 |
| 6. | | Elective – IV | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | Total | 20 | 6 | 24 |

* Four week industrial practice school during summer vacation for scholarship students (optional).

**Semester III**

| Sl. No | Course Code | Course Title | Contact Hours /week | | *Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE651 | M.Tech. Dissertation Phase I | 28** | | 14 |
| | | Total | 28 | | 14 |

**Semester IV**

| Sl. No | Course Code | Course Title | Contact Hours /week | | *Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE652 | M.Tech. Dissertation Phase II | 28** | | 14 |
| | | Total | 28 | | 14 |

*****1 Credit in Theory/Tutorial means 1 contact hour and 1 credit practice/Project Thesis means 2 contact hours in a week.
****Contact Hours/ week**

## M. Tech. in Electronics and Communication Engineering (Defence Electronics Systems)

**Semester I**

| Sl. No | Course Code | Course Title | Contact Hours/ Week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1. | EE601 | Microwave Engineering | 3 | 1 | 4 |
| 2. | EE602 | Digital Signal Processing | 3 | 1 | 4 |
| 3. | EE603 | Wireless and Mobile Communication | 3 | 1 | 4 |
| 4. | EE604 | Radar System Design | 3 | 1 | 4 |
| 5. | EE624 | Digital System Design using FPGA | 3 | 1 | 4 |
| 6. | AM607 | Mathematics for Engineers | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | Total | 20 | 6 | 26 |

**Semester II**

| Sl. No | Course Code | Course Title | Contact Hours/ Week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE609 | Antenna Systems | 3 | 1 | 4 |
| 2 | EE614 | EMI/EMC Design | 3 | 1 | 4 |
| 3 | | Departmental Elective I | 3 | 1 | 4 |
| 4 | | Departmental Elective II | 3 | 1 | 4 |
| 5. | | Elective – III | 3 | 1 | 4 |
| 6. | | Elective – IV | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | Total | 20 | 6 | 24 |

*Four week industrial practice school during summer vacation for scholarship students (optional).

**Semester III**

| Sl. No | Course Code | Course Title | Contact Hours /week | | *Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE651 | M.Tech. Dissertation Phase I | 28** | | 14 |
| | | Total | 28 | | 14 |

**Semester IV**

| Sl. No | Course Code | Course Title | Contact Hours /week | | *Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE652 | M.Tech. Dissertation Phase II | 28** | | 14 |
| | | Total | 28 | | 14 |

*****1 Credit in Theory/Tutorial means 1 contact hour and 1 credit practice/Project Thesis means 2 contact hours in a week.

****Contact Hours/ week**

## M. Tech. in Electronics and Communication Engineering (VLSI and Embedded Systems)

**Semester I (@DIAT, Pune)**

| Sl. No | Course Code | Course Title | Contact Hours/ Week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1. | EE602 | Digital Signal Processing | 3 | 1 | 4 |
| 2. | EE621 | Digital IC Design | 3 | 1 | 4 |
| 3. | EE622 | RF IC Design | 3 | 1 | 4 |
| 4. | EE650 | Semiconductor devices for high speed and high power applications | 3 | 1 | 4 |
| 5. | EE624 | Digital System Design using FPGA | 3 | 1 | 4 |
| 6. | AM607 | Mathematics for Engineers | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | Total | 20 | 6 | 26 |

**Semester II (@DIAT, Pune)**

| Sl. No | Course Code | Course Title | Contact Hours/ Week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1. | EE638 | Analog and Mixed mode VLSI Design | 3 | 1 | 4 |
| 2. | EE648 | VLSI Fabrication Technology | 3 | 1 | 4 |
| 3. | | Departmental Elective I | 3 | 1 | 4 |
| 4. | | Departmental Elective II | 3 | 1 | 4 |
| 5. | | Elective – III | 3 | 1 | 4 |
| 6. | | Elective – IV | 3 | 1 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | Total | 20 | 6 | 24 |

**Semester III (@ NIELIT CALICUT)**

| Sl. No | Course Code | Course Title | Contact Hours /week | | *Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE651 | M.Tech. Dissertation Phase I | 28** | | 14 |
| | | Total | 28 | | 14 |

**Semester IV (@ NIELIT CALICUT)**

| Sl. No | Course Code | Course Title | Contact Hours /week | | *Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE652 | M.Tech. Dissertation Phase II | 28** | | 14 |
| | | Total | 28 | | 14 |

***1** Credit in Theory/Tutorial means 1 contact hour and 1 credit practice/Project Thesis means 2 contact hours in a week.

****Contact Hours/ week**

**Semester III and Semester IV [Project work and VLSI related Courses @ NIELIT CALICUT].**

**<u>List of Electives</u>**

| Sl. No. | Course Code | Course Title | Contact hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | EE605 | Navigation System Concepts | 3 | 1 | 4 |
| 2 | EE608 | Modern Wireless Communications | 3 | 1 | 1 |
| 3 | EE612 | High Power Microwave Systems | 3 | 1 | 4 |
| 4 | EE613 | Electronic Warfare | 3 | 1 | 4 |
| 5 | EE619 | Software Defined Radio | 3 | 1 | 4 |
| 6 | EE620 | SoC and Embedded Systems | 3 | 1 | 4 |
| 7 | EE623 | Semiconductor Devices | 3 | 1 | 4 |
| 8 | EE625 | High Performance DSP using FPGA | 3 | 1 | 4 |
| 9 | EE626 | Compressed Sensing & Sparse Signal Processing | 3 | 1 | 4 |
| 10 | EE627 | Signal Theory, Linear Algebra & Transform Techniques | 3 | 1 | 4 |
| 11 | EE628 | Advanced Electronics Systems | 3 | 1 | 4 |
| 12 | EE629 | Sonar Signal Processing | 3 | 1 | 4 |
| 13 | EE630 | Sonar System Engineering | 3 | 1 | 4 |
| 14 | EE631 | Satellite Communication | 3 | 1 | 4 |
| 15 | EE632 | Advanced Communication Systems | 3 | 1 | 4 |
| 16 | EE633 | Underwater Communications | 3 | 1 | 4 |
| 17 | EE634 | Monolithic Microwave | 3 | 1 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| | | Integrated Circuit | | | |
| 18 | EE635 | Inertial Sensors and Systems | 3 | 1 | 4 |
| 19 | EE636 | Navigation & Avionic Systems | 3 | 1 | 4 |
| 20 | EE637 | ASIC Verification using System Verilog | 3 | 1 | 4 |
| 21 | EE638 | Analog and Mixed mode VLSI Design | 3 | 1 | 4 |
| 22 | EE639 | Computer Aided Design for VLSI Circuits | 3 | 1 | 4 |
| 23 | EE640 | FPGA Architecture and Applications | 3 | 1 | 4 |
| 24 | EE641 | VLSI Signal Processing | 3 | 1 | 4 |
| 25 | EE642 | SoC Design and Verification | 3 | 1 | 4 |
| 26 | EE643 | Digital Interface Design | 3 | 1 | 4 |
| 27 | EE644 | MIMO Communications | 3 | 1 | 4 |
| 28 | EE645 | Advanced Digital Signal Processing | 3 | 1 | 4 |
| 29 | EE646 | Advanced Simulation Techniques | 3 | 1 | 4 |
| 30 | EE647 | RF Photonics | 3 | 1 | 4 |
| 31 | EE648 | VLSI Fabrication Technology | 3 | 1 | 4 |
| 32 | EE649 | Introduction to Electronics Systems | 3 | 1 | 4 |
| 33 | EE650 | Semiconductor devices for high speed and high power applications | 3 | 1 | 4 |
| 34 | EE651 | Quantum Transport in nanoscale FETs | 3 | 1 | 4 |

## A. Program Outcomes (POs)

**PO1:** An ability to independently carry out research /investigation and development work to solve practical problems.

**PO2:** An ability to write and present a substantial technical report/document.

**PO3:** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate post-graduate program.

## B. Program Specific Outcomes (PSOs)

**PSO1:** The M.Tech. Electronics & Communication Engineering aims at developing skilled knowledgeable human task force in the field of radar and signal processing, catering the needs of defense, social, and DRDO requirements.

**PSO2:** The M.Tech. Electronics & Communication Engineering aims at developing skilled knowledgeable human task force in the field of VLSI and Embedded systems, Defence Electronics systems, catering the needs of defense, Semiconductor industries and DRDO requirements.

## Detailed Contents

***Course Name: MICROWAVE ENGINEERING***
***Course Code: EE601***

**Course Outcome-**

| Course Outcomes | Description |
|---|---|
| **CO1** | Understanding of fundamentals of Maxwell's equations and Transmission line theory. |
| **CO2** | Understanding of the various Two-port Parameters Z-Matrix, Y-Matrix, ABCD-Matrix, S-Matrix |
| **CO3** | Students will understand the basics of microwave components and design: Directional Couplers, Filters, Power dividers, Amplifiers. |

**UNIT-I: INTRODUCTION TO EM WAVE AND TRANSMISSION LINES** Introduction to microwaves,
Maxwell's equations, wave Equation, Plane wave reflection, Dielectric Interference, circuit model and field
analysis, Quarter-wave transformer, lossy transmission lines, TEM, TE and TW wave solutions, types of waveguides, strip lines, relation between dB, dBm, dBw, dB.

**UNIT-II: MICROWAVE NETWORK ANALYSIS:** Impedance, voltage, current, Matrices, scattering, transmission (ABCD) matrix, signal flow graph, Discontinuities and Model analysis, Excitation of waveguides,
Lumped elements, stub tuning, Binomial and Chebyshev multi-section, tapered lines, Bode-Fano criterion.

**UNIT-III: MICROWAVE RESONATORS, DIVIDERS AND COUPLERS:** Serial and parallel resonant circuit, line resonators, Cavity resonators, Excitation of resonators, cavity perturbations, properties of dividers and couplers, Wilkinson power dividers, directional couplers, Quadrature (90˚) Hybrid, Coupled line directional couplers, large couplers, other couplers.

**UNIT-IV: MICROWAVE FILTERS:** Periodic structures filter design by Image Parameter Method, Insertion loss method, filter transformation, filter implementation, stepped-Impedance low-pass filters, coupled line filters, filters using coupled resonators.

**UNIT-V: MICROWAVE DEVICE AND AMPLIFIES DESIGN:** Diode circuits, BJT, FET, Microwave integrated circuits, Microwave tubes, RF oscillators, Microwave oscillators, Phase noise, frequency multiplier, mixers, Two-port power gain, single stage- broadband transistor amplifier design, power amplifiers.

**UNIT-VI: MICROWAVE MEASUREMENTS:** S-parameter measurements, Network analyzer, Spectral characteristics measurements, Spectrum analyzer, Phase noise measurement, Power measurement, Microwave subsystem and system characteristics.

**TEXT BOOKS:**

1. David M. Pozar, Microwave Engineering, John Wiley, India.
2. Robert E. Collin, Foundations of Microwave Engineering, John Wiley USA.

**REFERENCE BOOKS:**

1. Reinhold Ludwing and G. Bogdanov, RF Circuit Design: Theory and applications, Pearson Education, Asia.
2. Lio SY, Microwave Devices and Circuits, Prentice Hall, India.
3. K.D Prasad, Antenna and wave propagation, Satyaprakash Publications, New Dehli.
4. Electromagnetic,John D. Kraus, Mcgraw-Hill.

**LIST OF EXPERIMENTS**

| Sr. No. | Experiments |
|---|---|
| **1.** | Characteristics of Klystron Tube and to determine its electronics tuning range |
| **2.** | Practical and theoretical aspects of V-I characteristics of Gunn diode |
| **3.** | Determine the frequency and wavelength in a rectangular wave guide working on TE10 mode and<br>determine the standing wave ratio and Reflection coefficient |
| **4.** | Functions of multi-hole directional coupler by measuring the following parameter<br>a) Main line and Auxiliary line SWR<br>b) Coupling factor and directivity<br>c) Study of magic tee<br>d) Study of circulator / Isolator<br>e) Study of attenuator (Fixed and Variable Type) |
| 5. | Working of Doppler Radar using Trainer Kit |
| 6. | Radiation Pattern measurement of Antenna |

***Course Name: DIGITAL SIGNAL PROCESSING***

***Course Code: EE602***

**Course Outcome-**

| Course Outcomes | Description |
|---|---|
| **CO1** | Learn the basics of linear algebra, signal, and system. |
| **CO2** | Gain the theory of random variable, probability, and random process. |
| **CO3** | Acquire the basics of transforms such as Fourier transform, Laplace transform, and Hilbert transform |
| **CO4** | Learn the concept of Analog and digital filters |

**UNIT-I: INTRODUCTION TO LINEAR ALGEBRA, SIGNALS AND SYSTEMS**
**Linear algebra:** vector spaces, subspaces, linear independence, dimension, norms, orthogonal bases and Gram Schmidt orthogonalization, linear transformation, Kernel and range, inverse transformations, matrices of linear transformations, change of basis, similarity, Eigen values and Eigen vectors, diagonalization, orthogonal diagonalization of symmetric matrices, singular value decomposition.
**Signals:** classification of signals, continuous and discrete time signals, sampling theorem, sampling and reconstruction of continuous time signals, baseband and bandpass sampling, complex signal.
**Systems:** LTI system, system properties, impulse response and system functions, FIR and IIR systems, convolution and correlation, linear convolution and circular convolution.

**UNIT-II: PROBABILITY, RANDOM VARIABLE AND RANDOM PROCESS**
Randomness, axioms of probability, repeated trails, random variable, distribution and density function, conditional distribution and density, moments, characteristic function, one random variable, two random variable, correlation, covariance, independence, orthogonality, statistics, stochastic process, mathematical description of random signals, concept of a random process, stationarity, Ergodicity, autocorrelation function, cross correlation function, power spectral density function, white noise, Markov Chain.

**UNIT-III: REAL TIME DIGITAL SYSTEM DESIGN AND IMPLEMENTATION**
**Finite word length effects:** fixed-point and floating-point number representations, truncation and rounding errors, quantization noise, coefficient quantization error, product quantization error, overflow error.
**Implementation:** scalar operation, vector operation, matrix operation, complex number representation and operation.
**(Design and implementation of all techniques and algorithms studied in this course).**

**UNIT-IV: TRANSFORMS Transforms:** Fourier series, Fourier transform, discrete time Fourier transform, discrete Fourier transform, Laplace transform, Z-transform, Wavelet Transform, Hilbert transform and their properties and inverse transforms. FFT computations using decimation in time and decimation in frequency, overlap-add and overlap-save method.

**UNIT-V: FILTERS Filters:** analog and digital filters, FIR filter design, IIR filter design, and realization using direct, cascade and parallel forms, lattice structures.

**REFERENCE BOOKS:**
1. S.K. Mitra, Digital Signal Processing: A Computer Based approach, 3rd Ed., Tata McGraw Hill.
2. J. G. Proakis& D. G. Manolakis, Digital Signal Processing: Principles, Algorithms & Applications, 4th Ed., PHI.
3. Alan V Oppenheim & Ronald W Schaffer, Discrete Time Signal Processing, PHI.
4. Athanasios Papoulis, Probability, Random Variables, and Stochastic Processes, TATA McGraw Hill.

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| 1. | Introduction of Matlab/Simulink, Labview and its tool boxes |
| 2. | Sampling and Reconstruction of signals |

| | |
|---|---|
| 3. | Deterministic & Random Signal analysis using power spectral estimation techniques<br>□Period gram power spectral estimation technique<br>□PSD through correlogram technique<br>□Spectrogram analysis |
| 4. | Model based power spectral estimation techniques<br>1. AR Model , MA Model, ARMA Model<br>2. Covariance methods |
| 5. | Speech analysis using LPC. Performance analysis with respect to the Prediction Filter Order & SNR |
| 6. | Digital filter design using Matlab & implementation in FPGA<br>a) FIR & IIR Filters |
| 7. | High Resolution pseudo-spectral estimation technique via<br>a) MUSIC & ESPRIT |
| 8. | Design of Quadrature Mirror Filters (QMF) |

***Course Name: WIRELESS AND MOBILE COMMUNICATIONS***
***Course Code: EE603***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Basics of wireless communication, understanding of basic terms such as Bit error rate, symbol error rate, etc. and advantages and disadvantages of different wireless communication techniques. |
| **CO-2** | Basics of wireless channel modeling, Inter symbol interference, and Doppler fading. |
| **CO-3** | Introduction to cellular communication, understanding of frequency reuse, handover and various multiple access techniques. |
| **CO-4** | A detailed description of multiple access techniques, understanding of phenomenon such as reflection, refraction, scattering, and diffraction. |
| **CO-5** | Basics of RFID, understanding of Basic propagation channel in RFID, various near-field and far-field wireless techniques. |

**UNIT-I: WIRELESS COMMUNICATIONS AND DIVERSITY:**
Introduction to Wireless Communication, Motivation, Types of Wireless Communication, Wireless Channel Modeling, Random Variable, Fading Channels, Linear Transformation, Bit Error Rate (BER) and Symbol Error rate (SER), BER and SER performance for Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), M-ary Pulse Amplitude Modulation (PAM) and M-ary PSK in Additive White Gaussian Noise (AWGN), Diversity Techniques, Issues in Wireless Communication.
**UNIT-II: WIRELESS CHANNEL MODELING:**
Basics of Wireless Channel Modeling, Maximum Delay Spread, RMS Delay Spread, RMS delay based on power profile, Average Delay Spread in Outdoor Cellular Channels, Coherence Bandwidth in Wireless Communications, Intersymbol Interference (ISI), Doppler Fading in Wireless Systems, Doppler Impact on a Wireless Channel, Coherence Time of the Wireless Channel.
**UNIT-III: CELLULAR COMMUNICATIONS:**
Introduction to Cellular Communications, Cell Capacity and Frequency reuse, Coverage Improvement, Multiple Access Technologies, Cellular Processes Call Setup, Handover, Teletraffic Theory, Equalization

and Diversity Techniques, Modulation and Coding Techniques for Mobile Communication, GSM, CDMA, 4G, VOLTE and 5 G technologies, Introduction to Wireless OFDM – OFDM principles, system model – Generation of sub carrier using IFFT, windowing, choice of OFDM parameters, OFDM signal processing.

**UNIT IV: MOBILE RADIO PROPAGATION:**

Introduction to Mobile Radio Propagation, Reflection, Diffraction, Scattering, Propagation Models, Doppler Effect, Delay Spread, Ultra-Wideband Communication System, Fading, TDM, FDM, TDMA, FDMA, CDMA, OFDM.

**UNIT V: NEAR-FIELD WIRELESS COMMUNICATIONS:**

Introduction to RFID System, RFID Reader and Tag Design, Compact RFID Readers, Propagation Channel, Conventional and Unconventional Applications of RFID, Link Budget, Multipath and Ground Reflections, Localization, RFID Standards, Specific Absorption Rate, Chipless RFID, NFC.

**TEXT BOOKS:**

1. Fundamentals of Wireless Communications – David Tse and Pramod Viswanath, Publisher Cambridge University Press.
2. Wireless Communications: Andrea Goldsmith, Cambridge University Press.
3. Wireless Communications: Principles and Practice –Theodore Rapp port Prentice Hall.
4. MIMO Wireless Communications – Ezio Biglieri – Cambridge University Press. A joint venture by IISc and IIT

**REFERENCE BOOKS:**

1. Introduction to Space Time Wireless Communications – Arogyaswami Paulraj –Cambridge University Press.
2. Digital Communications – John G Proakis – McGraw Hill Science/Engineering/Math.
3. Wireless Communications – Andreas Molisch – Wiley IEEE Press.
4. MobileWireless Communications – Mischa Schwartz – Cambridge University Press.

**LIST OF EXPERIMENTS:**

| **Sr. No.** | **Experiments** |
|---|---|
| 1. | Error Vector Magnitude Measurement for GSM Signal Objective<br>i) To measure the error vector magnitude, occupied bandwidth, and channel power of a GSM modulated RF signal using an oscilloscope and the VSA software |
| 2. | Spectrum Analysis of CDMA Signal Objectives<br>i) To measure the channel power of a CDMA modulated RF signal using an oscilloscope and the VSA software<br>ii) To perform an in-band limit test or spectrum emission mask test on a CDMA modulated spectrum |
| 3. | Spectrum Analysis of GSM Signal<br>Objectives<br>i) To measure the spurious and harmonics of the GSM and CDMA modulated RF signal using an oscilloscope and the VSA software<br>ii) To perform an out-of-band limit test that identifies the pass or fail level of the spurious and harmonics |
| 4. | Occupied Bandwidth Measurement for GSM and CDMA Signals |

| | |
|---|---|
| | Objectives<br>i) To measure the occupied bandwidth of a GSM and CDMA modulated RF signal using an oscilloscope and the VSA software<br>ii) To determine the parameter that changes the occupied bandwidth |
| 5. | Adjacent Channel Power Ratio Measurement for GSM and CDMA Signals<br>Objective<br>i) To measure the adjacent channel power ratio of the GSM and CDMA modulated RF signal using oscilloscope and VSA software |
| 6. | Noise and Error Influence for GSM Signal<br>Objective<br>i) To measure the error vector magnitude of a GSM modulated RF signal with influence of noise and error using oscilloscope and VSA software |

***Course Name: RADAR SYSTEM DESIGN***
***Course Code: EE604***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Analysis, design and development of RADAR transmitter receiver, and Antenna. |
| **CO-2** | Students will learn formulated RADAR equations for various types of RADARs (Bi-static, surveillance and static) and also understands the concepts of jamming. |
| **CO-3** | Students will acquire knowledge of RADAR cross section, clutter, atmospheric propagation and probability of false detection |
| **CO-4** | Students will be capable of applying their knowledge and skills to design RADAR transmitter and receiver. |
| **CO-5** | ents will be able to apply their knowledge and skills to simulate moving target<br>)ARs, Measurement of Doppler shift, and other real time situations. |

**UNIT-I: INTRODUCTION TO RADAR -** Basic principle of radar, Frequencies of operation, Classification of radars, their functionality and applications, Types of radar – CW, FMCW, Pulse Doppler, – principles and applications.

**UNIT-II: RADAR PARAMETERS/DEFINITIONS -** Radar Range, Cross Range and Doppler/Velocity measurements and Resolutions, Peak power, Average power and Duty Cycle, Target, Noise Power, Noise Power density, False Alarm, Concept of Detection.

**UNIT-III: RADAR EQUATIONS:** Derivation of the Basic Radar Equation, Point Target in Interference, Receiver Noise and Noise Bandwidth, Signal to Noise Ratio (SNR), Losses in Radar Equation, Signal Integration and Processing Gain, Radar Equation for Bistatic, Search and Tracking Radars, Equation for Beacon, Cover Up and Self Protection Jamming.

**UNIT-IV: RADAR CROSS SECTION (RCS) & THEORY OF DETECTION -** Probability of Detection Pd, Probability of False Alarm PFA and Relation between Pd, Pfa and SNR–statistical phenomenon of Noise. Target characteristics– RCS, RCS fluctuation, Swirling Models, SNR deviation for fluctuating targets,

**UNIT-V: CLUTTER** – Ground/Surface, Sea clutter, Radar Equation for low Grazing Angle, Volume clutter – Rain, birds, chaff, Clutter discrete, Clutter characteristics of airborne radar – Clutter limited operation Vs Noise limited operation of radar, Losses.

**UNIT-VI: ATMOSPHERIC PROPAGATION -** Layers of the Atmosphere and Ray Travel, Interference and Diffraction Region, Refraction of EM Waves, Effective Earth Model, Anomalous Propagation, Ionosphere Refraction and Attenuation.

**UNIT-VII: SURVEILLANCE AND TRACKING RADAR –** Concept of Tracking, Conical Scan Angle Tracking, Lobing Angle Tracking, Monopulse Tracking; Amplitude and Phase Comparison, Wideband Monopulse Tracking, Conventional 2D Surveillance radar : Battlefield Surveillance Radar, Coastal Surveillance radars, AESA radars and Airborne Radars.

**RADAR DESIGNS; RADAR ELEMENTS' DESIGN**

**UNIT-VIII: RADAR TRANSMITTER DESIGN-** Functions of Radar Transmitters, Transmitter Features, Transmitter Sub-Systems, Active Device for Different Frequency Bands, Tube Transmitters, Solid State Transmitters, Concept of Distributed Transmitters.

**UNIT-IX: RADAR ANTENNA DESIGN-** Function and Features of Radar Antenna, Types of Antennae, Phased Array Antenna, Antenna Elements, Architectures for phased array, Antenna based architecture, Bandwidth based architecture, function based radar, electronic/mechanical steering phased array, Phase shifters, and radiators, frequency scan array, beam agility, Interleaving of detection, Frame time, Radar Scheduling- Algorithms for scheduling.

**UNIT-X: DUPLEXER/TR SWITCH & RADAR RECEIVER -** Function and Characteristics, Types of Duplexer, Radar Receiver Characteristics, Receiver Parameters, Receiver Architectures, Digital Receiver, modern radar concepts **-** Synthetic Aperture Radar principle**, t**he SAR characteristics like cross range, aperture, Doppler, chirp, SAR modes: strip map, spotlight**,** Doppler beam sharpening, Inverse SAR**,** Advancements in Pulsed and CW radars, ECCM techniques

**TEXT BOOKS:**

1. Mark A. Richards, Principles of Modern Radar: Basic Principles, Yes Dee Publishing Pvt., Ltd.
2. M.I. Skolnik, Introduction to Radar Systems, Tata MG Hill.
3. T.W. Jeffrey Phased – Array Radar Design, Scitech Publishing.
4. I.G. Cumming, Digital Processing of Synthetic Aperture Radar Data: Algorithms and Implementations, Artech House.

**REFERENCE BOOKS:**

1. B.R. Mahafza, Radar System Analysis and Design Using, CRC press.
2. Peyton Z. Peebles, Radar Principles, Wiley.
3. Harold R. Raemer, Radar Systems Principles, CRC press.
4. George W. Stimson, Introduction to Airborne Radar, Scitech Publishing.

**LIST OF EXPERIMENTS**:

| Sr. No. | Experiments |
|---|---|

| | |
|---|---|
| 1 | Generation of different Radar waveforms, Measurement of Doppler frequency shift, RCS measurement, Range measurement using Radar trainer kit. |
| 2 | Calculation of probability of detection for fluctuating targets, Modeling a pulse Doppler radar system, MIMO radar simulation using SystemVue tools. |
| 3 | Simulating moving targets, FMCW simulation using SystemVue. |
| 4 | Target cluster forming and range finding, Dead-zone marking and target detection using BFSR. |
| 5 | Target relative range/speed estimation, Realization of TWS using BFSR |
| **6** | Demonstration of the principle of IFF, Realization of Target position prediction using its data. |

***Course Name: NAVIGATION SYSTEM CONCEPTS***
***Course Code: EE605***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Basics of navigation, position fixing, radio and satellite navigation, and terrestrial radio navigation, understanding of coordinate frames, kinematics, earth surface and gravity models. |
| **CO-2** | Understanding of satellite navigation, global positioning system, GNSSS, and detailed comparison between various navigation systems. |
| **CO-3** | Basic understanding of Multipath Mitigation, Signal Monitoring, Semi-Codeless Tracking, Radio Positioning Configurations and Methods. |
| **CO-4** | Basics of Aircraft Navigation Systems, Error Sources, Differential Loran, Ultra-wideband, Short-Range Communications Systems, Other Positioning Technologies, Receiver Hardware, and Antenna. |
| **CO-5** | Knowledge of Attitude Measurement, Height and Depth Measurement, Other Dead-Reckoning Techniques, Sequential Processing, Laser TRN, Barometric TRN, Sonar TRN, Stellar Navigation, Magnetic Field Variation, and Measurement Models. |

1. **Introduction to Navigation:** What Is Navigation, Position Fixing, Dead Reckoning, Inertial Navigation, Radio and Satellite Navigation, Terrestrial Radio Navigation, Satellite Navigation, Feature Matching, The Complete Navigation System.

2. **Navigation Mathematics:** Coordinate Frames, Kinematics, and the Earth: Coordinate Frames, Kinematics, Earth Surface and Gravity Models, Frame Transformations.

3. **GNSS: Fundamentals, Signals, and Satellites:** Fundamentals of Satellite Navigation, The Systems: Global Positioning System, GLONASS, Galileo, Beidou, REGIONAL NAVIGATION SYSTEMS: Beidou and Compass, QZSS, IRNSS, GNSS INTEROPERABILITY: Frequency Compatibility, User Competition, Multistandard User Equipment Augmentation Systems, System Compatibility, GNSS Signals, Navigation Data Messages, Comparison between GNSS, GPS, Galileo and other Nav Systems

4. **Inertial Navigation:** Inertial-Frame Navigation Equations, Earth-Frame Navigation Equations, Local-Navigation-Frame Navigation Equations, Navigation Equations Precission, Initialization and Alignment, INS Error Propagation, Platform INS, Horizontal Plane Inertial Navigation, types of GYROS: Mechanical, Ring Laser and Fiber Optic, Accelerometers.

5. **Advanced Satellite Navigation:** Differential GNSS, Carrier-Phase Positioning and Attitude, Poor Signal-to-Noise Environments, Multipath Mitigation, Signal Monitoring, Semi-Codeless Tracking

6. **Principles of Radio Positioning:** Radio Positioning Configurations and Methods, Positioning Signals, User Equipment, Propagation, Error Sources, and Positioning Accuracy

7. **Terrestrial Radio Navigation:** Point-Source Systems, Loran, Instrument Landing System, Urban and Indoor Positioning, Relative Navigation, Tracking, Sonar Transponders

8. **Long- and Medium-Range Radio Navigation:** Aircraft Navigation Systems, Signals, User Equipment and Positioning, Error Sources, Differential Loran, Phone Positioning, Proximity and Pattern Matching, Ranging, Other Systems

9. **Short-Range Positioning**: Pseudolites, Ultra-wideband, Short-Range Communications Systems, Underwater Acoustic Positioning, Other Positioning Technologies

10. **Satellite Navigation Processing, Errors, and Geometry:** Satellite Navigation Geometry, Receiver Hardware and Antenna, Ranging Processor, Range Error Sources, Navigation Processor.

11. **Dead Reckoning, Attitude, and Height Measurement:** Attitude Measurement, Height and Depth Measurement, Barometric Altimeter, Depth Pressure Sensor, Radar Altimeter, Odometers, Pedestrian Dead Reckoning, Doppler Radar and Sonar, Other Dead-Reckoning Techniques: Image Processing, Landmark Tracking, Correlation Velocity Log, Air Data, Ship's Log.

12. **Feature Matching:** Terrain-Referenced Navigation, Sequential Processing, Batch Processing, Performance, Laser TRN, Barometric TRN, Sonar TRN, Image Matching, Scene Matching by Area Correlation, Continuous Visual Navigation, Map Matching, Other Feature-Matching Techniques, Stellar Navigation, Gravity Gradiometry, Magnetic Field Variation.

13. **INS/GNSS Integration:** Integration Architectures, System Model and State Selection, Measurement Models, Advanced INS/GNSS Integration.

**TEXT BOOK:**

1. Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Paul D. Groves Artech House, 2008 and 2013 Second Edition.

**REFERENCE BOOKS:**

1. B. Hofmann Wollenhof, H. Lichtenegger, and J. Collins, "GPS Theory and Practice", Springer Wien, new York, 2000.

2. PratapMisra and Per Enge, “Global Positioning System Signals, Measurements, and Performance,” Ganga-Jamuna Press, Massachusetts, 2001.

3. Ahmed El-Rabbany, “Introduction to GPS,” Artech House, Boston, 2002.

4. Bradford W. Parkinson and James J. Spilker, “Global Positioning System: Theory and Applications,” Volume II, American Institute of Aeronautics and Astronautics, Inc., Washington, 1996.

**LIST OF EXPERIMENTS:**

| S. No. | Experiment | Objectives |
|---|---|---|
| 1 | Single satellite waveform | Simulate single satellite with C/A code for GPS, IRNSS, GLONASS,<br>Galileo, Beidou, SBAS (should include GAGAN) and QZSS<br>Specify the frequency channel, dynamic pattern: Static, constant velocity, constant acceleration |
| 2 | Multi satellite waveform | Simulate multi-satellite signals<br>Constellation from GPS, GLONASS, QZSS, Galileo, Beidou |
| 3 | GPS,GLONASS, Galileo, Beidou, SBA Sa nd QZSS real time signal generation | Simulate upto 15line-of-sightsatellitesforeach constellation: GPS L1C/A,<br>GLONASS L1C/A, or Beidou B1,Gailleo,SBAZ,QZSS<br>Provide real-time control for individual satellites, including satellite on/off, absolute or relative satellite power, adding multipath, and applying a pseudo-range error. |
| 4 | Scenario generation and editing | Create custom scenarios with your choice of location, date, time, and duration<br>for either static and moving receivers |
| 5 | Satellite based augmentation system (SBAS) | SBAS message editor to configure the SBAS<br>message for PRN Mask, Fast Correction, Fast Correction Degradation Data<br>Factor, Network Time, GPMask, Long Term Correction and Ionosphere Correction |
| 6 | Real time CW interference | Should support adding multiple CW interference signal to real time GNSS signals within GPS, GLONASS or Beidou bands. |
| 7 | Real-time display | Display the location of each satellite in sky-view to get real-time update<br>of the satellite as its azimuth/elevation changes in time.<br>Bar view of real-time satellite power for all visible satellites.<br>Real-time receiver trajectory view to display the history trajectory of the<br>playing scenario with detailed information on UTC, longitude, latitude, altitude, heading and velocity. |

***Course Name: STATISTICAL SIGNAL PROCESSING***
***Course Code: EE606***

**Course Outcome-**

| Course Outcomes | Description |
|---|---|
| **CO1** | Generalize the properties of statistical models in the analysis of signals using Stochastic processes. Students learned the forward and backword linear prediction for filter design. |
| **CO2** | Learn the last-square methods for filter design. |
| **CO3** | Acquire the basics of adaptive filters, time-frequency analysis, and Wavelet transform. |
| **CO4** | Applying knowledge and skills to visualize different type data/signals in time domain, frequency domain, and time-frequency domain. They are capable to design various type filters. |

**UNIT I: INTRODUCTION**

Characterization of Signals, Characterization of Linear Time-Invariant Systems, Sampling of Signals. Linear Filtering Methods Based on the DFT, the Cepstrum, Summary and References, Problems.

**UNIT II: LINEAR PREDICTION AND OPTIMUM LINEAR FILTERS**

Innovations Representation of a Stationary Random Process, Rational power spectra, Forward and Backward Linear Prediction, Solution of the Normal Equations, Properties of the Linear Prediction-Error Filters, AR Lattice and ARMA Lattice-Ladder Filters, Wiener Filters for Filtering and Prediction, Summary and References, Problems.

**UNIT III: LEAST-SQUARES METHODS FOR SYSTEM MODELING AND FILTER DESIGN.**

System Modeling and Identification, Lease-Squares Filter Design for Prediction and Deconvolution, Solution of Least-Squares Estimation Problems, Summary and References, Problems.

**UNIT IV: ADAPTIVE FILTERS.**

Applications of Adaptive Filters, Adaptive Direct-Form FIR Filters, Adaptive Lattice-Ladder Filters, Summary and References, Problems.

**UNIT V: TIME FREQUENCY ANALYSIS**

Time-Frequency Distributions: Fundamental Ideas, Global average, local average, shift invariance, Uncertainty Principle and Joint distribution, Short-Time Fourier Transform and Spectrogram, Wigner-Ville Distribution, Time-Varying Power Spectral Density Distribution, Filtered Function of Time, Instantaneous Power Spectra, Quadratic TFDs, Time-Varying Power Spectra of Nonstationary Random Processes.

**UNIT VI: WAVELT TRANSFORM FOR SIGNAL ANALYSIS**

Continuous wavelet transform, Wavelet bases. Balian-Low theorem. Classes of wavelets: Haar, Daubechies, and bi-orthogonal. Discrete Wavelet Transform and Filter banks. Orthogonal and biorthogonal two-channel filter banks, Design of two-channel filter banks. Wavelet methods for signal processing. Noise suppression. Representation of noise-corrupted signals using frames. Algorithm for reconstruction from corrupted frame representation. Audio classification. Compression, Gabor Wavelets for statistical signal processing.

**UNIT VII FEATURE EXTRACTION AND STATISTICAL MODELS -** Difference between Statistical and structural Characterisation, orientation histograms and co-occurrence matrices, convolutional models in range and angle, frequency domain model.

**TEXT BOOKS:**

1. Algorithms for Statistical Signal Processing John G. Proakis.
2. Probability & Random Processes with Applications to Signal Processing, 2001, 3Edn. Henry Stark and John W Woods, Prentice Hall
3. Adaptive Signal Processing Bernard Widrow, Samuel D. Stearns.
4. Time Frequency Analysis, 1995 by L. Cohen, Prentice Hall PTR.
5. A Wavelet Tour of Signal Processing, 2nd edition, S. Mallat, Academic Press, 1999.

**REFERENCE BOOKS:**

1. Optimum signal processing: An introduction - Sophocles. J. Orfamadis, 2 ed., 1988, McGraw-Hill, Newyork
2. Adaptive signal processing-Theory and Applications, S. Thomas Alexander, 1986, Springer –Verlag.
3. Signal analysis – Candy, Mc Graw Hill Int. Student Edition
4. James V. Candy, Signal Processing: A Modern Approach, McGraw-Hill, International Edition, 1988.
5. Multiresolution and Multirate Signal Processing: Introduction, Principles and Applications - V.M. Gadre, A.S. Abhyankar, 2016, Mc Graw Hill Education (India) Private Limited.

**LIST OF EXPERIMENTS:**

| **Sr. No.** | **Experiments** |
|---|---|
| 1. | Simulation of multi-component sinusoidal, AM, FM, AM-FM signals and their frequency spectrum, time-frequency representation visualization. |
| 2. | Simulation of multi-component sinusoidal, AM, FM, AM-FM signals in noisy environment (AWGN level -5dB, 0dB, 5dB, 10dB, 20dB) and their frequency spectrum, time-frequency representation visualization. |
| 3. | Simulation of analytic form of signal possesses (a) mono-component signal, (b) multicomponent signal. |
| 4. | Design a FIR adaptive filter to remove different type noises from a natural signal such as physiological signals EEG, ECG, speech signals. |
| 5. | Wavelet transform based case study |

***Course Name: DETECTION AND ESTIMATION THEORY***

***Course Code: EE607***

Course Outcome-

| **Course Outcomes** | **Description** |
|---|---|
| **CO1** | Learn basics of vector, matrices, bases functions, orthogonality SVD, EVD, SSA, PCA. Moreover the concept of ergodicity, PSD, covariance matrices, response of LTI system to random process, and spectral factorization are grasped. |
| **CO2** | Students got the concepts of the last-square methods for filter design, detection in noisy case, correlator and matched filter, Hypothesis testing, N-P theorem, Likelihood ratio test, |

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|---|---|
| | Deflection coefficient, Receiver operating characteristic, Bayes' criterion of signal detection, ML detector, MAP, LMS, and entropy detectors. |
| **CO3** | Learn the basics of minimum variance estimators, CR lower bound, linear models, system identification, Markov classification, and clustering algorithms. The basics of Wiener-Hopf equation, error variance computation, causal Wiener filter, and Kalman filter are given to students. |
| **CO4** | Apply knowledge and skills to visualize different type data/signals in time domain, frequency domain, and time-frequency domain. They are capable to design various type filters. |

**UNIT-I: REVIEW OF VECTOR SPACES:** Vectors and matrices: notation and properties, orthogonality and linear independence, bases, distance properties, matrix operations, eigenvalues and eigenvectors.

**UNIT-II: PROPERTIES OF SYMMETRIC MATRICES:** Diagonalization of symmetric matrices, symmetric positive definite and semi definite matrices, principal component analysis (PCA), and singular value decomposition.

**UNIT-III: STOCHASTIC PROCESSES:** Time average and moments, ergodicity, power spectral density, covariance matrices, response of LTI system to random process, cyclostationary process, and spectral factorization.

**UNIT-IV: DETECTION THEORY:** Detection in white Gaussian noise, correlator and matched filter interpretation, Binary hypothesis testing, Neyman-Pearson theorem, Likelihood ratio test, Deflection coefficient, Receiver operating characteristic, Bayes' criterion of signal detection, Maximum likelihood detector, MAP, LMS, entropy detectors, detection in colored Gaussian noise, Karhunen-Loeve expansions and whitening filters.

**UNIT-V: ESTIMATION THEORY:** Minimum variance estimators, Cramer-Rao lower bound, examples of linear models, system identification, Markov classification, clustering algorithms.

**UNIT-VI: TOPICS IN KALMAN AND WEINER FILTERING:** Discrete time Wiener-Hopf equation, error variance computation, causal discrete time Wiener filter, discrete Kalman filter, extended Kalman filter, examples.

**TEXT/REFERENCE BOOKS:**

1. Fundamentals of statistical signal processing, vol. 1 and 2, S M Kay, Prentice Hall, 1998
2. Linear Estimation, Kailath, Sayed, and Hassibi, Prentice Hall, 2000.
3. An Introduction to Signal Detection and Estimation, H. Vincent Poor, 2nd Edition, Springer, 1998.

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| 1 | Introduction of Matlab/Simulink, Lab view and its tool boxes to simulate Signal models in the presence of various ambient Noise models (correlated/uncorrelated , |

| | |
|---|---|
| | White/Colored with Gaussian mixture models) |
| 2 | Target Signal & Ambient Noise Simulation (Scalar & Vector Sensor Array Data Vector Simulation):Generation of Multiple spatially separated targets in presence of Strong interferences and Additive Correlated/Uncorrelated, White/Colored Ambient Noise |
| 3 | Development of Detection Techniques for following cases<br>1. Constant amplitude Signal in AWGN<br>2. Time varying Known Signals in AWGN<br>3. Unknown Signals in AWGN |
| 4 | Development and performance comparison of the following Estimation techniques using a given signal & noise model ( senor data model) - MLE, MMSE , Bays Estimator, MAP Estimator, Expectation Maximization (EM) algorithm |
| 5 | Case Study: Detection of targets using NP Criterion & target parameter (Range, bearing, Doppler, etc.) estimation algorithms Performance comparison of Conventional Energy Detectors and Coherent Matched Filter Techniques |

***Course Name: MODERN WIRELESS COMMUNICATIONS***
***Course Code: EE608***

**Course Outcomes:**

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|---|---|
| **CO-1** | Knowledge of modern wireless communication systems, understanding of basic terms such as signal to noise ratio, diversity, fading etc. |
| **CO-2** | Understanding of MIMO, Singular Value Decomposition, and beamforming. |
| **CO-3** | Knowledge of OFDM, OFDM-MIMO, and modulation techniques. |
| **CO-4** | Basic understanding of new wireless technologies such as 5G, NOMA, FBMC, Massive MIMO etc. |
| **CO-5** | Knowledge of various wireless standards. |

**UNIT I: INTRODUCTION TO WIRELESS COMMUNICATIONS:**
Motivation, Applications of Wireless Communication, Multipath Propagation, Wireless Channel Modeling, Fading Nature of the Wireless Channel, Probability Density Function of Amplitude and Phase, Deep Fade Phenomenon in Wireless Channels, Optimal Receiver Combining, SNR Performance, BER Performance with Diversity – Analysis, Diversity in Wireless Systems, Diversity Order, Types of Diversity, Antenna Spacing Requirement, Deep Fade Analysis with Diversity, Autocorrelation Function.

**UNIT-II: MULTIPLE INPUT MULTIPLE OUTPUT (MIMO):**
Introduction to MIMO, MIMO System Model, MIMO Zero-Forcing and Minimum Mean Square Error (MMSE) Receivers, Introduction to Singular Value Decomposition (SVD), Examples of SVD and Eigenmodes of the MIMO Channel, MIMO Channel Capacity, MIMO Diversity – Alamouti, Orthogonal SpaceTime Block Codes (OSTBC), MIMO Beamforming.

**UNIT-III: OFDM:**

Introduction to OFDM, Multicarrier basics, Multicarrier transmission, Modulation and Cyclic Prefix in OFDM, impact of cyclic prefix in data rate, Bit-error rate for OFDM, , Effect of frequency offset issue in OFDM, OFDM– Peak-to-Average Power Ratio (PAPR), SNR performance, MIMO-OFDM.

**UNIT-IV: NEW WIRELESS TECHNOLOGY:**
Introduction to 5G Wireless Technologies, Massive Multiple Input Multiple Output, mmWave, Non-orthogonal Multiple Access (NOMA), Filter Bank Multi Carrier (FBMC) Technique and Full Duplex.

**UNIT-V: WIRELESS STANDARDS:**
IEEE 802.11 Wireless Standards, Comparison of IEEE 802.11 Wireless Standards, Wi-Fi, Bluetooth, Wireless Local Area Network (WLAN), Introduction to Long-Term Evolution (LTE), Introduction to Worldwide Interoperability for microwave Access (WiMAX), LTE-TDD and LTE- FDD, Frequency Bands and Technology Specs.

**Text Books:**

1. Andrea Goldsmith, Wireless Communication, Cambridge University Press, The Edinburgh Building, Cambridge, UK.
2. Tse, David and Viswanath, Pramod, Fundamentals of Wireless Communication, Cambridge University Press (2004).
3. Aditya Jagannatham, Principles of Modern Wireless Communication Systems, McGraw Hill, (2016)

**Reference Books/reports:**

1. Theodore Rappaport, Wireless Communications, principles and Practices, 2nd Edition, Pearson.
2. P. W. Wolniansky, G. J. Foschini, G. D. Golden, R. A. Valenzuela “V-BLAST: An Architecture for Realizing Very High Data Rates Over the Rich-Scattering Wireless Channel”, Bell Labs Report, 1998.
3. Marco Di Renzo et. al, “Spatial Modulation for Generalized MIMO: Challenges, Opportunities and Implementation”, Vol. 102, No.1, 2014.

***Course Name: ANTENNA SYSTEMS***
***Course Code: EE609***

**Course Outcome-**

| Course Outcomes | Description |
|---|---|
| **CO1** | Understanding of Basics of EM radiation and conventional antennas. |
| **CO2** | Design and synthesis of Antenna arrays and beam forming. |
| **CO3** | Design of planar antennas of various configurations. |
| **CO4** | Design of planar antennas of various configurations |

**UNIT-I: PRE-REQUISITE:** Introduction: Definition, Types and Parameters of Antennas, Definition of Parameter: Radiation Patterns-Fields(E&H), Concept of Near and Far Fields, Solid Angle, Beam Width, Radiation Efficiency, Radiation Intensity, Directivity, Gain, Efficiency, Input Impedance, Radiation Resistance, Bandwidth, Circular Polarization, Antenna Noise Temperatures, Power Handling Capability: Voltage and Current Breakdown, Weathering Effect on Antennas.

**UNIT-II: BASIC OF RADIATION MECHANISM** -Concept of Electric and Magnetic Current Distribution of Antennas, Vector and Scalar Potentials (Electrical and Magnetic), Derivation of Radiation Patterns for Ideal, Small and Half Wavelength Dipole Antennas, WIRE ANTENNAS: Monopole, Dipole, Loop, Yagi Uda Antenna, Design of dipole and monopole antenna.

**UNIT-III: ANTENNA ARRAYS -** Principles of Antenna Array: N element linear arrays – uniform amplitude and spacing- - Directivity of Broadside and End fire arrays, Half Power Beam Width, Main lobe, Nulls, Side lobes, Inter-element spacing, Pattern multiplication, electronic scanning, Mutual Coupling, Grating lobes. Planar Arrays: array grid (Rectangular & Triangular), Selection of radiating elements for electronic scanning, scan loss, active impedance, scan blindness.

**UNIT-IV: ARRAY SYNTHESIS AND BEAM FORMING –**Schelkun off and Woodward Synthesis for beam formation. Binomial, Dolph- Tchebycheff and Taylor distribution arrays.

**UNIT V: PLANAR/ PATCH ANTENNAS–** Microstrip Antennas (MSAs): Principle of radiation of Rectangular Microstrip Antenna, Feeding Techniques of MSAs, E & H field, RLC model, basic design equation, impedance and beam width characteristics, Circular and Triangular MSAs, Compact Microstrip Antennas, Broad banding techniques. Printed Dipole and Monopoles – principles and broad banding techniques. Design a Rectangular, Circular and Trangular Patch Antennas.

**UNIT VI: APERTURE ANTENNAS–**Babinet –Brookner Theorm, Slot Antennas, Horn Antennas: E-plane Sectoral Horn, H-plane Sectoral Horn, Pyramidal Horn, Conical Horn, Aperture Matched Horn, Corrugated Horn, Broadband Horn Antenna, Reflector Antennas- Planar, Angular and Curved Reflector Antennas: Parabolic Reflector; Front feed, Cassegrain –feed and Gregorian- feed, Spherical Reflector, Design of a Pyramidal and Conical Horn Antenna.

**UNIT VII: BROADBANDAND TRAVELLING WAVE ANTENNAS –** Concept of Frequency Independent and Travelling Wave Antennas, Self-Complementary Antennas, Biconical Antenna, Log Periodical Antennas, Helical Antennas; Normal and Axial Mode, Spiral Antennas, Design of a Dipole Log Periodic Array and Helical Antenna.

**UNIT VIII: ANTENNA MEASUREMENTS –** Input impedance, Return Loss, VSWR, Bandwidth, Polarization, Radiation Patterns, Beam-width, Gain, Antenna Noise Power.

**TEXT BOOKS:**

1. Richard Poisel, Search Results Antenna Systems and Electronic Warfare Applications, Artech House.
2. Vijay Madisetti, Wireless, Networking, Radar, Sensor Array Processing, and Nonlinear signal processing,
CRC press....
3. Kai Chang, RF and Microwave Wireless Systems, Wiley series.

**REFERENCE BOOKS:**

1. Mike Golio, ,Janet RF and Microwave Passive and Active Technologies, CRC press.
**2.** Frank Gustrau, RF and Microwave Engineering, Wiley.

**LIST OF EXPERIMENTS**

| Sr. No. | Experiments |
|---|---|
| **1.** | Measure the functions of the front panel board keys's of Vector Network Analyzer (VNAZVA40) for the<br>frequency range from 10MHz to 40 GHz for measurement of various antenna parameters. |
| **2.** | Measurement of various parameters of antenna on VNA (i.e. Return loss, VSWR, gain, bandwidth,<br>radiation pattern, E-palne and H-plane etc.) |
| **3.** | Radiation pattern measurement using DAMS controller and their connectivity to the antenna positioner<br>inside the anechoic chamber and to the VNA. |
| **4.** | Measure and understood the antenna software which support to VNA, Antenna positioned and DAMS<br>controller for "automated antenna measurement system". |
| **5.** | Delay measurement between two micro strip antennas using two port VNA ZVA40 |

***Course Name: RADAR SIGNAL PROCESSING***
***Course Code: EE610***

**Course Outcome:**

| | |
|---|---|
| **CO1** | Gaining Knowledge on Mathematical interpretation & operation in Signals, Radar receiver & its components, DLC & its application & limitation, MTI & matched filter approximation. |
| **CO2** | Getting fundamentals of Pulse compression requirement & its technique. Radar based on pulse compression |
| **CO3** | Knowing Basics of tracking algorithms & its components & its limitation & advancement in technology. Different tracking Schemes |
| **CO4** | Knowing Basics of Beam forming for different types of target. Need of Photonic radar & its component & Application. |
| **CO5** | Students will be exposed to Signals & waveform techniques. Need of airborne radar. Understanding of Significance of Doppler frequency in radar application. Introduction to array & its advancement. |

**UNIT-I: RADAR SIGNALS AND NETWORKS:** Real/Complex/Analytic Radar signal, Radar signal, Transmission of signal through network, signal representation using Fourier series, Spectra of few common Radar Signal, FT of DT sequence, Review of Impulse function/Deterministic/Random signal, random variable.

**UNIT-II: RADAR SIGNAL PROCESSING CHAIN:** Introduction, Radar receiver chain, derivation of Doppler frequency shift, N-pulse DLC, Moving Target Indictor (MTI), Optimum MTIs, Improvement Factor, Coherent Pulse integration – FFT, FIR filters, Concept of Constant False Alarm Rate(CFAR), CFARs for various scenarios, Clutter map CFAR, site adaptive Radar signal processing, Radar displays, convolutional models in range and angle, frequency domain models, Doppler processing, Matched filter (vector formulation), MTI and matched filter approximation.

**UNIT-III: PULSE COMPRESSION AND MICRO-DOPPLER PROCESSING:** Radar modulation techniques, FMCW waveforms, Nonlinear FM, Stepped LFM, SFCW Radar, multi-frequency Radar, Bi-phase, poly-phase codes, Stretch Processing, Matched Filtering, Ambiguity diagram, Micro-Doppler effect - Phenomenon and application, modeling and simulation.

**UNIT-VI: TRACKING ALGORITHMS:** Kalman Filters, Manouver Detection, Adaptive Kalman Filter, Interactive Multiple Model (IMM), Kalman Filter Track Initiation, False Track handling, Track Quality Tracking in Clutter, Data Association, Probabilistic Data Association, Multi-Target Tracking, Multiple Hypothesis Tracking on moving Platform, Tracking with Phased Array Radars, Performance Measures, Multi-Radar Tracking Schemes.

**UNIT-V: DATA PROCESSING FOR PHASED ARRAY RADAR:** Introduction, analog and digital beam forming, verification and Tracking, multi target tracking, high precision tracking, adaptive array processing, Introduction to photonics Radar.

**UNIT-VI: AIRBORNE/SYNTHETIC APERTURE RADAR:** Signal Processing, Waveform design – LPRF, MPRF, HPRF, Platform Motion Compensation. Advanced Processing for Airborne Radars – Space Time Adaptive Processing, Principles, GLRT, AMF, Reduced Rank and Reduced Data STAP. Geometry of imaging radar, Doppler frequency and radar image processing, spherical wave front Vs Planar wave front, quadratic phase Errors, Polar Format Algorithm, Range Migration Algorithm, Platform Motion Compensation, Future growth of Modern Radar: UWB radar, Knowledge based radar, Cognitive radar.

**UNIT-VII: ADAPTIVE ARRAY PROCESSING:** Introduction, General array, linear array, Adaptive array processing, Non-linear beam forming (LMS, ALMS), sidelobe cancellers. Spatial filtering beam forming.

**TEXT BOOKS:**

1. Mark A. Richards, Fundamentals of radar signal processing, Tata MG Hill.
2. Eyung W. Kang, Radar systems: analysis, design and simulation, Artech house.
3. B.R. Mahafza, Radar Signal Analysis and Processing using MATLAB, CRC Press.
4. George W. Stimson, Introduction to Airborne Radar, Scitech Publishing.
5. Ian G. Cumming and Frank H. Wong, Digital processing of synthetic aperture radar, Artech House.

**REFERENCE BOOKS:**

1. D. Curtis Schleher, MTI and Pulsed Doppler radar with MATLAB, Artech house.
2. Peyton Z. Peebles, Radar Principles, Wiley.
3. A. Farina, Radar Data Processing, John Wiley & Sons.
4. Bu-Chin Wang, Digital Signal Processing Techniques and Applications in Radar Image processing, Wiley.

**LIST OF EXPERIMENTS:**

| Sr. No. | Experiments |
|---|---|
| 1 | Radar clutter modeling and statistical analysis of various clutter distributions, Realization of N-pulses DLC MTI using FPGA, Analysis of detection performance improvement due to coherent/non-coherent pulse integration using MATLAB. |
| 2 | Realization of various CFAR using FPGA, Generation and spectral analysis of different pulse compression waveforms using MATLAB. |
| 3 | Realization of Matched filtering operation and detection concept, analyzing the ambiguity diagram for different Radar waveforms, Modeling and simulation of micro-Doppler effect and processing. |
| 4 | Realization of adaptive Mono-pulse, Kalman and other tracking algorithms. |
| 5 | Simulating the phased array assisted tracking technique, Realization of digital and non adaptive beam forming, Adaptive array processing using LMS algorithm. |
| 6 | Modeling an adaptive digital beam former using, SAR simulation and Moving platform (airborne, space-borne and ship-borne) modeling using System Vue. |

***Course Name: ARRAY SIGNAL PROCESSING***
***Course Code: EE611***
**Course Outcome:**

| | |
|---|---|
| **CO-1** | Fundamentals of Array Signal Processing, Sampling Theorem, Frequency Domain and Uniform and non-uniform array |
| **CO-2** | Earth to Satellite linking and their calculations for losses. |
| **CO-3** | Concept of Beam forming and beamforming technologies. |
| **CO-4** | Compressed sensing, algorithms and measurement matrices study |

**UNIT – I: SPATIAL SIGNALS**
Array processing fundamentals, signals in space and time, spatial frequency, frequency wave number, direction vs. frequency, beam pattern, wave front, far field and near field, spatial sampling, Nyquist criterion, aliasing in spatial frequency domain, sensor arrays, spatial domain filtering, spatial DFT/FFT.

**UNIT – II: SENSOR ARRAYS**
Uniform linear arrays, electronic steering, array performance measures, non-isotropic element pattern, tapering, null steering, non-uniform linear arrays, beam space processing, planar and volumetric arrays, wideband arrays.

**UNIT – III: BEAMFORMING**
Time delay beamforming, frequency domain beamforming, optimum beamformers: MVDR, MPDR, MMSE, Max SNR, LCMV, LCMP, GSC, mismatched beam former, eigenvector beamformer, beam space beamformer, broadband beamformer, adaptive beam formers: LMS and RLS.

**UNIT – IV: DIRECTION OF ARRIVAL ESTIMATION**
DoA estimation: ML, MAP, MUSIC, ESPRIT, for uncorrelated, correlated and coherent signals.

**UNIT-V: COMPRESSED SENSING AND SPARSE SIGNAL PROCESSING**
Introduction to CS, sparse representations: motivations and basic formulations, uniqueness of sparse representation. Measurement matrices: null space property, Restricted Isometry Property (RIP), Johnson

Linden strauss Lemma, Random Matrices and RIP. Reconstruction algorithms: convex optimization methods, basis pursuit, basis pursuit demonising. Greedy algorithms: matching pursuit, orthogonal matching pursuit, subspace pursuit, compressive sampling matching pursuit.

**REFERENCE BOOKS:**

1. H.L. Van Trees, "Optimum Array Processing, Part 4 of Detection, Estimation and Modulation Theory, John Wiley & Sons, 2002.
2. Adaptive signal processing Bernard Widrow, Samuel D. Stearns.
3. A Mathematical Introduction to Compressive Sensing, Simon Foucart, Holger Rauhut Springer New York, 21-Jun-2013
4. Compressed Sensing: Theory and Applications, Yonina C. Elda, Cambridge University Press

**LIST OF EXPERIMENTS**

| **Sl. No** | **Experiment** |
|---|---|
| 1 | Introduction of Matlab/Octave to simulate spatially coherent signals in the presence of spatially and temporally correlated/uncorrelated noise |
| 2 | Signal & noise simulation, generation of multiple spatial signals in presence of strong interferences and additive noise |
| 3 | Conventional beam former via Delay & Sum technique<br>Conventional beam former via Phase Shift based technique |
| 4 | Simulation of optimum beam forming: MVDR, MPDR, LCMV and LCMP |
| 5 | Performance comparison of beam formers in the presence of strong interferences and spatially correlated noise |
| 6 | Direction of Arrival estimation of a source in single and multiple sources scenario |

***Course Name: HIGH POWER MICROWAVE SYSTEMS***
***Course Code: EE612***
**Course Outcome:**

| | |
|---|---|
| **CO-1** | Introduction to High Power Microwave Systems and Microwave Fundamental Concepts |
| **CO-2** | Technological advancement in HPM and Microwave |
| **CO-3** | HPM Generation related structures and their studies |
| **CO-4** | Applications of HPM technologies in various areas. |

**UNIT-I: INTRODUCTION AND DESIGN OF HPMW SYSTEMS:** Introduction, HPM operating regimes, future directions in HPM, system approach, components linking, system issues and advanced systems.

**UNIT-II: MW FUNDAMENTALS:** Introduction, Basic concepts in EMs, Periodic slow-wave structures, cavities, intense relativistic electron beam, rotating magnetically insulated electron layers, microwave generating interactions, amplifiers and oscillators, high and low current operating regimes, multispectral sources.

**UNIT-III: HPM TECHNOLOGIES:** Introduction, pulse power, electron beam generation/propagation, pulse compression, diagnostics, computations technology, HPM facilities, beam less systems, UWB switching technologies, UWB systems and non-linear transmission line.

**UNIT-IV: HPM SOURCES AND STRUCTURES:** Introduction, design principle, operational features, R&D issues: Relativistic magnetron, MILOs, BWOs, MWCGs and O-type Cerenkov devices, Klystrons and Reltrons, Vircators, Gyrotrons, Electron Cyclotron masers and free-electron lasers.

**UNIT-V: HPM APPLICATIONS:** HPM weapons, EM terrorism, counter DEW, High-power radar, power beaming, space propulsion, plasma heating and particle accelerators.

**TEXT BOOKS:**

1. James Benford, John A. Swegle and EdlSchamiloglu ,High Power Microwave, CRC Press.
2. A. V. Gaponov-Grekhov, ,Granatstein .Victor LApplications of High-power Microwaves, Artech House.

**REFERENCE BOOKS:**

1. Victor L. Granatstein, ,Igor AlexeffHigh-power Microwave Sources, Artech House.
2. Robert J. Barker, EdlSchamiloglu, High-Power Microwave Sources and Technologies, Wiley.
3. R.A Cairns, ,Phelps .R.D.AGeneration and Application of High Power Microwaves, CRC Press.

***Course Name: ELECTRONIC WARFARE***
***Course Code: EE613***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding of electronic defence, intercept system characteristic and functions. |
| **CO-2** | Knowledge of crystal video receiver, IFM receiver, super heterodyne receiver, channelized receiver, bragg cell receiver. |
| **CO-3** | Understanding of various types of jamming and ECM techniques. |
| **CO-4** | Basic understanding of Search radar counter-countermeasures and tracking radar counter-countermeasures. |
| **CO-5** | Knowledge of New electronic defence techniques and technologies trend. |

**UNIT-I: INTRODUCTION TO ELECTRONIC WARFARE**

Electronic defence, electronic combat (ESM-ECM-ECCM), SIGNIT, intercept system characteristics and functions, frequency coverage, analysis bandwidth, dynamic range, dynamic range requirements, sensitivity, noise figure, probability of intercept.

**UNIT-II: ELECTRONIC SUPPORT MEASURES**

Typical ESM systems, sensitivity, receivers - crystal video receiver, IFM receiver, super heterodyne receiver, channelized receiver, bragg cell receiver, compressive receiver, digital receivers. DoA/AoA measurement emitter location - the role of emitter location, emitter location geometry, emitter location accuracy, amplitude-based emitter location, interferometer direction finding, interferometric DF implementation, direction finding using the doppler principle, time of arrival emitter location.

**UNIT-III: ELECTRONIC COUNTER MEASURES**

Principals of electronic attack (EA), jamming-to-signal ratio, jamming types: burn-through, cover jamming, range deceptive jamming, inverse gain jamming, repeater jamming equations, noise jamming vs. deception, repeater vs. transponder, side lobe jamming vs. main lobe jamming, stand-off jamming, escort jamming, self protection jamming. ECM techniques, on-board ECM systems, off-board ECM systems.

**UNIT-IV: ELECTRONIC COUNTER-COUNTERMEASURES**
Search radar counter-countermeasures, tracking radar counter-countermeasures.

**UNIT-V: NEW ELECTRONIC DEFENSE TECHNIQUES**
New electronic defense techniques and technologies trend, shared apertures, anti anti-radiation missile techniques, anti-stealth techniques, RF directed energy weapons, RWR, MAWS, Features and Capabilities of AEW&C and AWACS platforms, IFF Mark XII S

**TEXT BOOKS:**

1. EW101: A First Course in Electronic Warfare, David Adamy, Artech House
2. EW102: A Second Course in Electronic Warfare, David Adamy, Artech House
3. Introduction to Electronic Defence Systems, Second Edition, Artech House by Filippo Neri
4. Introduction to Electronic Warfare 1984, Schleher Dc, Artech House
5. Microwave Receiver with EW applications, 1986, James Bao& Yen Tsui, Wiley and Sons.

**REFERENCE BOOKS:**

1. Electronic Warfare in the Information Age, 1999,D. Curtis Schleher, Artech House, Boston, London
2. Radar hand book, 1972/1990, Skolnik MI, Mc Graw Hill.
3. Fundamentals of Electronic Warfare, Artech House by Sergei A. Vakin

**LIST OF EXPERIMENTS:**

| S. No. | Objectives |
|---|---|
| 1. | Simulation of ESM techniques using Spectrum Analysers |
| 2. | Simulation of ECM techniques using Signal Generators and Spectrum Analysers |
| 3. | Simulation of direction finding techniques |
| 4. | Location Estimation technique using GPS Receivers |
| 5. | Simulation of noise cancellation techniques |

***Course Name: EMI/EMC DESIGN***
***Course Code: EE614***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | The effect of EM interference and how it hampers the performance of other circuits, Basics of Electromagnetic Interference and Basics of EM Radiation, Components behaviour at higher frequencies, Indian and International Standards of EMI/EMC. |
| **CO-2** | Understanding of EMI Instruments and testing, shielded structures and their functioning, Techniques to detect the EMI disturbances and ways of calibration, Design of EMI controlled circuitry. |
| **CO-3** | Knowledge of System level analysis and design of EMI controlled subsystems, Techniques |

| | |
|---|---|
| | to manage the ambient EMI and related concepts. |
| **CO-4** | Basic knowledge of different testing levels of EMI, their classification, experimental validation of EMI concepts, interpretation and inferences. |
| **CO-5** | working knowledge of EM modeling and simulation in an electromagnetic simulator, steps for designing and developing circuits and PCBs. |

**UNIT-I: Theory and Principles of EMI/EMC**

Sources of EMI, Conducted and Radiated EMI, Transient EMI, EMI/EMC definitions and units, Conducted, Radiated and Transient Coupling, Common Impedance Ground Coupling, Common Mode and Differential Mode coupling, Near-/Far-field coupling, Near Field Cable to Cable Coupling, Power Mains and Power Supply Coupling.

**UNIT-II: EMI Tests and Measurements and Control Techniques**

EMI Test Instrumentation/Systems, EMI Test, EMI Shielded Chambers, Open Area Test Site, TEM cell Antennas, Conducted Sensors/Injectors/Couplers, Military Test Method and Procedures (MIL-STD-461E), Calibration Procedures, Shielding, Filtering, Grounding, Bounding, Isolation Transformer,.

**UNIT-III: EMC Design of Electronic Systems**

Requirements for Electronic Systems, System Design for EMC, PCB Traces Cross Talk, Impedance Control, Power Distribution Decoupling, Zoning, Transient Suppressors, Surge Protection Devices, Cable Routing, Signal Control, Component Selection and Mounting, Motherboard Designs and Propagation Delay Performance Models.

**UNIT-IV: EMI Standards and Electromagnetic Radiation Hazards**

Units of specifications, Civilian standards (CISPER, FCC, EN, IEC), Military standards -MIL-STD-461E, MIL-STD-1385, RADHAZ, HERO, NEMP, Biological Effects of EMR, Thermal and Non-Thermal, Prediction and Analysis of EMR Hazards, Mitigation Techniques.

**UNIT-V: EMC Management Concepts**

Electromagnetic Environmental Effects (E3) Management, Spectrum Supportability Risk Assessment (SSRA), Spectrum Management and Requirements, Program management services to DoD and military departments, Military Department Operational Spectrum Management, EM Modeling and Simulation (M&S) services, steps for the proper development of an EMC control plan.

**Text Books:**


1. Introduction to Electromagnetic Compatibility, 2nd Edition, Clayton R. Paul, ISBN: 978-0-471-75500-5, 1016 pages, December 2005, ©2006, Wiley publishers, Wiley Series in Microwave and Optical Engineering, 2006.
2. Principles of Electromagnetic Compatibility, B Keiser, Artech house, 2008.
3. V.P. Kodali, “Engineering Electromagnetic Compatibility”, IEEE Publication, printed in India by S. Chand & Co. Ltd., New Delhi, 2000. Course Name: EMI/EMC DESIGN Course Code: EE614 2nd Ed. 333
4. Wilium DuffG., and Donald RJ, Series on “Electromagnetic Interference and Compatibility”, Vol.5, EMI Prediction and Analysis Technique, 1972.
5. Weston David. A., “Electromagnetic Compatibility, Principles and Applications”, 1991.

6. Kaiser BE., “Principles of Electromagnetic Compatibility”, Artech House, 1987.
7. “Electromagnetic Interference and Compatibility IMPACT series”, IIT Delhi,
**8.** Modules1- 9. 7. C. R. Pal, “Introduction to Electromagnetic Compatibility”, Ny, John Wiley, 1992.

**Reference Books:**

1. Electromagnetic Compatibility Engineering, Henry W. Ott, ISBN: 978-0-470-18930-6, 872 pages, August 2009, Wiley publishers.
2. Handbook for EMC- testing and measurement, Morgan D.
3. EMI & Compatibility Vol 1to 6 Electrical Noise & EMI SPEC, White, DON white
4. EMC for Product Designers, Tin Williams, Elsevier (2007).
1. Electromagnetic compatibility management guide for platforms, systems and equipment, Standard Handbook, 1981 - Science - 125 pages, Pennsylvania State University.

**LIST OF EXPERIMENTS:**

| **S. No.** | **Experiments** |
|---|---|
| **1** | Hands-On with EM Simulator (ADS/CST)<br>**Objectives**<br>i) Design and simulate RF circuits in EM simulator<br>ii) Develop circuits through photolithography and measure the performance |
| **2** | Observe the Reflections after Terminating RF Cables/Planer Transmission Lines with Different Impedances<br>**Objectives**<br>i) Develop printed transmission lines on dielectric sheets<br>ii) Measure the performance and compare with that obtained through simulations |
| **3** | PCB Board Level EMC Simulation<br>**Objective**<br>i) Observe the effects of shielding, grounding, etc. in EM simulator using appropriate probes |
| **4** | Controlling Crosstalk: Frequency-Domain Perspective<br>**Objectives**<br>i) To measure crosstalk in the frequency domain<br>ii) To investigate the factors affecting the crosstalk level |
| **5** | Controlling Common Impedance Coupling<br>**Objectives**<br>i) To illustrate the effect of power supply noise on sensitive circuits<br>ii) To illustrate the usage of decoupling capacitors and printed circuit board (PCB) layout in<br>reducing power supply noise |
| **6** | Controlling Radiated Emission from Cable and PCB<br>**Objectives**<br>i) To observe the frequency spectrum of the near-field electromagnetic (EM) radiation from cables<br>and printed circuit board (PCB) traces using a near-field probe and spectrum analyzer<br>ii) To learn some simple methods to reduce unwanted radiation using ferrite beads, |

| | |
|---|---|
| | grounding, and<br>differential signaling |
| **7** | Transfer Impedance Measurement<br>**Objective**<br>i) To measure the transfer impedance of a coaxial cable as a function of frequency<br>ii) To understand the importance of transfer impedance as a gauge of the shielding capability of a<br>cable |
| **8** | Measure the EMI using EMI test receiver, LISN, EMI software's etc. |
| **9** | Measurement of frequency ranges of various EMI/EMC antennas and there various test range<br>comparison to MIL-STD-461F |
| **10** | Different probes of EMI/EMC used to measure the EMI (for H-field, E-field), which is present in various electronic circuits and their frequency of operations. |

***Course Name: GNSS RECEIVER DESIGN AND APPLICATIONS***
***Course Code: EE615***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarize with applications as a function of GNSS receiver design |
| **CO-2** | Understanding basic concepts of GNSS receiver design and modifications for high sensitivity applications, high signal dynamic applications |
| **CO-3** | Analysis of GNSS receiver design and modifications for integration with other sensors. |
| **CO-4** | Knowledge of GNSS in advanced system level applications. |

**UNIT-I: UNDERSTANDING APPLICATIONS AS A FUNCTION OF GNSS RECEIVER DESIGN**: Detailed explanation of a Receiver Input Output Diagram and explanation of possible applications at various sub-system levels.

**UNIT-II: GNSS RECEIVER DESIGN AND MODIFICATIONS FOR HIGH SENSITIVITY APPLICATIONS**: Detailed elaboration of receiver design for high sensitivity applications and its nuances. Case study of an application Module.

**UNIT-III: GNSS RECEIVER DESIGN AND MODIFICATIONS FOR HIGH SIGNAL DYNAMIC APPLICATIONS**: Detailed elaboration of receiver design for high signal applications and its nuances. Case study of an application.

**UNIT-IV: GNSS RECEIVER DESIGN AND MODIFICATIONS FOR HIGH INTEGRITY APPLICATIONS**: Detailed elaboration of receiver design for aerospace applications and its nuances. Introduction to SBAS. Case study of an application, Module.

**UNIT-V: GNSS RECEIVER DESIGN AND MODIFICATIONS FOR INTEGRATION WITH OTHER**

**SENSORS**: Need for integration with other sensors and its merits case study of one integration concept Module.

**UNIT-VI: INTRODUCTION OF GNSS IN ADVANCED SYSTEM LEVEL APPLICATIONS**: Introduction
and explanation of how GNSS is used in determination of attitude of a vehicle, precision farming, anti-collision techniques say in train and discussion on some new potential topics.

**TEXT/REFERENCE BOOKS:**

1 B. Hofmann Wollenhof, H. Lichtenegger, and J. Collins, "GPS Theory and Practice", Springer Wien, new York, 2000.
2 Pratap Misra and Per Enge, "Global Positioning System Signals, Measurements, and Performance," Ganga Jamuna Press, Massachusetts, 2001.
3 Ahmed El-Rabbany, "Introduction to GPS," Artech House, Boston, 2002.
4 Bradford W. Parkinson and James J. Spilker, "Global Positioning System: Theory and Applications," Volume II, American Institute of Aeronautics and Astronautics, Inc., Washington, 1996.

**LIST OF EXPERIMENTS:**

| **Sr. No.** | **Experiments** |
|---|---|
| 1. | Simulation of Receiver Design and modifications for high sensitivity applications |
| 2. | GNSS Receiver Design and modifications for integration with other sensors |
| 3. | GNSS Receiver Design and modifications for high signal dynamic applications |
| 4. | GNSS Receiver Design and modifications for high integrity applications Suggested |

***Course Name: MULTI SENSOR INTEGRATED NAVIGATION***
***Course Code: EE616***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarize with navigation system and introduction to integrated navigation types of Navigation |
| **CO-2** | Understanding basic concepts of estimation theory |
| **CO-3** | Analysis of linear systems & kalman filtering |
| **CO-4** | Knowledge of integrated navigation |

**UNIT-I: NAVIGATION SYSTEM AND INTRODUCTION TO INTEGRATED NAVIGATION TYPES OF NAVIGATION**: Inertial Navigation, Terrestrial navigation, Radio Navigation, Satellite Navigation – Properties of Inertial Navigation system, Need for Navigation aids - Navigation Aids: Doppler Velocity Sensor, Radar Altimeter, Distance Measuring Equipment, Comparison of Inertial navigation systems with satellite navigation systems, concepts of integrated navigation.

**UNIT-II: BASIC CONCEPTS OF ESTIMATION THEORY:** Random signals, Random variables, Joint & conditional probability, Bayes Rule, continuous random variables, PDF, Gaussian Random variables, Correlation, covariance ,independence , orthogonality, Transformation of random variables, General properties of random variables, Random process, stationary Process, Markov process, Ergodicity, Autocorrelation, Cross correlation, PSD, White noise & Colored noise, Decoloration, Random walk and

Wiener process problem of parameter estimation, Models for estimation of a parameter, Unbiased Estimators, Minimum Variance Unbiased Estimation - CRLB, Best Linear Unbiased Estimators(BLUE),MLE, LSE: Order-recursive Least squares, Sequential Least squares, Constrained Least Squares, Nonlinear Least squares, Weighted LS, Recursive LS, Bayesian estimators: MMSE, MAP

**UNIT-III: LINEAR SYSTEMS & KALMAN FILTERING:** Introduction to linear systems, Dynamic system representation using State space , State space Analysis, Concepts of observability , state observer - Discrete time state space models – State Models for stochastic process - Linear state estimation – Basics of Kalman Filter, Continuous Time Kalman Filter, discrete time kalman Filter, Derivations of K.F equations in discrete domain, K.F Properties, K.F implementation issues, K.F implementation for asynchronous measurements, Computational aspects of K.F - Sequential KF, Information Filtering, Joseph stabilized form, Nonlinear applications: Linearization, LKF, EKF, UKF

**UNIT-IV: INTEGRATED NAVIGATION:** INS Mechanization equations, INS Error state dynamic equations, Pinson Error Model, Linearization, Augmented state equations with sensor errors, Navigation aiding measurements & Measurement Model, Observability analysis, GPS/INS integration, Integration by Complementary filtering, Integration using K.F, Kalman Filter Tuning, Integration Schemes: Uncoupled, Loosely coupled, tightly coupled integration, Deep Integration/Ultra tight Integration , Case studies : Barometer Aiding,

**TEXT BOOKS:**

1. Fundamentals of Statistical Signal Processing: Estimation Theory by Steven M. Kay
2. Introduction to Random signals and Applied Kalman Filtering with Matlab exercises by Robert Grover Brown & Patrick Y. C. Hwang.
3. Optimal state estimation: Kalman, H∞, and NonLinear Approaches by Dan Simon.
4. Estimation with Applications to tracking and navigation by Yaakov Bar-Shalom, X. Rong Li, Thiagalingam
Kirubarajan.
5. Mathematical techniques in multi-sensor data fusion, David L. Hall, Artech House, Boston.
6. Applied Mathematics in Integrated Navigation Systems, Robert M Rogers
7. Kalman Filtering Theory & Practice using Matlab, Mohinder S .Grewal.
8. Aided Navigation GPS with High rate sensors, Jay A Farrell

**LIST OF EXPERIMENTS:**

| Sr. No. | Experiments |
|---|---|
| 1. | Using MATLAB program to check the (A) Controllability and (B) Observability of a system given by its state space model. |
| 2. | Obtain a state-space representation of the system with given transfer function using MATLAB. 3.Obtain a transfer function of the system with given state-space representation using MATLAB. 4. Using MATLAB determines the state feedback-gain matrix K of a state space model given closed loop poles. |
| 3. | Using MATLAB determine the observer gain matrix Ke of a state space model given closed loop poles. |

***Course Name: INERTIAL NAVIGATION SYSTEMS***
***Course Code: EE617***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarize with frames of references and inertial navigation fundamentals, concept of frames of references. |
| **CO-2** | Understanding strapdown inertial navigation computations sensor geometry, inertial navigation system alignment |
| **CO-3** | Analysis of navigation system simulation and error analysis error analysis |
| **CO-4** | Knowledge of advanced navigation concepts |

**UNIT-I: FRAMES OF REFERENCES AND INERTIAL NAVIGATION FUNDAMENTALS CONCEPT OF FRAMES OF REFERENCES:** Inertial frames, non-inertial frames, geographic frame, geocentric frame, body frame; **Principles of inertial navigation**: types of inertial navigation, stabilized platform and strap down systems, comparison; **Earth models:** ellipsoid geometry, ellipsoid gravity, earth gravity field, gravitational potential, gravity and gravitation, plum-bob gravity; **Concepts of coordinate transformations:** direction cosine matrix(DCM), Euler angles, quaternion; relation between DCM, Euler angles & quaternion.

**UNIT-II: CONCEPTS OF STRAPDOWN INERTIAL NAVIGATION INERTIAL MEASUREMENTS: c**oncept of specific force, basic principles of accelerometer: pendulous and vibrating beam, basic principle of gyroscope: mechanical and optical; **Navigation equations formulation:** forces in inertial & non-inertial frames, navigation equations in inertial & non-inertial frames, choice of reference frame, strap down system mechanization for different frames: inertial frames, earth fixed frames, geographic frames.

**UNIT-III: STRAPDOWN INERTIAL NAVIGATION COMPUTATIONS SENSOR GEOMETRY:** measurement model, concepts of DOP, failure detectability, optimal sensor geometry for different number of sensors; sensor modeling & compensation algorithms (scale factor, bias, misalignment etc.), practical constraints; **Failure detection and isolation**: concepts of parity vectors, generalized likelihood test; **Attitude propagation algorithm:** using Euler angle, DCM and quaternion; quaternion in terms of rotation vector, first and second order orientation vector algorithms for quaternion propagation, acceleration transformations, velocity & position update algorithms, numerical integration methods, comparison.

**UNIT-IV: INERTIAL NAVIGATION SYSTEM ALIGNMENT** Initialization of inertial navigation system; **Principle of alignment**: alignment on a fixed platform: azimuth and level alignment, alignment on a moving platform: in-flight alignment and shipboard alignment: one shot transfer alignment, measurement matching, methods of measurement matching; gyro-compassing; self corrective alignment scheme.

**UNIT-V: NAVIGATION SYSTEM SIMULATION AND ERROR ANALYSIS ERROR**

**ANALYSIS**: development of perturbation models, attitude response under angular vibration, velocity response under combined angular and linear vibration, size effect errors, modeling of sensor assembly response to system level vibration; specialized error analysis for strap down mechanization, **INS Simulation:** simulation of sensors, measurement electronics and navigation algorithm; **Navigation algorithm validation**: comparison testing, closed loop simulations using NGC software together, hardware in-loop simulations; static navigation test, Monte Carlo & covariance analysis; **General strap down algorithm validation:** spin-cone, spin-accel, spin-rock-size, gennav.

**UNIT-VI: ADVANCED NAVIGATION CONCEPTS**

Fundamentals of screw theory; fundamentals of Clifford algebra; dual quaternion and its applications in navigation.

**TEXT BOOKS:**

1. David A Vallado; Fundamentals of astrodynamics and applications,
2. Kenneth R Britting; Inertial navigation system analysis
3. David H Titterton& John L Weston; Strap down inertial navigation technology.
4. Robert M Rogers; Applied mathematics in integrated navigation systems
5. Paul G Savage; Strapdown analytics
6. Mark A Sturza; Navigation System integrity monitoring using redundant measurements, Navigation: journal of institute of navigation, vol35, No.4, winter1988-89,
7. Oleg Salychev; Applied Inertial Navigation: Problems & Solutions

**LIST OF EXPERIMENTS:**

| **Sr. No.** | **Experiments** |
|---|---|
| **1.** | Use MATLAB to calculate the reliability of a TMR system if each component is having reliability R and only single module exist. |
| **2.** | Use MATLAB to calculate the measurement matrix of navigation sensors arranged in a skew symmetry given half cone angle. |
| **3.** | Use MATLAB to calculate the sensitivity of sensor errors. |
| **4.** | Use MATLAB to calculate the GDOP for sensor performance. |
| **5.** | Use MATLAB to calculate the PDOP for sensor performance. |

***Course Name: INDOOR NAVIGATION***

***Course Code: EE618***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarize with Location-Based Services (LBS), History of Navigation. |
| **CO-2** | Analyze Basic Positioning Techniques |
| **CO-3** | Building-modeling maps, Indor OSM, position refinement. |
| **CO-4** | Apply the knowledge of Simultaneous Localization And Mapping In Buildings, Case Studies |

**UNIT-I: INTRODUCTION:**

Location-Based Services (LBS),Indoor LBS and Ubiquitous Computing, Classical Research Areas Related to Indoor LBS, Classical Applications of LBS, Information Services, Navigation Service, Safety-of-Life Applications, Retail and Commerce, Management, Social Networking and Joint Activities, Gaming, A Short History of Navigation,

**UNIT-II: BASIC POSITIONING TECHNIQUES:**

Methods for Location Determination, Method of Least Squares, Lateration, Hyperbolic Lateration, Angulation, Proximity Detection, Inertial Navigation, Fingerprinting, Properties and Evaluation of Positioning Systems, Examples of Positioning Systems, Pseudolites and High Sensitivity GNSS, Light-Based Systems, Camera-Based Systems, Radio-Based Systems, Inertial Navigation, Audio-Based Systems, Pressure-Based Systems,

**UNIT-III: BUILDING-MODELING:**

Coordinate Systems, Geometric Coordinate Systems, Symbolic Coordinate Systems, Location Models, Choice of Dimension, Vector Maps, Basic Algorithms for Vector Maps, Maps, Environmental Models, Set-Based Environmental Models, Graph-Based Environmental Models, Hybrid Approaches, Geometric Nearest Neighbors and Range Queries, Standardization, GML and City GML, Indoor OSM

**UNIT-IV: POSITION-REFINEMENT:**

Least Squares Estimation with Correlation, Recursive Least Squares Estimation, Discrete Kalman Filtering, The Extended Kalman Filter, Particle Filtering, Grid-Based Methods, Sampling Importance Resampling.

**UNIT-V: TRAJECTORY-COMPUTING:**

The Process of Trajectory Computing, Trajectories, Trajectory Comparison, Hausdorff Distance, Fréchet Distance, Jaccard Distance, Closet Pair Distance, Euclidean Distance Sum, Dynamic Time Warping, Longest Common Subsequence (LCSS), Edit Distance on Real Sequences, Edit Distance with Real Penalties, Outlook, Trajectory Computing for Indoor LBS, Trajectory Computing for Positioning, Movement Patterns, Spatial Movement Patterns, Group-Based Motion Patterns

**UNIT-VI: EVENT-DETECTION FOR INDOOR LBS:**

Event-Driven Applications, Event Sources for Indoor Navigation, Primary Events from Environmental Knowledge, Primary Events from Infrastructure, Primary Events from User Interface, Primary Events from Positioning, Primary Events from Activity Recognition, Secondary Events Relevant to the Navigational Task.

**UNIT-VII: SIMULTANEOUS LOCALIZATION AND MAPPING IN BUILDINGS**:

Data Sources for SLAM, Data from Inertial Navigation Systems, Data from Laser Scanners, Data from Landmarks, Data from Camera Systems, Important Algorithms for SLAM Systems, Visual Feature Point Extraction, Optical Flow Estimation, Iterative Closest Points, Random Sample Consensus, Graph-Based Optimization Algorithms, Several Well-Known SLAM Approaches, Extended-Kalman-Filter SLAM, Fast SLAM, Grid-SLAM. Privacy and Security Considerations: Multiparty Computation, k-Anonymity, l-Diversity, Spatial and Temporal Cloaking, Differential Privacy, Private Information Retrieval, Quadratic Residues, Private Information Retrieval Using Quadratic Residuosity

**UNIT-VIII: OPEN PROBLEM SPACES (CASE STUDIES):**

Open Problems in Prerequisites, Sensor and Timing Accuracy, Ambient Sensors and Building Automation, Basic Positioning Techniques, Building Modeling, Position Refinement, Trajectory Computing, Event Detection, Simultaneous Localization and Mapping in Buildings, Privacy and Security Considerations

**TEXT BOOKS:**

1. Indoor Location-Based Services Prerequisites and Foundations, Werner, Martin, Publisher: Springer; 2014 Edition ,ISBN-10: 3319106988

**REFERENCE BOOKS:**

1. Principles of GNSS, Inertial, and Multi-sensor Integrated Navigation Systems, Paul D. Groves Artech House, 2008 and 2013 Second Edition.
2. B. Hofmann Wollenhof, H. Lichtenegger, and J.Collins, "GPS Theory and Practice", Springer Wien, NewYork, 2000.
3. Pratap Misra and Per Enge, "Global Positioning System Signals, Measurements, and Performance," Ganga-Jamuna Press, Massachusetts, 2001.
4. Ahmed El-Rabbany, "Introduction to GPS," Artech House, Boston, 2002.
5. Bradford W. Parkinson and James J. Spilker, "Global Positioning System: Theory and Applications," Volume II, American Institute of Aeronautics and Astronautics, Inc., Washington, 1996.

**LIST OF EXPERIMENTS:**

| **Sr. No.** | **Objectives** |
|---|---|
| 1. | Single satellite- waveform by using WLAN or Signal generator or GPRS |
| 2. | Multi-satellite waveform by using WLAN or Signal generator or GPRS |
| 3. | Indoor Mapping using WLAN |
| 4. | Scenario generation and editing- by using WLAN or Signal generator or GPRS |
| 5. | Satellite based augmentation system (SBAS)- by using WLAN or Signal generator |
| 6. | Real-time CW interference- by using WLAN or Signal generator |
| 7 | Real-time display- by using WLAN or Signal generator |

***Course Name: SOFTWARE DEFINED RADIO***

***Course Code: EE619***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarize with Software-Defined Radio and its various systems |
| **CO-2** | Analyze General-Purpose Processors and , Digital Signal Processors |
| **CO-3** | Classify Cognitive radio architecture, SDR architecture Applications of Cognitive radio, Spectrum sensing Single node sensing with its hardware platforms. |
| **CO-4** | Apply the knowledge and skills to Simulate SDR Flow in SystemVue, FPGA, GNU radio Simulation Software. |

**UNIT I: INTRODUCTION TO SDR:** What is Software-Defined Radio, The Requirement for Software-Defined Radio, Legacy Systems, The Benefits of Multi-standard Terminals, Economies of Scale, Global Roaming, Service Upgrading, Adaptive Modulation and Coding, Operational Requirements, Key Requirements, Reconfiguration Mechanisms, , Handset Model, New Base-Station and Network, Architectures, Separation of Digital and RF, Tower Top Mounting, BTS Hoteling, Smart Antenna

Systems, Smart Antenna System Architectures, Power Consumption Issues, Calibration Issues, Projects and Sources of Information on Software Defined Radio,

**UNIT II: BASIC ARCHITECTURE OF A SOFTWARE DEFINED RADIO:** Software Defined Radio Architectures, Ideal Software Defined Radio Architecture, Required Hardware Specifications, Digital Aspects of a Software Defined Radio, Digital Hardware, Alternative Digital Processing Options for BTS Applications, Alternative Digital Processing Options for Handset Applications, Current Technology Limitations, A/D Signal-to Noise Ratio and Power 343 Consumption, Derivation of Minimum Power Consumption, Power Consumption Examples, ADC Performance Trends, Impact of Superconducting Technologies on Future SDR Systems.

**UNIT III: SIGNAL PROCESSING DEVICES AND ARCHITECTURES:** General Purpose Processors, Digital Signal Processors, Field Programmable Gate Arrays, Specialized Processing Units, Tilera Tile Processor, Application-Specific Integrated Circuits, Hybrid Solutions, Choosing a DSP Solution. GPP-Based SDR, Non real time Radios, High-Throughput GPP-Based SDR, FPGA-Based SDR, Separate Configurations, Multi-Waveform Configuration, Partial Reconfiguration, Host Interface, Memory-Mapped Interface to Hardware, Packet Interface, Architecture for FPGA-Based SDR, Configuration, Data Flow, Advanced Bus Architectures, Parallelizing for Higher Throughput, Hybrid and Multi-FPGA Architectures, Hardware Acceleration, Software Considerations, Multiple HA and Resource Sharing, Multi-Channel SDR, Airborne SDRs, Adhoc Network architecture for Airborne SDRs.

**UNIT IV: COGNITIVE RADIO : TECHNIQUES AND SIGNAL PROCESSING** History and background, Communication policy and Spectrum Management, Cognitive radio cycle, Cognitive radio architecture, SDR architecture for cognitive radio, Spectrum sensing Single node sensing: energy detection, cyclostationary and wavelet based sensing- problem formulation and performance analysis based on probability of detection vs SNR. Cooperative sensing: different fusion rules, wideband spectrum sensing- problem formulation and performance analysis based on probability of detection vs SNR.

**UNIT V: COGNITIVE RADIO: HARDWARE AND APPLICATIONS:** Spectrum allocation models. Spectrum handoff, Cognitive radio performance analysis. Hardware platforms for Cognitive radio (USRP, WARP), details of USRP board, Applications of Cognitive radio

**TEXT BOOKS:**

1. “RF and Baseband Techniques for Software Defined Radio” Peter B. Kenington, ARTECH HOUSE, INC © 2005.
2. “Implementing Software Defined Radio”, Eugene Grayver, Springer, New York Heidelberg Dordrecht London, ISBN 978-1-4419-9332-8 (eBook) 2013.
3. “Cognitive Radio Technology”, by Bruce A. Fette, Elsevier, ISBN 10: 0-7506-7952-2, 2006.
4. “Cognitive Radio, Software Defined Radio and Adaptive Wireless Systems”, HüseyinArslan, Springer, ISBN 978-1-4020-5541-6 (HB), 2007.

**LIST OF EXPERIMENTS:**

| Sr. No. | Experiments |
|---|---|
| 1. | Simulation of SDR Flow in SystemVue |

| | |
|---|---|
| 2. | Simulation of SDR Flow in FPGA. |
| 3. | Simulation of SDR/CR using GNU radio Simulation Software |
| 4. | Study of Wideband and Narrow Band frequency allocations and applications /Signals using USRP |
| 5. | Simulation of SDR Flow in SystemVue |

***Course Name: SoC AND EMBEDDED SYSTEMS***
***Course Code: EE620***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | To understand the memory interface concept and I/O interface concept in microprocessor and microcontroller. |
| **CO-2** | To understand the various device and buses and network protocol in the various processors |
| **CO-3** | To understand the DSP Processor , PSoc and CUDA platform for various application. |
| **CO-4** | To understand the fundamental of RTOS. |

**UNIT-I: INTRODUCTION:** Definition and Classification, Overview of Processors and hardware units in an embedded system, Software embedded into the system, , Ebedded Systems on a Chip (SoC) and the use of VLSI designed circuits. Design flow of ASIC, SoC and FPGA. Comparison of various processors such as generic microprocessor, microcontroller, DSP processors, Tesla parallel computing hardware .Memory Interfacing and I/O interfacing with processors.

**UNIT-II: DEVICES AND BUSES FOR DEVICES NETWORK**:
I/O Devices, Device I/O Types and Examples, Synchronous, I/o synchronous and Asynchronous Communications from Serial Devices, Examples of Internal Serial-Communication Devices, UART, Parallel Port Devices, Sophisticated interfacing features in Devices/Ports, Timer and Counting Devices, I2C, USB, CAN and advanced I/O Serial high speed buses, ISA, PCI, PCI-X and advanced buses.

**UNIT-III: EMBEDDED COMPUTING**: Embedded processors, ARM processor, Architecture, Instruction sets and programming Case Studies, Parallel Computing, CUDA platform for radar Application.

**UNIT-IV: ADVANCED EMBEDDED COMPUTING:** Programmable System on Chip, Cypress PSoC Technology. Advance DSP Processors. FPGA Technology towards Embedded system aspects- Pico blaze and micro blaze processors- Embedded RAM- Embedded multiplier FPGA coding using VHDL/ Verilog Associated Labs: Assignments using Microcontroller kits, FPGA kits.

**UNIT-IV: RTOS: Introduction to RTOS** Task Management, Memory management, Device Management, File management, Time management Scheduling Interrupt Handling, Event handling ,Inter process communication ,Inter process synchronization, Networking Hardware: computer architecture, micro processors, memories, peripheral devices, interconnections Case study: VxWorks and RTLinux RTOS in computing systems: embedded system, real time system, parallel system, and distributed system

**UNIT-V :** Case Study: underwater gylider controller –Interfacing of various sensors such as inertial sensors and actuators using various processors and its performance comparison.

**TEXT BOOKS**:

1. ARM System-on-Chip Architecture (2nd Edition) Steve Furber.
2. Real-time digital signal processing: Based on the TMS320C6000, Nasser Kehtarnavaz .
3. Advanced FPGA Design: Architecture, Implementation, and Optimization, Steve Kilts, IEEE press Wiley 2007.

**REFERENCE BOOKS:**

1. http://www.xilinx.com/publications/xcellonline: Xcell Journal.
2. DSP Architecture, Programming and Application- B Venkataramani, M Bhaskar.
3. Wayne Wolf, Computers as Components; Principles of Embedded Computing System Design – Harcourt India.

**LIST OF EXPERIMENTS:**

| Sr. No | Experiment |
|---|---|
| Lab 1 | Simulation of ALP using 8086 Emulator |
| Lab 2 | FPGA programming using VHDL. |
| Lab 3 | Radar signal generation using FPGA. |
| Lab 4 | Creating a custom IP core using the IP Integrator in Vivado IDE |
| Lab 5 | Recording and play back of audio signal using Zedboard DMA |
| Lab 6 | Peripheral Module Interface using soft core processor Microblaze |
| Lab 7 | PWM Applications using PSoC |
| Lab 8 | Introduction to CUDA programming and Tesla Processors |

***Course Name: DIGITAL INTEGRATED CIRCUIT DESIGN***
***Course Code: EE621***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Design of Combinational MOS Logic circuits |
| **CO-2** | Design of sequential MOS Logic circuits |
| **CO-3** | Develop the understanding of Large signal and small signal analysis of complex circuits. |
| **CO-4** | Develop the knowledge of Semiconductor memories |
| **CO-5** | Apply the knowledge for Simulation of circuits using PSpice and Microwind Backend Tools. |

**UNIT –I: MOS DESIGN:** Pseudo NMOS Logic – Inverter, Inverter threshold voltage, Output high voltage, Output Low voltage, Gain at gate threshold voltage, Transient response, Rise time, Fall time, Pseudo NMOS logic gates, Transistor equivalency, CMOS Inverter logic.

**UNIT –II: COMBINATIONAL MOS LOGIC CIRCUITS:**MOS logic circuits with NMOS loads, Primitive CMOS logic gates – NOR & NAND gate, Complex Logic circuits design – Realizing Boolean expressions using NMOS gates and CMOS gates , AOI and OIA gates, CMOS full adder, CMOS transmission gates, Designing with Transmission gates.

**UNIT –III: Sequential MOS Logic Circuits:** Behavior of bistable elements, SR Latch, Clocked latch and flip flop circuits, CMOS D latch and edge triggered flip flop.

**UNIT –IV: Dynamic Logic Circuits**: Basic principle, Voltage Bootstrapping, Synchronous dynamic pass transistor circuits, Dynamic CMOS transmission gate logic, High performance Dynamic CMOS circuits.

**UNIT –V: Semiconductor Memories**: Types, RAM array organization, DRAM – Types, Operation, Leakage currents in DRAM cell and refresh operation, SRAM operation Leakage currents in SRAM cells, Flash Memory NOR flash and NAND flash. **Emerging memory technologies:** Phase Change Memory (PCM); Resistive Random Access Memory, Magneto-resistive Random Access Memory (MRAM); Ferroelectric Random Access Memory (FeRAM); Comparison and future directions.

**TEXT BOOKS:**

1. Digital Integrated Circuit Design – Ken Martin, Oxford University Press, 2011.
2. CMOS Digital Integrated Circuits Analysis and Design – Sung-Mo Kang, Yusuf Leblebici, TMH, 3rd Ed., 2011.

**REFERENCE BOOKS:**

1. Introduction to VLSI Systems: A Logic, Circuit and System Perspective – Ming-BO Lin, CRC Press, 2011
2. Digital Integrated Circuits – A Design Perspective, Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, 2nd Ed., PHI.

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| Lab 1 | Use of SPICE for MOSFET modeling and simulation of Digital combinational Circuits. |
| Lab 2 | Schematic gate level Simulation of Digital combinational circuits |
| Lab 3 | LVS simulation of Digital circuits. |
| Lab 4 | Schematic gate level Simulation of Digital sequential circuits |
| Lab 5 | Simulation of memory circuits using PSPICE |

***Course Name: RF IC DESIGN***
***Course Code: EE622***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Generalize the basic concept/idea of RF transceiver, its design issues, linearity, non-linearity, and distortion. Students learned about device noise also. |
| **CO-2** | Students learned the basics of low noise amplifier, oscillator, and mixer. |
| **CO-3** | The concept of Gilbert mixer, single balanced mixer, and double balanced mixer, amplifier, and some part of power amplifier are given to students. |
| **CO-4** | Students will be capable of applying their knowledge and skills to design power amplifier, its use in transmitter, and multi-tier transceiver architecture. |

**UNIT I BASIC CONCEPT IN RF DESIGN:** Time variance, Non-linearity, Effect of nonlinearity, Harmonic distortion, Gain compression, Cross modulation, Intermodulation, Cascaded nonlinear stages, AM-PM conversion, Noise spectrum, effect of transfer function on noise, device noise, Sensitivity, Dynamic range.

**UNIT II COMPONENTS AND DEVICES:** Integrated inductors, resistors, MOSFET and BJT AMPLIFIER DESIGN: Low Noise Amplifier Design – Wideband LNA - Design Narrowband LNA - Impedance Matching, Automatic-Gain-Control-Amplifiers.

**UNIT-III-MIXERS:**

Mixer - Qualitative Description of the Gilbert Mixer, Single balanced mixer, Double balanced mixer, - Conversion Gain-Distortion Low Frequency Case: Analysis of Gilbert Mixer – Distortion - High-Frequency Case – Noise - A Complete Active Mixer. Switching Mixer - Distortion in Unbalanced Switching Mixer – Conversion Gain in Unbalanced witching Mixer - Noise in Unbalanced Switching Mixer - A Practical Unbalanced Switching Mixer. Sampling Mixer - Conversion Gain in Single Ended Sampling Mixer - Distortion in Single Ended Sampling Mixer – Intrinsic Noise in Single Ended Sampling Mixer - Extrinsic Noise in Single Ended Sampling Mixer.

**UNIT IV FREQUENCY SYNTHESIZERS:** Phase Locked Loops - Voltage Controlled Oscillators – Phase Detector – Analog Phase Detectors – Digital Phase Detectors - Frequency Dividers - LC Oscillators – Ring Oscillators - Phase Noise - A Complete Synthesizer Design Example (DECT Application).

**UNIT V AMPLIFIERS AND DESIGN CONCEPT:** Power amplifiers, Adaptive Filters, Equalizers. Transceivers- system level considerations, Receiver design, Transmitter design, and Synthesizer design.

**UNIT VI IMPLEMENTATIONS:**

VLSI architecture for Multitier Wireless System - Hardware Design Issues for a Next generation CDMA System

**REFERENCE BOOKS:**

**1.** B. Razavi, "RF Microelectronics", Prentice-Hall ,1998

**2.** Bosco H Leung, "VLSI for Wireless Communication", Pearson Education, 2002.

**3.** Thomas H. Lee, "The Design of CMOS Radio –Frequency Integrated Circuits", Cambridge University Press, 2003.

**4.** Emad N Farag and Mohamed I Elmasry, "Mixed Signal VLSI Wireless Design - Circuits and Systems", Kluwer Academic Publishers, 2000.

**5.**BehzadRazavi, "Design of Analog CMOS Integrated Circuits" McGraw-Hill, 1999.

**6.** J. Crols and M. Steyaert, "CMOS Wireless Transceiver Design," Boston, Kluwer Academic Pub., 1997.

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| 1 | Characterization of Mixer using FieldFox |
| 2 | Characterization of LNA and Power Amplifier using FieldFox |
| 3 | Characterization of Frequency Synthesizers. |
| 4 | Simulation of LNA using ADS/Matlab Software. |

| | |
|---|---|
| 5 | Simulation of Power Amplifier using ADS/Matlab Software. |
| 6 | Simulation of Mixer using ADS Software. |

***Course Name: SEMICONDUCTOR DEVICES***

***Course Code: EE623***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | To understand the fundamentals of Semiconductor physics and junction Theory. |
| **CO-2** | To understand the concept of MOS capacitors and its Characteristics |
| **CO-3** | To understand the concept of BJT and HBT |
| **CO-4** | The future roadmap of the next generation of FET |

**UNIT-I Basic Semiconductor Physics:** Crystal lattice, energy band model, density of states, distribution statistics – Maxwell-Boltzmann and Fermi Dirac, doping, carrier transport mechanisms, - drift, diffusion, thermionic emission, and tunneling; excess carriers, carrier lifetime, recombination mechanisms – SHR, Auger, radiative, and surface.

**UNIT-II: Junctions:** p-n junctions – fabrication, basic operation – forward and reverse bias, DC model, charge control model, IVcharacteristic, steadystate and transient conditions, capacitance model, reverse-bias breakdown,metalsemiconductor junctions –fabrication, Schottky barriers, rectifying ad ohmic contacts, I-V characteristics.

**UNIT III: MOS Capacitors and MOSFETs:** The MOS capacitor – fabrication, surface charge – accumulation, depletion, inversion, threshold voltage, CVcharacteristics – low and high frequency; the MOSFET – fabrication, operation, gradual channel approximation, simple charge control model (SCCM), I-V characteristic, second order effects – Velocity saturation, short-channel effects, charge sharing model, hot-carrier effects, gate tunneling; subthreshold operation – drain induced barrier lowering (DIBL) effect, unified charge control model (UCCM).MESFETs –fabrication, basic operation, I-V characteristics, high frequency response, back gating effect, HEMTs – fabrication, modulation (delta) doping, analysis of III-V heterojunctions, charge control, I-V characteristics, SPICE model.

**UNIT IV**: **BJTs and HBTs:** Fabrication, basic operation, minority carrier distributions and terminal currents, I-V characteristic, switching, second-order effects – base narrowing, avalanche multiplication, high injection, emitter crowding, Kirk effect, etc.; breakdown, high-frequency response, Gummel-Poon model, SPICE model; HBTs: - fabrication, basic operation, technological aspects, I-V characteristics, SPICE model.

**Unit V: Roadmap for Next Generation Field Effect Transistors:** Disadvantages associated with Scaling of FETs, Future roadmap for FETs, Recent trends in FETs: Fully Depleted SOI MOSFET, Fin-FET, Gate all around Fin-FETs, Thin sheet Fin-FET, Negative Capacitance FET (NCFET), Tunnel FET (TFET), Impact Ionization MOS (IMOS), and Future Improvement Possibilities.

**REFERENCE BOOKS:**

1. Ben G. Streetman, Solid State Electronic Devices, Prentice Hall, 1997.
2. Richard S. Muller and Theodore I. Kamins, Device Electronics for Integrated Circuits, JohnWiley,1986.

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| 1 | Use of SPICE for semiconductor modeling.<br>Large signal and small signal modeling of PN Junctions |
| 2 | Schottky diode implementation in SPICE2 |
| 3 | MOS Capacitor modeling in SPICE<br>SPICE level 1, 2, and 3, and Berkeley short-channel IGFET modeling |
| 4 | I-V characteristics, Large Signal and small signal modeling of MOSFET |
| 5 | I-V characteristics, SPICE Modeling of BJTs and HBTs |

***Course Name: DIGITAL SYSTEM DESIGN USING FPGAs***
***Course Code: EE624***

**Course Outcome:**

| | |
|---|---|
| **CO-1** | Familiarized with the design of Combinational and Synchronous and Asynchronous Sequential Circuits. Gave an Overview of PLDs and PALs |
| **CO-2** | Covered basic introduction of VHDL and the basic language elements. Various Combinational and Sequential circuits were designed using VHDL |
| **CO-3** | In-depth analysis of Faults and testability in digital systems including modelling and detection |
| **CO-4** | Interfacing various sensors and reading/writing to/from various file formats. Implementing various modulation schemes |
| **CO-5** | Design of a RISC CPU, data and control path components. Introduction to various floating/fractional/fixed-point arithmetic operations. Implementing Data encryption/Decryption system, Error correction, communication modules, BERT |

**UNIT I Digital system design techniques:** Combinational Circuit Design - Synchronous Sequential Circuit Design - Mealy and Moore model - State machine design - Analysis of Synchronous sequential circuit - State equivalence - State Assignment and Reduction – Analysis of Asynchronous Sequential Circuit - flow table reduction – races - state assignment - Design of Asynchronous Sequential Circuit - Designing with PLDs – Overview of PLDs – ROMs - EPROMs – PLA – PAL - Gate Arrays – CPLDs and FPGAs, Designing with ROMs - Programmable Logic Arrays - Programmable Array logic.

**UNIT II VHDL basics and computation module designs:** Introduction to VHDL - Behavioral modeling - Data flow modeling - Structural modeling - Basic language elements – Entity – Architecture - Configurations – Arrays declaration - Subprograms & operator overloading - Packages & libraries – Advanced Features - Model simulation - Realization of combinational and sequential circuits using VHDL – Registers – Flip flops - counters – Shift registers – Multiplexers - sequential machine – Multiplier – Divider, ALU, MAC, CORDIC, Introduction to Synthesis.

**UNIT III Fault modeling, detection and test pattern generation algorithms:** Introduction to testing – Faults in Digital Circuits – Modeling of faults – Logical Fault Models – Fault detection – Fault Location

– Fault dominance – Logic simulation – Test generation for combinational logic circuits – Testable combinational logic circuit design - Introduction to Design for Testability - BIST..

**UNIT IV Digital system design with real-time I/O interface:** Sensors interface - uni-polar & bi-polar A/D converter - D/A converter interface - display devices interface - RS232, USB, Ethernet, VGA interface - RF data link - high voltage switch control - realy/AC/DC motor & buzzer control - PWM signal generation - PS/2 key-board & matrix keypad interface – digital camera interface, arbitrary data/signal generation – sensor data acquisition and writing/reading to/from .xlsx and .doc file - implementation of modulation schemes.

**UNIT V Contemporary designs and solutions:** Design of data path components, Control path components - Design of a simple RISC CPU - Debugging using Embedded Logic Analyzers - Audio codec (AC97) interface – Test-bench design – Chip Scope Pro Analyzer - introduction to floating/fractional/fixed-point arithmetic operations - Xilinx Sys-Gen tools - MATLAB/VHDL interface with Sys-Gen tools -BERT interface – implementation of DPCM, data encryption/decryption system, EC techniques, communication modules design, DA based computations.

**TEXT BOOKS:**

1. Parag K. Lala, "Digital System Design using programmable Logic Devices", Prentice Hall, NJ, 1994.
2. Geoff Bestock, "FPGAs and programmable LSI; A Designers Handbook", Butterworth Heinemann, 1996.
3. Miron Abramovici, Melvin A. Breuer and Arthur D. Friedman, "Digital Systems Testing and Testable Design", John Wiley & Sons Inc.
4. Parag K. Lala "Fault Tolerant and Fault Testable Hardware Design" B S Publications, 2002.
5. J. Bhasker, "A VHDL Primer", Addison-Weseley Longman Singapore Pte Ltd. 1992.

**REFERENCE BOOKS:**

1. Jesse H. Jenkins, "Designing with FPGAs and CPLDs", Prentice Hall, NJ,1994
2. Fundamentals of Logic Design – Charles H. Roth, 5th ed., Cengage Learning.
3. Kevin Skahill, "VHDL for Programmable Logic", Addison -Wesley, 1996
4. Z. Navabi, "VHDL Analysis and Modeling of Digital Systems", McGRAW-Hill, 1998
5. Digital Circuits and Logic Design – Samuel C. Lee , PHI
6. Smith, "Application Specific Integrated Circuits", Addison-Wesley, 1997
7. P.K. Lala, "Digital Circuit Testing and Testability", Academic Press, 2002

**LIST OF EXPERIMENTS:**

| SL No | NAME OF EXPERIMENTS |
|---|---|
| 01. | The Basic FPGA Design Flow<br>1. To understand use of Xilinx ISE<br>2. To understand Xilinx Synthesis Technology or XST.<br>3. Familiarization of Xilinx Vivado Design Tools. |
| 02. | Familiarization of FPGA Boards<br>1. Xilinx FPGA Boards (Virtex 6,Kintex7)<br>2.Implementation of Full adder, ALU , Memory and FIFO on FPGA |
| 03. | Fault Detection Logic Implementation on FPGA |

| | |
|---|---|
| | 1. Stuck at Fault<br>2.Memory BIST |
| 04. | Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analyzers. |

***Course Name: HIGH PERFORMANCE DSP USING FPGA***
***Course Code: EE625***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding basics of system design and design tools like vivado, ISE etc. Also learning about the features of different FPGA boards. |
| **CO-2** | Learning different hybrid programming tools for system implementation like integration of MATLAB & Simulink, C & LABVIEW, etc. Learning IP core design for various DSP applications |
| **CO-3** | Learning to design algorithms for real-time DSP systems and different transforms. Also learning the applications of FPGA in modern technologies |
| **CO-4** | Learning FPGA hardware and using them for real-time experiments. |

**1. Introduction to high performance digital computations:** Digital system design, signal processing, fixed and floating point computations, standards for high resolution computing, Design with Vivado design suite (IP, SysGen for DSP and image processing, model composer, embedded development, AI and ML tools), testing with high speed logical analyzer, advanced features of modern FPGAs (Kintex-7, Virtex-7, Zynq-7000, Artix-7, Kintex Ultra Scale, Kintex Ultra Scale+,Virtex Ultra Scale, Virtex UltraScale+, ZynqUltraScale+ and RFSoC etc.,), external memory interface, designs with advanced VHDL, advanced design with the PlanAhead analysis/design-tools, debugging techniques using the ChipScope Pro tools, FPGA power optimization.

**2. System implementation using hybrid simulink-programming tools:** Introduction to SysGen tools, integration of MATLAB & Simulink with SysGen platform, Model composer algorithms, integrated mixed language based design, high level synthesis, MATLAB & simulink, C and LabVIEW based HLS designs, massive parallel computations, designs with advanced XDC and STA, debugging techniques using Vivado logic Analyzer, designing with the Xilinx analog mixed signal solution.

**3. IP core library and design managements:** IP core design flow, IP core subsystems and integrations, parallelism, full/partial reconfiguration, flexible DSP blocks and multipliers, processor cores, embedded block RAM, embedded designs, standard communication interfaces, mixed signals based design, Multi-Rate Systems, MAC-Based FIR, Distributed Arithmetic and Multipliers Realization, FIFO, creating and managing reusable IPs, designs using Xilinx IP with Third-Party Synthesis Tools, Programming and Debugging Embedded Processors, SoC Processor Design, Embedded Micro Blaze Processor.

**4. Algorithm implementations using DSP tools:** Ultra fast algorithm design methodology, reconfigurable FPGA-based DSP Systems, real-time DSP System on Chip (SoC), Graphical Representation of DSP Algorithms, FIR/IIR filters, Adaptive filters, CORDIC algorithm implementations, multirate signal processing, FT/T_F analysis, spectral estimation and analysis, optimum and estimation techniques, image and speech processing, implementations of advanced transforms, Wavelet based designs.

**5. Contemporary applications and solutions:** Video and image processing, database and data analysis, control systems, high-speed, wired, wireless communications, network accelerations, test and M/m systems, HT generations/ detections, AI and machine learning algorithm implementations, 5G adaptive beamforming, RF transceiver modules interface, software driven DDS/SDR platform interface, Gbps Ethernet/optical-fiber dynamic switching, Designing an Integrated PCI Express System, IoE designs, soft controller designs.

**References:**

1. Michael P, Digital Signal Processing 101: Everything You Need to Know to Get Started, 2010, Elsevier.
2. Steve K, Advanced FPGA Design: Architecture, Implementation, and Optimization, 2007, IEEE.
3. Sanjay Churiwala, Designing with Xilinx® FPGAs: Using Vivado, 2017, Springer.
4. Roger Woods et al., FPGA-based Implementation of Signal Processing Systems, 2017, Wiley.
5. Donald G. Bailey, Design for Embedded Image Processing on FPGAs, 2011, IEEE.
6. Uwe Meyer-Baese Digital Signal Processing with Field Programmable Gate Arrays, 2013, Springer.
7. Nasser Kehtarnavaz, Digital Signal Processing Laboratory: LabVIEW-Based FPGA Implementation, 2010, Brown Walker press.
8. https://www.xilinx.com/support.html#knowledgebase.

**LIST OF EXPERIMENTS:**

| SL No | NAME OF EXPERIMENTS |
|---|---|
| 01. | The Basic Design Flow of DSP Implementation in FPGA.<br>1. To understand use of Xilinx System Generator.<br>2. To understand Xilinx Synthesis Technology or XST.<br>3. Familiarization of Simulink, Signal Processing Toolbox, Signal Processing Block-set. |
| 02. | Implementation of Dual Port RAMS, Addressable Shift Register, FIFO And ROM in FPGA.<br>1. Familiarization with Memory Blocks implementation in FPGA.<br>2. To Understand FGPGA Hardware.<br>3. Familiarization of XUP board (Vertex-5). |
| 03. | Implementation of M Code Adder in FPGA<br>1. This exercise provides an introduction to the integration of M Code into a System Generator System.<br>2. To understand functionality of a basic 2-input adder is interpreted from the M-code. |
| 04. | Generation of Simulink System Period<br>1. To understand Simulink system periods, and confirm the meaning of this parameter from the simulation results. |

***Course Name: COMPRESSED SENSING AND SPARSE SIGNAL PROCESSING***

***Course Code: EE626***

**Course Outcome-**

| Course Outcomes | Description |
|---|---|

| | |
|---|---|
| **CO1** | Generalize the concept of compressed sensing. |
| **CO2** | Gain the theory of null space property and RIP. |
| **CO3** | Acquire the basics of convex optimization and basis pursuit. |
| **CO4** | Applying knowledge and skills to demonstrate in short project. |

**UNIT-I: Introduction**: Introduction to CS, Review of Linear Algebra.

**UNIT-II: Sparse Representations**: Motivations and basic formulations, Uniqueness of sparse representation.

**UNIT- III: Measurement Matrices**: Null Space Property, Restricted Isometry Property (RIP), Johnson Lindenstrauss Lemma, Random Matrices and RIP.

**UNIT-IV: Reconstruction Algorithms**: Convex Optimisation methods, Basis Pursuit, Basis Pursuit Demonising, Introducing software packages like L1-magic, sparselab, etc. Greedy Algorithms: Matching Pursuit, Orthogonal Matching Pursuit, Subspace Pursuit, Compressive Sampling Matching Pursuit. Theoretical Guarantees of the algorithms Implementation of the algorithms in Matlab and simulations

**UNIT-V:** Applications: Classification.There can be a mini project for the course

**TEXT BOOKS:**

1. A Mathematical Introduction to Compressive Sensing, Simon Foucart, Holger Rauhut Springer New York, 21-Jun-2013
2. Compressed Sensing: Theory and Applications, Yonina C. Elda, Cambridge University Press

**LIST OF EXPERIMENTS:**

| **Sr. No.** | **Experiments** |
|---|---|
| 1. | Simulation of algorithms in Matlab/Lab view.<br>a. Basic Pursuit<br>b. Matching Pursuit,<br>c. Orthogonal Matching Pursuit,<br>d. Subspace Pursuit,<br>e. Compressive Sampling Matching Pursuit. |

***Course Name: SIGNAL THEORY, LINER ALGEBRA & TRANSFORM TECHNIQUES***

***Course Code: EE627***

**Course Outcome-**

| **Course Outcomes** | **Description** |
|---|---|
| **CO1** | Learn the basics of random variable, probability, density function, and correlation. |
| **CO2** | Gain the theory of Laplace transform, and Wavelet transform. |
| **CO3** | Acquire the basics of orthogonal basis, linear independence ization convex optimization and basis pursuit. |
| **CO4** | Learn the application of SVD and EVD to demonstrate using a short project. |

**UNIT I: PROBABILITY AND RANDOM VARIABLES:** Random variables, Probability Distribution and Density functions, Normal or Gaussian Random Variables, Multiple Random Variables, Correlation, Covariance and Orthogonality, Transformation of Random variables, Multivariate Normal Density Function, Linear Transformation and General Properties of Normal, Random Variables, Mathematical Description of Random Signals, Concept of a Random Process, Probabilistic Description of a Random Process, Gaussian Random Process, Stationarity, Ergodicity, and Classification of Processes, Autocorrelation Function, Cross correlation Function, Power Spectral Density Function, Cross Spectral Density Function, White Noise.

**UNIT II: TRANSFORM TECHNIQUES:** Laplace Transform: Introduction, Region of absolute convergence, Properties, Convolution, Inverse Laplace transform. **Z TRANSFORM:** Basic Properties, z-transform inversion, Difference equation. **FOURIER TRANSFORM:** Prelude to Fourier series, Transform properties, Discrete Fourier Transform, Properties, FFT, fast convolution. **WAVELET TRANSFORM:** Continuous wavelet transforms Different wavelets and multi- resolution analysis.

**UNIT III:** Linear Algebra General (real) vector spaces, Subspaces, Linear independence, Dimension, Norms, Orthogonal bases and Gram-Schmidt orthogonalization, Linear transformation, Kernel and range, Inverse transformations, Matrices of linear transformations, Change of basis, Similarity, Eigen values and Eigen vectors, Diagonalization, Orthogonal diagonalization of symmetric matrices, Singular value decomposition and its applications.

**TEXT-BOOKS:**

1.Linear Algebra and its Applications, 1980, Gilber-strang, Academic press 2nd Edn,
2.Probability, Random Variables, and Stochastic Processes, 1965, Athanasios Papoulis, McGraw Hill.

**REFERENCE BOOKS:**

1. Probability & Random Processes with Applications to Signal Processing, 2001, 3Edn. Henry Stark and John W Woods, Prentice Hall.
2. Introduction to linear algebra, 1984, Roger C. Mecann, Harcourt Brace Jovancovich Publishers.
3. First Course in Linear Algebra, 1983, P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Wiley Eastern.
4. Signal Processing, 1975, Mischa Schwartz and Leonard Shaw, New York, Mc Graw Hill.

**LIST OF EXPERIMENTS:**

| **Sr. No.** | **Experiments** |
|---|---|
| 1. | Simulation of the following techniques:<br>a) Transform Techniques<br>b) Z Transform<br>c) Fourier Transform<br>d) Wavelet Transform |
| 2. | Gram-Schmidt orthogonalization for multiple wave forms |
| 3. | Real time implementation Eigen values and singular values for speech signals |

***Course Name: ADVANCED ELECTRONICS SYSTEMS***
***Course Code: EE628***

**Course Outcome-**

| Course Outcomes | Description |
|---|---|
| **CO1** | Learn the basics of Analog IC Design Flow -Digital IC Design Flow, Sensors and advanced topics |
| **CO2** | Gain the theory of Analog IC Design |
| **CO3** | Acquire the basics of Digital IC Design |
| **CO4** | Learn the basics and application of RF Microelectronics. |

**UNIT -I: Introduction:** Analog IC Design Flow -Digital IC Design Flow- Bipolar and CMOS Technology.

**UNIT -II: Sensors and advanced topics :** Sensors as system components- Temperature sensors- Force and pressure sensors- Magnetic field sensors – Optical sensors - Microwave sensors - Miscellaneous sensors –MEMS-Fabrication steps.

**UNIT -III: Analog IC Design:** Analog Conditioning circuits. Advanced Current Sources & sinks; Voltage Reference circuit, Operational amplifiers - Architectures-Instrumentation Amplifiers, feedback-Filter Design-ADC-DAC. Concepts of Virtual Instrumentation: Lab View (can be supported by laboratory).

**UNIT -IV: Digital IC Design:** MOS inverter- Static and switching characteristics, Combinational MOS logic circuits –static logic Synchronous system and Sequential circuits design.

**UNIT -V: RF Microelectronics:** Low Noise Amplifier (LNA), Mixer, Oscillator, VCO and PLL, Power amplifier-Transceiver Architecture.

**REFERENCE BOOKS:**

1. Jan M. Rabaey; Anantha Chandrakasan; BorivojeNikoli´c, "Digital Integrated Circuits A Design Perspective", (Second Edition) Prentice-Hall Electronics and VLSI Series. (2003)
2. Behzad Razavi,"Design of Analog CMOS integrated circuits", McGraw Hill International Edition. 2001.
3. Behzad Razavi,"RF Microelectronics", PHI International Second Edition. 2012.
4. Neil H.E. Weste, Kamran Eshraghian, "Principles of CMOS VLSI Design, Addison-Wesley Publishing Company.
5. Handbook of Modern Sensors by Fraden
6. D. V.S. Murthy, Transducers in instrumentation, Prentice Hall, 1995.
7. J. P. Bentley, Principles of measurement systems, Wiley, 1989
8. J. W. Gardner, Microsensors, principles and applications, Wiley, 1996.
9. S.M. Sze, Semiconductor Sensors, Wiley, 1994.

**LIST OF EXPERIMENTS**

| S. No. | Name of the Experiments |
|---|---|
| 01 | Write VHDL programs for the a) Full Adder b) Multiplexer c) BCD-Gray code converter d) |

| | |
|---|---|
| | Shift Registers e) Barrel Shifters.<br>Aim: 1. To understand the Various modeling such as a)data flow modeling b) behavioral modeling C)Structural<br>modeling of VHDL.<br>2. Writing the test bench to create various stimulus for the DUT. |
| 02 | Implement the Booth Multiplier using structural modeling in FPGA.<br>Aim:<br>1. To understand the Structural modeling of VHDL.<br>2. To understand the word length effects.<br>3. To understand the use of Xilinx ISE 16.1.<br>4. Hands on experience in SPARTAN 3E FPGA kits. |
| 03 | Implement a Traffic Light controller using Mealy Machine in FPGA.<br>Aim:<br>1. To understand the Mealy State machine.<br>2. To understand the use of Xilinx ISE 16.1.<br>3.Hands on experience in SPARTAN 3E FPGA kits |
| 04 | Implement a Sequence Detector using Moore machine in FPGA.<br>Aim:<br>1. To understand the Moore State machine.<br>2. To understand the use of Xilinx ISE 16.1.<br>3. Hands on experience in SPARTAN 3E FPGA kits. |
| 05 | Design a 8 bit Processor contain both combinational and sequential circuits to perform various arithmetic<br>and logical operations.<br>Aim:<br>1. To understand the mixed modeling styles of VHDL.<br>2. To understand the use of Xilinx ISE 16.1.<br>3. Hands on experience in SPARTAN 3E FPGA kits |

***Course Name: SONAR SIGNAL PROCESSING***
***Course Code: EE 629***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | To understand the basic of Sound and underwater channel models |
| **CO-2** | To understand the ambient Noise and radiated noise in the ocean |
| **CO-3** | To understand the refection and scattering by sonar targets |
| **CO-4** | To understand the shallow water acoustics and passive Sonar classifier. |

**UNIT-I: HISTORICAL BACK GROUND AND BASICS OF SOUND:** History of sonar evolution, basics of sound measurement, measurement parameters, sound velocity profile and its variation, medium parameters.

**UNIT-II: UNDERWATER CHANNEL MODELS:** Multipath Propagation, Ray Model, Helmholtz Equation, Wave Propagation, Adiabatic Model, PE model, Computational Ocean Acoustics.

**UNIT-III: AMBIENT NOISE IN THE OCEAN AND SONAR EQUATION:** Sources of sound in the ocean, propagation impact, characteristics of the sources and there, impact on sonar performance. Sonar parameters, sonar equation for active and passive sonar.

**UNIT-IV: RADIATED NOISE FROM MARINE VESSELS:** Components of radiated noise, transmission of the components, propulsion types and their characteristics, ship design and stealth aspects.

**UNIT-V: REFLECTION AND SCATTERING BY SONAR TARGETS:** Active sonar target characteristics, design and stealth aspects, Sensor performance and self noise characteristics, ROC, statistical analysis for detection, State-of-the-art.

**UNIT-VI: SHALLOW WATER ACOUSTICS:** Deep Vs Shallow waters, Propagation in Tropical Littoral Waters, Band limited Channel Characteristics, Fluctuations of a Shallow Water Underwater Channel.

**UNIT-VII: PASSIVE SONAR CLASSIFIER:** Feature Extraction, Feature Transformation, Acoustic Signature Characteristics, Classification Algorithms, Practical Classifiers, Cepstral Features.

**TEXT BOOKS:**

1. Underwater Acoustic System Analysis, W S Burdic.
2. R. O. Nielsen, Sonar Signal Processing (Artech House, Boston, 1991).
3. Paul C. Etter, Underwater Acoustic Modelling and Simulation (Spon Press, Taylor and Francis Group, London and New York, third edition, 2003).

**LIST OF EXPERIMENTS:**

| Sr. No | Experiments |
|---|---|
| 1 | Introduction of Matlab/Simulink, Lab view and its tool boxes for simulating a single spatially coherent underwater acoustic signals in the presence of spatially and temporally correlated/uncorrelated noise (Simulation of hydrophone array data vector) |
| 2 | Target Signal & Ambient Noise Simulation (Scalar & Vector Sensor Array Data Vector Simulation): Generation of Multiple surface and subsurface targets in presence of Strong interferences and Additive Correlated/Uncorrelated, White/Colored, Gaussian/Non-Gaussian Ambient Noise Process. |
| 3 | Development of Conventional Direction Of Arrival (DoA) estimation techniques for Passive & Active Sonar<br>1. Conventional Beam former Via Delay & Sum technique (Wideband Spatial Filter)<br>2. Conventional Beam former Via Phase Shift based technique (Narrowband Spatial Filter) |
| 4 | Development and performance comparison of the following High Resolution Adaptive Beam former techniques using Scalar sensor array & Acoustic Vector Sensor Array in Passive & Active Sonar:- |

| | |
|---|---|
| | MVDR, MPDR ,MUSIC, ESPRIT, Subspace Intersection Method (SIM), Generalized Side lobe Cancellation (GSC) Beam former |
| 5 | Performance comparison High resolution Passive & Active Sonar Signal Processing algorithms in the presence of strong interferences and Spatially Correlated Noise |
| 6 | Design & Development of STAP techniques to remove self-noise radiated from own ship. Compare the<br>Passive Sonar performance with & without STAP. |

***Course Name: SONAR SYSTEM ENGINEERING***
***Course Code: EE630***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | To understand the SONAR Equation and its fundamentals. |
| **CO-2** | Array concepts and Beam forming in SONAR applications. |
| **CO-3** | Various Noise in SONAR |
| **CO-4** | Characteristics of Passive and Active SONAR |

**UNIT I: SOUND-** Wave motion, Sound pressure, Reference intensity, Source level, Radiated power, Limitations to sonar power, Cavitation, Interaction, Octave Bands, dB Scale, Far Field and Near Field Measurements, Projector sensitivity, Hydrophone sensitivity, Spectrum level, Sound in air and in sea water.

**UNIT II: SONAR EQUATION-** The Active and Passive Sonar Equation. Sonar Parameters, Sound Velocity Profile (SVP), Sonar Performance, Limitations of the Sonar Equation, Detection Threshold and Receiver Operating Curve (ROC).

**UNIT III: ARRAYS-** Beam Forming, Beam Steering, Beam Patterns, Uniform Linear Arrays (ULA), Cylindrical Arrays, Shading, Delayand-Sum Beam forming, Conformal Arrays, Three dimensional Arrays, Cross Arrays, Spherical Arrays, Receiver and transmitter Arrays, Directivity Index, Sonar Domes, transducer design and characteristics.

**UNIT IV: PROPAGATION OF SOUND IN THE SEA-** Propagation loss, Spreading losses, Absorption losses, Propagation in the real ocean, The speed of sound, Sound speed profiles, Deep sound channel, Multi-path propagation, SOFAR Channel, Surface duct propagation, Convergence zone propagation, Bottom bounce propagation, Propagation loss models, Ray theory and the wave propagation models, Channel models.

**UNIT V: NOISE IN SONAR SYSTEMS-** Sonar System Noise, Self-Noise, Ambient Noise in the Ocean, Flow Noise, Radiated Noise, Noise Factor of a Sonar, Figure of Merit, Practical Noise Levels.

**UNIT VI: PASSIVE SONAR-** Radiated Noise, Ambient Noise Characteristics, LOFAR & DEMON, Passive Sonar Detection, Passive Sonar Classifier, Operational Limitation of Passive Sonars, Evolution of Passive Sonars, Acoustic Signatures, Ranging.

**UNIT VII: ACTIVE SONAR-** Pulse Characteristics, CW Sonars, Reverberation Levels, Target Strengths, Echo Characteristics, Sediment Classification, Doppler.

**TEXT BOOKS:**

1. Principles of Underwater Sound, R J Urick, Third Edition 1983.
2. Sonar for Practising Engineers Third Edition by A. D. Waite ; WILEY 2002.

***Course name: SATELLITE COMMUNICATION***

***Course Code : EE631***

**Course Outcome:**

| | |
|---|---|
| **CO-1** | Introduction to Satellite Systems, learning of orbital systems and sub systems. |
| **CO-2** | Earth to Satellite linking and their calculations for losses. |
| **CO-3** | Satellite switching technologies |
| **CO-4** | Applications of direct satellites broadcasting like GPS and other mobile services |

**UNIT-I: OVERVIEW OF SATELLITE SYSTEMS, ORBITS AND LAUNCHING METHODS-** Introduction, Frequency Allocations for Satellite Services, Intelsat, U.S. Domsats Polar Orbiting Satellites , Problems, Kepler's First Law , Kepler's Second Law, Kepler's Third Law , Definitions of Terms for Earth-orbiting Satellites , Orbital Elements , Apogee and Perigee Heights , Orbital Perturbations , Effects of a Nonspherical Earth , Atmospheric Drag , Inclined Orbits , Calendars , Universal Time , Julian Dates , Sidereal Time , The Orbital Plane , The Geocentric, Equatorial Coordinate System , Earth Station Referred to the IJK Frame , The Topcentric-Horizon Co-ordinate System , The Sub-satellite Point , Predicting Satellite Position.

**UNIT II: GEOSTATIONARY ORBIT & SPACE SEGMENT-** Introduction , Antenna Look Angels , The Polar Mount Antenna , Limits of Visibility , Near Geostationary Orbits , Earth Eclipse of Satellite , Sun Transit Outage , Launching Orbits , Problems, Power Supply , Attitude Control , Spinning Satellite Stabilization , Momentum Wheel Stabilization , Station Keeping , Thermal Control , TT&C Subsystem , Transponders , Wideband Receiver , Input Demultiplexer , Power Amplifier , Antenna Subsystem , Morelos , Anik-E , Advanced Tiros-N Spacecraft

**UNIT III: EARTH SEGMENT & SPACE LINK-** Introduction, Receive-Only Home TV Systems, Outdoor Unit, Indoor Unit for Analog (FM) TV, Master Antenna TV System , Community Antenna TV System , Transmit-Receive Earth Stations, Problems, Equivalent Isotropic Radiated Power, Transmission Losses, Free-Space Transmission, Feeder Losses, Antenna Misalignment Losses, Fixed Atmospheric and Ionospheric Losses, Link Power Budget Equation, System Noise, Antenna Noise, Amplifier Noise Temperature, Amplifiers in Cascade, Noise Factor, Noise Temperature of Absorptive Networks, Overall System Noise Temperature, Carrier-to-Noise Ratio, Uplink, Saturation Flux Density, Input Back Off, The Earth Station HPA, Downlink , Output Back off, Satellite TWTA Output, Effects of Rain, Uplink rain-fade margin, Downlink rain-fade margin, Combined Uplink and Downlink C/N Ratio, Intermodulation Noise

**UNIT IV: SATELLITE ACCESS-** Single Access, Preassigned FDMA, Demand-Assigned FDMA, SPADE System. Bandwidth-limited a Power-limited TWT amplifier operation, FDMA downlink analysis. DMA, Companion of uplink Power requirements for FDMA & TDMA. On-board signal processing for TDMA / FDMA operation, Satellite switched TDMA, CDMA.

**UNIT V: DIRECT BROADCAST SATELLITE SERVICES-** Introduction, Orbital Spacings, Power Rating and Number of Transponders, Frequencies and Polarization, Transponder Capacity, Bit Rates for Digital Television, MPEG Compression Standards, Forward Error Correction, Home Receiver Outdoor Unit (ODU), Home Receiver Indoor Unit (IDU), Downlink Analysis, Uplink, Problems, Satellite Mobile Services, VSATs, Radarsat, Global Positioning Satellite System, Orbcomm.

**Text Books:**

1. Satellite Communications, Dennis Roddy, McGraw-Hill Publication Third edition 2001
2. Satellite Communications – Timothy Pratt, Charles Bostian and Jeremy Allnutt, WSE, Wiley Publications, 2nd Edition, 2003.
3. Satellite Communications Engineering – Wilbur L. Pritchard, Robert A Nelson and Henri G.Suyderhoud, 2nd Edition, Pearson Publications, 2003.

Reference Books:

1. Timothy Pratt – Charles Bostian& Jeremy Allmuti, Satellite Communications, John Willy & Sons (Asia) Pvt. Ltd. 2004
2. Wilbur L. Pritchars Henri G.SuyderHond Robert A.Nelson, Satellite Communication Systems Engineering, Pearson Education Ltd., Second edition 2003.
3. Satellite Communications : Design Principles – M. Richharia, BS Publications, 2nd Edition, 2003.

**LIST OF EXPERIMENTS:**

| Sr. No. | Experiments |
|---|---|
| **1.** | To set up a satellite communication link and study of change in uplink and downlink frequency |
| **2.** | Transmission of Audio and Video signals and Data Communication over satellite link |
| **3.** | Different GPS data like longitude, latitude and different types of dilute of precision using GPS receiver |
| **4.** | Selection of various PN codes like Gold, Barker and MLS in CDMA Technology |
| **5.** | Generation (spreading) and demodulation (dispreading) of DSSS modulated signal |
| **6.** | Minimum shift keying modulation and demodulation |
| **7.** | Determination of Maximum bit rate of a digital fiber optic link |
| **8.** | Demonstrating different modulation techniques with suitable demodulation |
| **9.** | Demonstrating different optical fiber losses |
| **10.** | Simulation of FSOC data link |
| **11.** | Atmospheric losses in FSOC |
| **12.** | Modeling and simulation of atmospheric attenuation and turbulence strength |
| **13.** | Demonstrating the beam steering system |

***Course Name: ADVANCED COMMUNICATION SYSTEMS***
***Course Code: EE632***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Review of Fourier Transform, DTFT, Z-Transform, sampling theorem, PCM, DM, etc. |
| **CO-2** | Understanding of communication over AWGN channel, coding and equalization techniques |
| **CO-3** | knowledge of digital modulation and demodulation techniques. |
| **CO-4** | Knowledge of Signal & Noise Statistics in Coherent &Noncoherent Receivers. |
| **CO-5** | Basic understanding of source coding and entropies. |

**UNIT-1-Introduction:** Block diagram of digital communication system, Review of Fourier Transform properties, Discrete Sequences, DTFT, ZT, Channel capacity, Shannon's limit, sampling Theorem - Mathematical proof of sampling and reconstruction –ideal and Flat top sampling, Band pass sampling. Digital Representation of Analog Signals, Pulse code modulation, generation and detection of PCM, Uniform quantization and companding, Differential PCM; Delta modulation, Adaptive delta modulation; Signal-to- Noise Ratio calculations in PCM, DM.

**UNIT-2-Base band data transmission:** Communication over Band limited AWGN Channel, ISI in band limited channels, Zero-ISI condition- the Nyquist criterion, Solution for zero ISI, Raised cosine filters, Partial response signalling-Duo binary encoding, M-ary baseband system, eye pattern, adaptive Equalization.

**UNIT-3-Modulation Techniques:** Binary Baseband Digital Modulation Techniques, digital modulation techniques: ASK, BPSK, BFSK, DPSK, QPSK and M-ary signaling; M array Baseband Digital Modulation Techniques, PSK & QPSK, Offset QPSK, Minimum Shift Keying (MSK), Passband Waveforms for M-ary signaling, Passband Modulations for Band Limited Channels, Baseband & Passband Digital

**UNIT-4-Demodulations Techniques:** General Issues & Concepts, Matched Filters, Coherent Demodulation, Coherent Demodulation for Binary Wave Form, Coherent &Noncoherent Receivers for Orthogonal Signalling (OOK & FSK),

**UNIT-5-Performance Analysis:** Signal & Noise Statistics in Coherent &Noncoherent Receivers, Error Rates for Binary Signaling: Coherent Receivers, Performance of Non Coherent FSK & Differential Phase Shift Keying, Demodulation of DPSK & M-'ary Signals, Performance of M-ary Digital Modulations.

**UNIT-6-Information Theory techniques**: Entropy, Joint Entropy and Conditional Entropy, Relative Entropy and Mutual Information, Chain Rules, Data-Processing Inequality, Fano’s Inequality. Source Coding and Data Compression:Kraft Inequality, Huffman Codes, Optimality of Huffman Codes, Linear Binary Block Codes:Introduction, Generator and Parity-Check Matrices, Repetition and Single-Parity-Check Codes, Binary Hamming Codes, Error Detection with Linear Block Codes, Weight Distribution and Minimum Hamming Distance of a Linear Block Code, Hard-decision and Soft-decision Decoding of Linear Block Codes, Cyclic Codes, Parameters of BCH and RS Codes, Interleaved and Concatenated

Codes, Convolutional Codes:Encoder Realizations and Classifications, Minimal Encoders, Trellis representation, MLSD and the Viterbi Algorithm, Bit-wise MAP Decoding and the BCJR Algorithm

**TEXT BOOKS**

1. Sam Shanmugam, “Digital and analog communication system”, John Wiley,2005.
2. Herbert Taud, Donald L. Schiling, GoutamSaha, “Principles of Communication Systems”, – 3 rdEdition, McGraw – Hill2008.
3. Elements of Information Theory by Thomas Cover, Joy Thomas
4. Channel Codes: Classical and Modern by William Ryan, Shu Lin

**REFERENCE BOOKS**

1. Digital Communications –Simon Haykin, Jon Whiley,2005 2. Wayne Tomasi “Electronic communications systems”-5 thedition,pearson publication
2. Information Theory and Reliable Communication by Robert Gallager.

***Course Name: UNDERWATER COMMUNICATIONS***
***Course Code: EE633***
**Course Outcome-**

| **Course Outcomes** | **Description** |
|---|---|
| **CO1** | Learn the basics of Underwater Acoustics-Underwater Communication Media, Underwater Systems and Networks, |
| **CO2** | Gain the theory of UWA Channel Characteristics, Sound Velocity, and Doppler scale. |
| **CO3** | Acquire the basics of Modulation Techniques for UWA Communications. |
| **CO4** | Learn the application of Multi-Input Multi-Output Techniques-for underwater Acoustic Communications. |

**UNIT-1: INTRODUCTION-**Background and Context-Early Exploration of Underwater Acoustics-Underwater Communication Media, Underwater Systems and Networks,

**UNIT-2: UWA Channel:** UWA Channel Characteristics, Sound Velocity, Propagation Loss-Time-Varying Multipath-Acoustic Propagation Models-Ambient Noise and External Interference, Pass band Channel Input–Output Relationship, Linear Time-Varying Channel with Path-Specific Doppler Scales, Linear Time-Varying Channels with One Common Doppler Scale, Linear Time-Invariant Channel-Linear Time-Varying Channel with Both Amplitude and Delay Variations-Linear Time-Varying Channel with Frequency Dependent Attenuation.

**UNIT-3: UWA Modulation Techniques:** Modulation Techniques for UWA Communications, Frequency Hopped FSK, Direct Sequence Spread Spectrum, Single Carrier Modulation, Sweep-Spread Carrier (S2C) Modulation, Multicarrier Modulation,

**UNIT-4: MIMO-UWA:** Multi-Input Multi-Output Techniques-Recent Developments on Underwater Acoustic Communications.

**UNIT-5: OFDM BASICS -**Zero-Padded OFDM, Cyclic-Prefixed OFDM -OFDM Related Issues-ZP-

OFDM versus CP-OFDM -Peak-to-Average-Power Ratio -Power Spectrum and Bandwidth -Subcarrier Assignment-Overall Data Rate -Design Guidelines -Implementation via Discrete Fourier Transform -Challenges and Remedies for OFDM - Benefits of Diversity Combining and Channel Coding -MIMO OFDM

**UNIT-6: PAPR CONTROL -**PAPR Comparison-PAPR Reduction-Clipping-Selective Mapping-Peak Reduction Subcarriers,

**REFERENCES:**

1. Shengli Zhou, Zhaohui Wang, "OFDM for Underwater Acoustic Communications", John Wiley & Sons Ltd, 2014
2. Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, "MIMO-OFDM Wireless Communications with MATLAB", John Wiley & Sons Ltd, 2010

**REFERENCE BOOKS:**

1. Shengli Zhou, Zhaohui Wang, "OFDM for Underwater Acoustic Communications", John Wiley & Sons Ltd, 2014
2. Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, "MIMO-OFDM Wireless Communications with MATLAB", John Wiley & Sons Ltd, 2010

**LIST OF EXPERIMENTS:**

| Sr. No. | Experiments |
|---|---|
| 1. | Design and Simulation of conventional Underwater Communication techniques using Lab VIEW/Matlab |
| 2. | Design, Simulate OFDM system using Lab VIEW/Matlab/ FPGA and Test the system over 'Air Acoustic Channel' using Speaker and mike |
| 3. | Design, Simulate, MIMO-OFDM system using Lab VIEW- FPGA and Test the system over 'RF Channel' using LabVIEW NI USRP Platform |
| 4. | Test the MIMO-OFDM system over 'Underwater Acoustic Channel' using acoustic transducer in a glass tank at the lab |
| 5. | Test the MIMO-OFDM system over 'Underwater Acoustic Channel' using acoustic transducer in the Khadakwasla Lake |

***Course Name: MONOLITHIC MICROWAVE INTEGRATED CIRCUIT***
***Course Code: EE634***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding of planar technologies such as strip lines, microstrip lines, etc. |
| **CO-2** | Knowledge of microwave passive components such as branch line couplers, power dividers, circulators, phase shifters, etc. |
| **CO-3** | Understanding of microwave active circuits, stability and gain analysis through smith chart. |
| **CO-4** | Understanding of CAD techniques for oscillator, mixer designs. |
| **CO-5** | Knowledge of MMIC, hybrid MIC. |

**UNIT I**: **INTRODUCTION TO MICROWAVE INTEGRATED CIRCUITS AND APPLICATIONS:**
Introduction, Micro strip Lines, Characteristic Impedance of Micro strip Lines, Losses in Micro strip Lines, Quality Factor Q of Micro strip Lines, Parallel Strip Lines, Distributed Lines, Characteristic Impedance, Attenuation Losses, Coplanar Strip Lines, CPW lines, Shielded Strip Lines **METHODS OF ANALYSIS IN MIC:** Analysis of MIC by conformal transformation, Numerical method, Hybrid mode analysis, Losses in micro strip, Introduction to slot line and coplanar waveguide.

**UNIT II**: **COUPLERS AND LUMPED ELEMENTS: PASSIVE DEVICES:** Introduction to coupled micro strip, Evenand odd mode analysis, coplanar circuits, Design and fabrication of micro strip components: Branch line couplers, Filters, switches, attenuators, Directional couplers, lumped elements for169 MICs: Inductors, capacitors, resistors, multilayer techniques, Ferromagnetic substrates and inserts, Micro strip circulators, Phase shifters, Micro machined passive components, Comparison with distributed circuits.

**UNIT III**: **MICROWAVE ACTIVE DEVICES:** Microwave transistors, parametric diodes and amplifiers, PIN diodes, Transferred electron devices, Avalanche diodes, IMPATT, BARITT devices. RF CMOS devices, Microwave BJTs, GaAs FETs, MSFETs, low noise and power GaAs FETs and their applications.

**UNIT IV**: **HIGH &LOW POWER CIRCUITS:** Introduction, Impedance transformers, Filters, High powercircuits, Low power circuits, MICs in Radar and satellite **AMPLIFIERS:** Stability & gain analysis, matching techniques, reactively matched amplifier design, LNA

**UNIT V**: **OSCILLATORS:** Design principles, active device CAD techniques for large signal oscillators design, Phase noise, MMIC_VCO, mixers.

**UNIT VI**: **FABRICATION METHODS:** Fabrication process of MMIC, Hybrid MICs, Dielectric substances, Thick film and thin film technology and materials, Testing methods, Encapsulation and mounting of devices.

**TEXT BOOKS:**

1. Gupta K.C and Amarjit Singh, “Microwave Integrated Circuits”, John Wiley, New York, 1975.
2. Hoffman R.K “Hand Book of Microwave Integrated Circuits”, Artech House, Boston, 1987.
3. Ravender Goyal, “Monolithic MIC; Technology & Design”, Artech House, 1989.
4. Ulrich L. Rohde and David P.N., “RF / Microwave Circuit Design for Wireless Applications”, John Wiley,
2000.
5. C. Gentili, “Microwave Amplifiers and Oscillators”, North Oxford Academic, 1986.
6. Annapurna Das and Sisir K Das, “Microwave Engineering”, Tata McGraw-Hill Pub. Co. Ltd., 2004.
7. Samuel. Y. Liao, “Microwave Circuit Analysis and Amplifier Design”, Prentice Hall. Inc., 1987.
8. Mathew N.O. Sadiku, “Numerical techniques in Electromagnetic”, CRC Press, 2001.

**LIST OF EXPERIMENTS:**

| **Sr. No.** | **Experiments** |
|---|---|

| | |
|---|---|
| 1. | Impedance matching and S-Parameter analysis of : Coupled Transmission Line, Matching<br>Transformers |
| 2. | S-parameter analysis of :<br>a) Power dividers<br>b) Branch line couplers<br>c) Rat race |
| 3. | Filter design: Lumped to Micro strip Line transformation<br>a) Low pass filter<br>b) High Pass Filter<br>c) Band Pass Filters<br>d) Band Stop Filter |
| 4. | Amplifier Design and Stability Analysis (Simulation using ADS/Matlab)<br>a) Region of operation analysis<br>b) Gain analysis<br>c) Stability analysis using Smith Chart<br>d) V-I characteristic and S-Parameter analysis |
| 5. | Basic Oscillator Design and analysis using ADS/Matlab |
| 6. | Design a complete single micro strip antenna for single frequency to verify the results |
| 7. | Design different types of micro strip antennas and to verify the different results of these antenna |

***Course Name: INERTIAL SENSORS AND SYSTEMS***
***Course Code: EE635***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the fundamentals of Navigation and Inertial Navigation, gyroscope working principle, different types of gyropscopes. |
| **CO-2** | Knowledge of configuration, working principle, design of serve accelerometers and its types. |
| **CO-3** | Knowledge of MEMS Inertial Sensors, and Testing of Inertial Sensors and Systems. |
| **CO-4** | Understanding of Inertial Navigation Systems, Gimbaled platform technology, Strap down INS realization etc. |

**UNIT I:** Basic principles of Navigation and Inertial Navigation, Gimbaled platform and Strap down Navigation systems, Overview of Inertial Sensors.

**UNIT II:** Gyroscope working principle. Single degree of freedom rate gyro and rate integrating gyro. Dynamically Tuned Gyroscope: Principle of operation, Design features, Single gimbal and dual gimbal flexures, Rebalance loop configuration, DTG errors and error model. Ring Laser Gyro: Principle of operation and different types, Sagnac Effect, Design features, Lock in and Dither, RLG errors and error model. Fiber Optic Gyro: Principle of operation, Difference with RLG, Design features, open loop and closed loop operation, Error sources in FOG, difference between Fiber optic laser gyro and ring laser gyro. Hemispherical Resonator Gyro: Principle of operation, Design features, HRG errors and error model. Other types of gyros: Nuclear Magnetic Resonance Gyro, Electro statically Suspended Gyro, Atom Interferometric Gyro etc.

**UNIT III:** Configuration, working principle and design of pendulous servo accelerometers. Servo accelerometer errors and error model. Other types of accelerometers: Vibrating Beam Accelerometer, Fiber optic Accelerometers, Atom Interferometric Accelerometer etc.

**UNIT IV:** MEMS Inertial Sensors: Introduction to MEMS Inertial Sensors, Overview of MEMS Fabrication Techniques. MEMS Accelerometers: Pendulous and non-pendulous accelerometers, Resonant beam accelerometer. MEMS Gyros: Coriolis Vibrating gyro principle, Tuning fork gyro, Comb structure and Ring structure mechanizations.

**UNIT V:** Inertial Navigation Systems: Gimbaled platform technology and Strap down system technology, their mechanization. Redundant Inertial Navigation Systems: Basic concepts of sensor redundancy, redundant sensor configurations, Sensor Failure detection and Isolation. Strap down INS realization: Basic concepts of system configuration, vibration isolation and temperature control/compensation.

**UNIT VI:** Testing of Inertial Sensors and Systems: Basic concepts and test philosophy. Gyroscope Testing: Multi position test and Rate test, Frequency response test, Thermal test, Magnetic sensitivity test, Vibration test and Shock test. Accelerometer Testing: Multi position test, Centrifuge test, Frequency response test, Thermal test, Magnetic sensitivity test, Vibration test and Shock test. Gyro and Accelerometer error modeling and compensation. INS Testing: Rate test and Multi position test, Attitude test, Static navigation test, Hardware in Loop tests, Environmental tests like EMI, Thermal, Vibration and Shock.

**REFERENCE BOOKS:**

1. Strap down Inertial Navigation Technology: by D. H. Titterton and J. L. Weston.
2. Modern Inertial Sensors and Systems: by Amitava Bose, SomnathPuri and Paritosh Banerjee.
3. Fundamentals of Navigation and Inertial Sensors: by Amitava Bose, K. N. Bhat and Thomas Kurian
4. AGARD-LS-95: Strap down Inertial Systems.

**LIST OF EXPERIMENTS:**

| Sr No | Experiments |
|---|---|
| 1. | Obtain an interference pattern using Michelson interferometer.(Basics for SAGNAC effect) |
| 2. | Simulate DTG using MATLAB to calculate the rate |
| 3. | Use MATLAB to plot the frequency response (BODE Plot) of DTG given by its closed loop transfer function |
| 4. | Use MATLAB to calculate acceleration channel error model |
| 5. | Use MATLAB to calculate rate channel error model |

***Course Name: NAVIGATION & AVIONICS SYSTEMS***
***Course Code: EE636***

**Course Outcome-**

| Course Outcomes | Description |
|---|---|
| **CO1** | Learn the basics of navigation method, DR position, and EP. |
| **CO2** | Gain the theory of INS components. |
| **CO3** | Acquire the basics of different types of radio navigation, LORAN, and DECCA. |
| **CO4** | Learn the GPS system, position and velocity determination. |

**UNIT-I: INTRODUCTION-**Various navigation method, Dead Reckoning position (DR), estimated position (EP) & Observed Position,Gyroscopes, Mechanical, electromechanical, Ring Laser gyro, Fiber-optic gyro, Accelerometers

**UNIT-II: INERTIAL NAVIGATION SYSTEM-** INS components: transfer function and errors-The earth in inertial space, the coriolis effect-Mechanization. Platform and Strap down, INS system block diagram, Different coordinate systems, Schuler loop, compensation errors, Gimbal lock, Alignment

**UNIT-III: AVIONICS-** Need for Avionics in civil and military aircraft and space systems, Integrated Avionics and Weapon system, typical avionics sub systems, Design and Technologies, VHF avionics Communication system, data link, Telemetry

**UNIT-IV: RADIO NAVIGATION-** Different types of radio navigation, ADF, VOR/DME, Doppler, LORAN, DECCA and Omega, TACAN

**UNIT-V: SATELLITE APPROACH AND LANDING AID-** ILS, MLS, GLS - Ground controlled approach system surveillance systems-radio altimeter

**UNIT-VI: SATELLITE NAVIGATION AND HYBRID NAVIGATION-** Introduction to GPS system description, basic principles, position and velocity determination, signal structure, DGPS, Introduction to Kalman filtering, Estimation and mixed mode navigation, Integration of GPS and INS, utilization of navigation systems in aircraft

**UNIT-VII: RADAR NAVIGATION-** Navigation and traffic control using ground based radar and airborne radar, Tactical Air Navigation (TACAN), TACAN Equipment, Fischer Plotting, Radar Navigation Aid: radar reflectors, radar beacons, Principle of superposition Navigation, Chart matching equipment, accuracy obtained by chart matching, PPI Simulations.

**TEXT BOOKS:**

1. Myron Kyton, WalfredFried,"Avionics Navigation Systems" John wliey& Sons, 2nd edition, 1997
2. Nagaraja, N.S. "Elements of Electronic Navigation", Tata McGraw-Hill Pub. Co., New Delhi, 2nd edition, 1975.
3. Sen, A.K. & Bhattacharya, A.B. "Radar System and Radar Aids to Navigation", Khanna Publishers, 1988
4. Data & Network Communication, Michael A. Miller – DELMAR (Thomson learning) / Vikas Publication.

**LIST OF EXPERIMENTS:**

| Sr. No. | Experiments |
|---|---|
| 1. | Satellite Position fixing |
| 2. | User position fixing using 3, 4 and 5 satellites |
| 3. | DOPs Calculation |
| 4. | Elevation and Azimuth angle Calculation |
| 5. | Simulate of the following modulation schemes using MATLAB<br>a. Amplitude Modulation, Frequency Modulation, Phase Modulation.<br>b. Amplitude Shift keying, Frequency Shift Keying, Phase Shift keying. |

***Course Name: ASIC VERIFICATION USING SYSTEM VERILOG***
***Course Code: EE637***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | To understand the basic of System verilog- data types |
| **CO-2** | To understand the programming concept of System verilog |
| **CO-3** | To understand the verification tool by assertion coverage. |
| **CO-4** | Case study of Module verification by system verilog. |

**UNIT-I** Introduction to functional verification languages, Introduction to System Verilog, System Verilog data types. System Verilog procedures, Interfaces and modports, System Verilog routines.

**UNIT-II:** Introduction to object oriented programming, Classes and Objects, Inheritance, Composition, Inheritance v/s composition, Virtual methods. Parameterized classes, Virtual interface, Using OOP for verification, System Verilog Verification Constructs

**UNIT III: SYSTEM VERILOG ASSERTIONS**: Introduction to assertion, Overview of properties and assertion, Basics of properties and sequences, Advanced properties and sequences, Assertions in design and formal verification, some guidelines in assertion writing.

**UNIT IV:COVERAGE DRIVEN VERIFICATION AND FUNCTIONAL COVERAGE IN SV**: Coverage Driven Verification, Coverage Metrics, Code Coverage, Introduction to functional coverage, Functional coverage constructs, Assertion Coverage, Coverage measurement, Coverage Analysis. SV and C interfacing: Direct Programming Interface (DPI)

**UNIT V**:**CASE STUDIES**: System Verilog based Verification of UART,8 bit ALU, RISC CPU.

**TEXT BOOKS:**

1. “SystemVerilog for Design” : A Guide to Using SystemVerilog for Hardware Design and Modeling Sutherland, Stuart, Davidmann, Simon, Flake, Peter2nd ed., 2006
2. “SystemVerilog for Verification”: A Guide to Learning the Testbench Language Features, Chris Spear, 2006
3. “Hardware Verification with System Verilog”: An Object-Oriented Framework Mintz, Mike, Ekendahl, Robert 2007

**REFERENCE BOOKS:**

1. “Writing Test benches using System Verilog” Bergeron, Janick 2006,
2. “A Practical Guide for System Verilog Assertions” MeyyappanRamanathan

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| 1 | 1. Write an example to demonstrate the user defined data type enum, struct, struct packed, union, typedef and string.<br>2. Write an example to demonstrate the static array, multi-dimensional static array, dynamic array, associative array and queue type array.<br>3. Write an example to demonstrate a simple interface. |
| 2 | 1. Write an example to demonstrate class constructor, inheritance, encapsulation, and polymorphism.<br>2. Write an example to demonstrate randomization, rand casec, rand sequence, rand sequence abort.<br>3. Write an example to demonstrate DPI (Direct Programming Interface), both sv to c and c to sv.<br>4. Write an example to demonstrate semaphore, mailbox, virtual interface |
| 3 | Create SV based test environment for 1-bit adder.<br>Create class based test environment for 1-bit adder |
| 4 | 1. Create a class based test environment for RAM memory given.<br>2. Create a class based test environment for FIFO memory given. |
| 5 | 1. Create coverage and assertions for decade counter.<br>2. Create coverage and assertions for ones counter. |
| 6 | Create coverage and assertions for RAM memory previously created counter. |
| 7 | Create coverage and assertions for FIFO memory previously created counter. |

***Course Name: ANALOG AND MIXED MODE VLSI DESIGN***

***Course Code: EE638***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Develop the knowledge of Device modeling of MOSFET |
| **CO-2** | Illustrate the concept of Small signal analysis of single and multi stage amplifiers |
| **CO-3** | Designing of switched capacitor circuits |
| **CO-4** | Demonstrate the Data convertors and its applications |
| **CO-5** | Lab- Simulation of circuits using PSpice and Microwind Backend Tools. |

**UNIT-I: INTRODUCTION AND BASIC MOS DEVICES**: Challenges in analog design-Mixed signal layout issues-MOS FET structures and **characteristics**-large signal model –small signal model-single stage Amplifier-Source followerCommon gate stage –Cascode Stage

**UNIT-II: SUBMICRON CIRCUIT DESIGN**: Submicron CMOS process flow, Capacitors and resistors, Current mirrors, Digital Circuit Design, Delay Elements – Adders-OP Amp parameters and Design.

**UNIT III: DATA CONVERTERS**: Characteristics of Sample and Hold -Digital to Analog Converters-architecture-Differential Non linearity-Integral Non linearity-Voltage Scaling-Cyclic DAC-Pipeline DAC-Analog to Digital Converters-architecture –Flash ADCPipeline ADC-Differential Non linearity-Integral Non linearity

**UNIT IV :SNR IN DATA CONVERTERS** : Overview of SNR of Data Converters-Clock Jitters-Improving Using Averaging –Decimating Filters for ADC-Band pass and High Pass Sinc Filters-Interpolating Filters for DAC

**UNIT V: SWITCHED CAPACITOR CIRCUITS:** Resistors, First order low pass Circuit, Switched capacitor Amplifier, Switched Capacitor Integrator

**TEXT BOOKS:**

1. VineethaP.Gejji Analog and Mixed Mode Design Prentice Hall, 1st Edition , 2011
2. JeyaGowri Analog and Mixed Mode Design Sapna publishing House 2011.
3. Gray Paul R, Meyer, Robert G, Analysis and Design of Analog Integrated Circuits, 3rd edition, John Wiley &
Sons.
4. Jacob Baker, "CMOS Mixed-Signal circuit design", A John Willy & Sons, inc., publications, 2003.
5. Professor Bernhard Boser -"Analysis and Design of VLSI Analog-Digital Interface Integrated Circuits" "Addison Wisely publications" (1991).

**REFERENCE BOOKS:**

1. D A John, Ken Martin, Analog Integrated Circuit Design, 1st Edition, John Wiley
2. CMOS Analog Circuit Design, 2nd edition; by: Allen, Phillip E, Holberg , Douglas R, Oxford University
Press, (Indian Edition
3. Ken Martin, Digital Integrated Circuit Design, John Wiley
4. Sedra& Smith, Microelectronics Circuits, 5th Edition, Oxford University Press, (Indian Edition)
5. Jan M. Rabaey, AnanthaChadrakasan, B. Nikolic ,Digital Integrated Circuits – A Design Perspective 2nd
Edition, Prentice Hall of India (Eastern Economy Edition).
6. Sung-Mo Kang, Yusuf Leblebici, CMOS Digital Integrated Circuits Analysis & Design,2nd Ed, Tata McGraw Hill

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| 1 | AN INVERTER : Schematic Entry and Symbol Creation Building the Inverter Test Design , Simulation with Spectre, Parametric Analysis ,Creating Layout View of Inverter ,Physical Verification ,Creating the Configuration View, Generating Stream Data. |
| 2 | NAND DESIGN : Schematic Entry and Symbol Creation Building the NAND Test Design , Simulation with Spectre, Parametric Analysis ,Creating Layout View of NAND Gate ,Physical Verification ,Creating the Configuration View,Generating |

| | |
|---|---|
| | Stream Data. |
| 3 | SRAM DESIGN: Schematic Entry and Symbol Creation Building the SRAM Test Design, Simulation with Spectre, Creating Layout View of SRAM, Physical Verification. |
| 4 | COMMON SOURCE AMPLIFIER: Schematic Entry and Symbol Creation Building the COMMON SOURCE AMPILFIER Test Design, Analog Simulation with Spectre. |
| 5 | DIFFERENTIAL AMPLIFIER DESIGN: Schematic Entry and Symbol Creation Building the DIFFERENTIAL AMPLIFIER DESIGN Test Design, Analog Simulation with Spectre. |
| 6 | BASIC OP AMP DESIGN: Schematic Entry and Symbol Creation Building the OP AMP Test Design, Analog Simulation with Spectre. |
| 7 | ADC Design: Schematic Entry and Symbol Creation Building the ADC Test Design , Simulation with Spectre. |

***Course Name: COMPUTER AIDED DESIGN OF VLSI CIRCUITS***
***Course Code: EE639***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Develop knowledge about CAD tools used for digital VLSI design, digital logic simulation and physical design, including test and verification, develop understanding of FPGA CAD flow for design and implementation. |
| **CO-2** | Model digital systems at different levels of abstraction and simulate using verilog HDL, |
| **CO-3** | Develop understanding of automatic test program generation, testing algorithms, simulate and test circuits. |
| **CO-4** | Applying their knowledge and skills to model and synthesize logic circuits, do formal verification, transfer a design from a version possible to simulate to a version possible to synthesize |

**UNIT-I** Various CAD Tools for front end and Back end design, Schematic editors, Layout editors, Place and Route tools.Introduction to VLSI Methodologies - VLSI Physical Design Automation - Design and Fabrication of VLSI Devices - Fabrication process.

**UNIT-II:**Introduction to Design Tools: Introduction & Familiarity with Design Tools from various vendors e.g. Synopsis, CADENCE, Mentor Tools etc. Verilog Basics - Modeling Levels - Data Types - Modules and Ports - Instances - Basic Language Concepts - Dataflow modeling - Behavioral modeling Modeling and Simulation of systems/subsystems using Verilog HDL. Typical case studies.

**UNIT III:** Layout Algorithms Circuit partitioning, placement, and routing algorithms; Design rule verification; Circuit Compaction; Circuit extraction and post-layout simulation

**UNIT IV:** CAD Tools for Automatic Test Program Generation; Combinational testing D-Algorithm and PODEM algorithm; Scan-based testing of sequential circuits; Testability measures for circuits.

**UNIT V**: MODELLING AND SYNTHESIS: Linting Tools, Logic Synthesis, CAD Tools for Logic Synthesis, Gate level simulation, Formal verification. CAD Tools for Physical Verification and LVS.

**TEXT BOOKS:**

1. N.A. Sherwani, "Algorithms for VLSI Physical Design Automation ", 1999.
2. S.H. Gerez, "Algorithms for VLSI Design Automation ", 1998.4. J. Bhasker, "A VHDL Primer", AddisonWeseley Longman Singapore Pte Ltd. 1992
3. Drechsler, R., *Evolutionary Algorithms for VLSI CAD*, Kluwer Academic Publishers, Boston, 1998.
4. Verilog HDL by Samir Palnitkar

**REFERENCE BOOKS:**

1. VERILOG HDL SYNTHESIS: A PRACTICAL PRIMER by J Bhaskar
2. Hill, D., D. Shugard, J. Fishburn and K. Keutzer, *Algorithms and Techniques for VLSI Layout Synthesis*, Kluwer Academic Publishers, Boston, 1989.

**LIST OF EXPERIMENTS:**

| **Sl. No** | **Experiment** |
|---|---|
| 1 | Modelling and simulation of the following using Verilog Language and VLSI CAD Tools<br>1. Inverter 2.NAND GATE 3.Full adder 4.4 bit adder 5.4 bit counter |
| 2 | Modeling and Simulation of ALU using Verilog.<br>Modeling and Simulation of FSMs using Verilog |
| 3 | Modeling and simulation of Memory and FIFO in Verilog |
| 4 | Simulation of NMOS and CMOS circuits using SPICE. |
| 5 | RTL to GDSII Generation<br>1. Inverter 2.NAND GATE 3.4 bit Counter |
| 6 | Modeling of MOSFET using C |
| 7 | ATPG Generation using CAD Tools. |

***Course Name: FPGA ARCHITECTURE AND APPLICATIONS***
***Course Code: EE640***

**Course Outcome:**

| | |
|---|---|
| **CO-1** | Understanding the architecture, programming and applications of various Programmable Logic Devices (PLDs). |
| **CO-2** | Fundamental knowledge on basic building blocks, routing architecture and design flow of Field Programmable Gate Arrays (FPGAs) and advanced FPGAs. |
| **CO-3** | Skills to design Finite State Machines (FSMs) based on state transition table and realization of various state machines. |
| **CO-4** | Gaining knowledge on usage of different FPGA tools for data path, front end and system level design using FPGAs. |
| **CO-5** | Skills on FPGA design considerations using sequential and combinational circuits and |

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|---|---|
| | debugging using Logic Analysers. |

**UNIT-I: PROGRAMMABLE LOGIC DEVICES**: ROM, PLA, PAL, CPLD, FPGA Features, Architectures and Programming. Applications and Implementation of MSI circuits using Programmable logic Devices.

**UNIT-II: FPGAs**: Field Programmable Gate Arrays- Logic blocks, routing architecture, design flow, technology mapping for FPGAs, Case studies Xilinx XC4000 & ALTERA's FLEX 8000/10000 FPGAs.Introduction to advanced FPGAs: Xilinx Virtex and ALTERA Stratix

**UNIT III: FINITE STATE MACHINES (FSM):** Top Down Design, State Transition Table, State assignments for FPGAs, Realization of state machine charts using PAL, Alternative realization for state machine charts using microprogramming, linked state machine, encoded state machine. FSM Architectures: Architectures Centered around non registered PLDs, Design of state machines centered around shift registers, One Hot state machine, Petrinets for state machines-Basic concepts and properties, Finite State Machine-Case study.

**UNIT IV:SYSTEM LEVEL DESIGN**: Controller, data path designing, Functional partition, Digital front end digital design tools for FPGAs. System level design using mentor graphics/Xilinx EDA tool (FPGA Advantage/Xilinx ISE), Design flow using FPGAs.

**UNIT V**: Case studies: Design considerations using FPGAs of parallel adder cell, parallel adder sequential circuits, counters, multiplexers, parallel controllers. Debugging using Embedded Logic Analyzers.

**TEXT BOOKS:**

1. Field Programmable Gate Array Technology - S. Trimberger, Edr, 1994, Kluwer Academic Publications.
2. Engineering Digital Design - RICHARD F.TINDER, 2nd Edition, Academic press.
3. Fundamentals of logic design-Charles H. Roth, 4th Edition Jaico Publishing House.

**REFERENCE BOOKS:**

1. Digital Design Using Field Programmable Gate Array, P.K. Chan & S. Mourad, 1994, Prentice Hall.
2. Field programmable gate array, S. Brown, R.J. Francis, J. Rose, Z.G. Vranesic, 2007, BS

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| 1 | 4 bit Counter: Design and porting of 4 bit counter on FPGA Platform(Xilinx/ALTERA) |
| 2 | Real Time Clock: Design and Implementation of Real Time Clock (RTC) on FPGA Platform. |
| 3 | ALU Design: Porting of an 8 bit ALU on FPGA Platform |
| 4 | FSM: Design and porting of Melay and More FSM (Sequence Detector) on FPGA |
| 5 | Clock Management Circuits: Implementation of Clock management circuits on FPGA. |

| | |
|---|---|
| 6 | IP Core Implementation: BRAMs, FFT IP, CORDIC etc. |
| 7 | Emulation: Typical RISC CPU Emulation on FPGA. |

***Course Name: VLSI SIGNAL PROCESSING***
***Course Code: EE641***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Realisation of Algorithm in Data flow graph and Retiming and its applications |
| **CO-2** | Parallel processing and pipelining concept of FIR Filter |
| **CO-3** | Pipelining in Adaptive digital Filters |
| **CO-4** | Digital Arithmetic and Design of fixed point and floating point Adder and Multiplier |

**UNIT-I** An overview of DSP concepts-Linear system theory- DFT, FFT- realization of digital filters-Typical DSP algorithms- DSP applications- Data flow graph representation of DSP algorithm.- Loop bound and iteration bound Retiming and its applications.

**UNIT-II:** Algorithms for fast convolution- Algorithmic strength reduction in filters and transforms- DCT and inverse DCT- Parallel FIR filters- Pipelining of FIR filters- Parallel processing- Pipelining and parallel processing for low power.

**UNIT III:** Pipeline interleaving in digital filters- Pipelining and parallel processing for IIR filters-Low power IIR filter design using pipelining and parallel processing- Pipelined adaptive digital filters.

**UNIT IV : Design of Communication Architectures For SoCs:** State variable description of digital filters- Round off noise computation using state variable description- Scaling using slow-down, retiming and pipelining.

**UNIT V:** Digital arithmetic, Fixed point and floating point. Fixed point implementation of FIR filter. IEEE 754 Floating point standards, Floating point arithmetic operations. Design of floating point adder and multiplier.

**TEXT BOOKS:**

1. K.K. Parhi, VLSI Digital Signal Processing Systems, John-Wiley, 1999.
2. Pirsch, P., Architectures for Digital Signal Processing, Wiley, 1999.

**REFERENCE BOOKS:**

1. Allen, J., Computer Architectures for Digital Signal Processing, Proceedings of the IEEE, Vol.73, No.5, May 1985
2. Bateman A., and Yates, W., *Digital Signal Processing Design*, Computer Science Press, New York
3. S.Y. Kung, H.J. White House, T. Kailath, *VLSI and Modern Signal Processing, Prentice Hall*, 1985

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| 1 | RTL Modeling and testing of Digital filters<br>1) FIR |

| | |
|---|---|
| | 2)IIR |
| 2 | RTL Modelling and testing of 8 point FFT algorithm.<br>1) Serial architecture implementation<br>2) Parallel architecture implementation |
| 3 | Pipelined FIR Filter design and implementation using HDL |
| 4 | Design and implementation of Fixed point IIR Filter |
| 5 | Floating point adder and multiplier design |

***Course Name: SOC DESIGN AND VERIFICATION***
***Course Code: EE642***

**Course Outcome-**

| | |
|---|---|
| **CO1** | Different approaches of chip design process and its requirements. Design issues, verification and test strategies. |
| **CO2** | Designing and Developing of macro and the issues regarding designing it |
| **CO3** | Technology, Methods, languages, approach and plan for SOC verification on different levels. |
| **CO4** | Designing of communication architecture, design analysis. Need of adaptability of communication architecture. Understanding of base models. |
| **CO5** | Study of verification of design by using tools VMM,OVM and UVM |

**UNIT-I: SYSTEM ON CHIP DESIGN PROCESS:** A canonical SoC Design, SoC Design flow waterfall vs spiral, topdown vs Bottom up. Specification requirement, Types of Specification , System Design process, System level design issues, Soft IP Vs Hard IP, Design for timing closure, Logic design issues Verification strategy, Onchip buses and interfaces, Low Power, Manufacturing test strategies.

**UNIT-II:MACRO DESIGN PROCESS:** Top level Macro Design, Macro Integration, Soft Macro productization,
Developing hard macros, Design issues for hard macros, Design ,System Integration with reusable macros.

**UNIT III: SOC VERIFICATION:** Verification technology options, Verification methodology, Verification languages, Verification approaches, and Verification plans. System level verification, Block level verification, Hardware/software co verification and Static net list verification.

**UNIT IV: DESIGN OF COMMUNICATION ARCHITECTURES FOR SOCS:** On chip communication architectures, System level analysis for designing communication, Design space exploration, Adaptive communication architectures, Communication architecture tuners, Communication architectures for energy/battery efficient systems. Introduction to bus functional models and bus functional model based verification.

**UNIT V**: Verification architecture, Verification components, Introduction to VMM, OVM and UVM.

**TEXT BOOKS:**

1. "SoC Verification Methodology and Techniques", Prakash Rashinkar Peter Paterson and Leena Singh. Kluwer Academic Publishers, 2001.
2. "Reuse Methodology manual for System On A Chip Designs", Michael Keating, Pierre Bricaud, Kluwer Academic Publishers, second edition, 2001.

**REFERENCE BOOKS:**

1. "Design Verification: Simulation and Formal Method based Approaches", William K. Lam, Prentice Hall.
2. "System- on -a- Chip Design and Test", Rochit Raj suman, ISBN.
3. "Multiprocessor Systemsonchips", A.A. Jerraya, W.Wolf, M K Publishers.
4. "The EDA Hand Book", Dirk Jansen, Kluwer Academic Publishers.

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| 1 | 1. Verilog Simulation and RTL Verification<br>a) Memory<br>b) Clock Divider and Address Counter<br>c) n-Bit Binary Counter and RTL Verification |
| 2 | Basic Verification environment for FIFO/UART |
| 3 | Verification Planning for FIFO/UART<br>a) Development of the test cases as per the verification plan<br>b) Generation and Analysis of Code coverage Reports |
| 4 | Writing assertions for FIFO |
| 5 | Typical Soc Design and Emulation on FPGA Platform |

**Course Name -*Digital Interface Design***
**Course Code- *EE 643***

**Course Outcome :**

| | |
|---|---|
| **CO-1** | Students will be able to understand the fundamentals of Digital Interface Design including hardware units of basic Robotics. They will also learn about the Zed Board Embedded Systems on a Chip (SoC). |
| **CO-2** | Students will have Hands on experience/Knowledge on Sensor and Actuator Interface. They will also have the knowledge on various Sophisticated interfacing knowledge on Devices/Ports used in Robotics. |
| **CO-3** | Students will grow expertise on Data Convectors Interfacing. They will also be able to understand various specifications regarding robotics. |
| **CO-4** | Students will have working knowledge on Wireless and GPS interfacing. They will also be theoretically experienced on various Interfacing problems through case study. |

**Unit I: Introduction:** Definition and Classification, Overview of Robots and hardware units in Robotics, Introduction to Zed Board Embedded Systems on a Chip (SoC) and the use of FPGA in Robotics Application. State Machines and applications.

**Unit II: Sensor and actuator interfacing:** Sophisticated interfacing features in Devices/Ports, Timer and Counting Devices, 'I2C', 'USB', 'CAN'. PWM in HW for robot control.LCD interfacing with FPGA.

**Unit III: Data convectors interfacing:** Introduction to ADC and DAC. Various Types and **s**pecification. SPI interfacing in FPGA.

**Unit IV: Wireless and gps interfacing:** Introduction to Bluetooth- Zig Bee Interface. Introduction to Gyro and accelerometer – Gyro accelerometer interface using Complementary Filter - Case study: Underwater Glider motion controller. NI Compact RIO embedded control hardware for rapid prototyping.

**Text/References:**

1. Steve Kilts, *Advanced FPGA Design: Architecture, Implementation, and Optimization*, , IEEE press Wiley 2007
2. Yale Patt and Sanjay Patel, *Introduction to Computing Systems: From Bits and Gates to C and Beyond*, 2nd edition, Publication Date: August 5, 2003 | ISBN-10: 0072467509 | ISBN-13: 978-0072467505.
3. **Hamblen**, James O., **Hall,** Tyson S., **Furman,** Michael D, *Rapid Prototyping of Digital Systems*: Springer 2008.

**LIST OF EXPERIMENTS:**

| Sl. No | Experiment |
|---|---|
| 1 | 1. FPGA Interfacing Experiments<br>a) LCD<br>b) ADC |
| 2 | Motor Control and interface using PSoC |
| 3 | Case Study- underwater Glider and line follower Robot. |

**Course Name –*MIMO COMMUNICATIONS***
**Course Code- *EE644***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding of Modern multi-user communication technologies. |
| **CO-2** | Understanding of MIMO technology, coding, and diversity techniques. |
| **CO-3** | knowledge of channel estimation in massive MIMO and analysis with imperfect CSI. |
| **CO-4** | Basic Knowledge of new modulation schemes for 5G. |
| **CO-5** | Introduction to Cognitive radio technology, OFDM for CR, etc. |

**Unit-1: Introduction:** Modern multi-user communication technologies, Principles of Wireless Communication, Fading Channels, Bit-Error Rate (BER) Analysis, Multiple Antenna Systems, Diversity concept, Cross layer procedures: Link Adaptation, HARQ, Packet Scheduling and Radio Resource allocation for Best Effort and Real Time Traffic.

**Unit-2: MIMO:** Multiple-Input Multiple-Output (MIMO) Technology, MIMO signaling: Space Time coding, Diversity Multiplexing trade off, Multi-user MIMO and Network MIMO: Large MIMO; Small cells, relays and het-net (6); Green radio design considerations. MIMO Receivers, Multi-user MIMO, Beamforming, Precoding, Orthogonal Space Time Block Codes (OSTBC), Cooperative Communication, Optimal Combining, BER Analysis and Diversity of Cooperative Communication, Optimal Power Allocation with Cooperation.

**Unit-3-Massive MIMO:** Introduction to Massive MIMO, Analysis with Perfect CSI, Channel Estimation in Massive MIMO, Analysis with Imperfect CSI, Multi-cell Massive MIMO and Pilot contamination

**UNIT-4: Schemes for 5G:**New Modulation Schemes for 5G: Spatial Modulation (SM), Space shift keying, Generalized Spatial Modulation, Cooperative MIMO communication, Multi-Node Coopertaion, AF and DF Protocols for Cooperation.

**UNIT-5: Cognitive Radio:** Introduction to Cognitive Radio Technology, OFDM for CR, Spectrum Sensing in Fading Wireless Channels, MIMO systems, OFDM systems, Cooperative Spectrum Sensing, Eigenvalue based Spectrum Sensing, Multi-User Transmission in Interweave CR Systems, MIMO for Underlay CR Systems, Game Theory for Cognitive Radio, Spectrum Auctions.

**Books:**

1. Principles of Mobile Communications by G. Stuber, Springer, 2nd ed..
2. Wireless Communications by A. Goldsmith, Cambridge
3. Introduction to Space Time Wireless Communications by A. Paulraj, Nabar and Gore
4. LTE, UMTS and The Long Term Evolution by Sesia, Toufik and Baker 5. OFDM for Wireless Communications by R. Prasad
6. UMTS for LTE by Holma and Toshala
7. Adaptive PHY-MAC Design for Broadband Wireless Systems by R. Prasad, S. S. Das and Rahman
8. Single and Multi Carrier MIMO Transmission for Broadband Wireless Systems by R. Prasad, Rahman and S. S. Das.
9. Recent technical publications.

**Course Name –*ADVANCED DIGITAL SIGNAL PROCESSING***
**Course Code- *EE 645***

**Course Outcome-**

| Course Outcomes | Description |
|---|---|
| **CO1** | Learn the basics of Adaptive filters, MMSE, LMS, LS, and RLS. |
| **CO2** | Gain the theory of linear prediction, ARMA, and Kalman filter. |
| **CO3** | Acquire the basics of parametric and non-parametric methods. |
| **CO4** | Learn the idea of time frequency analysis. |

**UNIT-I: ADAPTIVE FILTERS-** Non-stationary signal analysis, adaptive direct-form FIR filters, adaptive lattice-ladder filters, Minimum Mean Square Error (MMSE), Least Mean Square (LMS), Least

Square (LS), RLS, QR decomposition, Levinson Durban method, Singular value decomposition, Givens rotation, Householder transform, Wiener filter. Optimization: gradient search algorithms and random search algorithms, gradient search by Newton's method and steepest descent method.

**UNIT II: LINEAR PREDICTION-** Forward and backward linear prediction, solution of the normal equations, properties of the linear prediction, prediction error, AR lattice and ARMA lattice, Wiener and Kalman filter for prediction. System modelling and identification.

**UNIT-III: SPECTRAL ESTIMATION- Non-Parametric methods:** estimation of spectrum from finite duration observation of signals, non-parametric methods: Bartlett, Welch and Blackman-Tukey methods, comparison of all methods. **Parametric methods:** autocorrelation and its properties, relation between auto correlation and model parameters, parametric methods: AR Models: Yule-Walker and Burg methods, MA and ARMA models for spectrum estimation. Minimum variance spectral estimation, Eigen analysis for spectrum estimation.

**UNIT-IV: MULTI RATE SIGNAL PROCESSING-** Introduction, decimation by a factor D, interpolation by a factor I, sampling rate conversion by a rational factor I/D, multistage implementation of sampling rate conversion, filter design and implementation for sampling rate conversion.

**UNIT-V: TIME-FREQUENCY ANALYSIS-** Short time Fourier transform, Wigner Ville distribution, Wavelet transform: continuous wavelet transforms different wavelets and multiresolution analysis.

**UNIT-VI: IMAGE PROCESSING**

**REFERENCE BOOKS:**

1. Modern Spectral Estimation: Theory & Application – S. M .Kay, 1988, PHI.
2. Multi Rate Systems and Filter Banks – P. P. Vaidyanathan – Pearson Education.
3. Digital Signal Processing Handbook – Vijay K. Madisetti and Douglas B. Williams
4. DSP – A Practical Approach – Emmanuel C. Ifeacher, Barrie. W. Jervis, 2nd Ed., Pearson Education.
5. Digital Signal Processing: A Practitioner's Approach, Kaluri V. Rangarao, Ranjan K. Mallik ISBN: 978-0-470-01769-2, 210 pages, November 2006.
6. Digital Signal Processing – S. Salivahanan, A. Vallavaraj, C. Gnanapriya, 2000, TMH.


***Course Name: RF PHOTONICS***
***Course Code: EE647***
**Course Outcome-**

| | |
|---|---|
| **CO-1** | Understanding the fundamentals of microwave-photonics and brief idea of opto-electronic components (sources, modulators, receivers etc.) |
| **CO-2** | Learn about the photonic integrated circuits, tunable RF filters design, photonics based pulsed and FMCW RF exciter and multiband radar. |
| **CO-3** | Knowledge of microwave photonics signal processing like: filters, ADC, delay, sampling, photonic measurements, ultra wideband free space beamforming etc. |
| **CO-4** | Understanding the concept of photonics-based broadband microwave measurements, signal parameter measurement-electric field, Phase Noise, Spectrum Analysis, Instantaneous Frequency and time-frequency analysis. |

| | |
|---|---|
| **CO-5** | Knowledge of full photonics radar, SAR/ISAR imaging, LIDAR systems, Fiber/FSO-connected Distributed Radar System. |

**1. Introduction to RF and Photonic Systems:** Introduction to microwave photonics, basic optical and RF components: sources, modulators, receivers, passive devices, RF mixers, wireless receivers; applications of microwave photonics, fibre/wireless links: basic configuration, signal generation, transport strategies, design and analysis, advantages and limitations, high-speed optical wireless links, multiple coherent photonic RF system operations, Optically controlled phased array antennas.

**2. RF signal generation and detection:** Optoelectronic oscillators (generation, frequency combs); microwave photonic integrated circuits (different platforms of integration, filter designs, microresonators, nonlinear effects), photonic based tuneable RF filter, multiple RoF and multiple RoFSO, CW, Pulsed and FMCW signal generation and detection photonic system assembly, stretch processing, Dual and multiband operations, photonics detectors for RF regeneration, PHODIR architecture.

**3. Photonics signal processing:** Microwave photonics signal processing: filters, photonics analog-digital-converters, true-time delay beamforming, electro-optic sampling, sampling signal generation, direct digitalization, optical vector mixing, RF down conversion, Photonic-assisted microwave channelization (SDM,WDM, TDM), far-field/near-field AoA measurement, Ultra-Wideband free space beamforming, SLM, optical PLL operation, wideband Programmable Microwave Photonic Signal Processing, Reconfigurable photonics,

**4. Microwave M/ms using photonics:** Microwave measurements, Electronics solutions and challenges, Introduction to photonics-based broadband microwave measurements, signal parameter measurement-electric field, Phase Noise, Spectrum Analysis, Instantaneous Frequency, IF based microwave/optical power monitoring, Multiple-Frequency Measurement Based on Frequency to-Time Mapping, Doppler Frequency Shift Estimation, measurements of other signal parameters (Time–frequency analysis, Compressive sensing for a spectrally sparse signal), Software-defined solutions for photonic microwave measurements.

**5. Contemporary applications of microwave photonics:** Fully Photonic based radar, single photonic multiband software defined radar, SAR/ISAR imaging, quantum radar, THz generation, sensing/imaging and beamforming, LIDAR systems, Fiber/FSO- connected Distributed Radar System, Distributed MIMO chaotic radar based on WDM technology, Microwave Passive Direction Finding, STAR, Integrated Photonic Beamforming Architecture for Phased-Array Antennas, Future multifunctional photonics radar concepts, microwave photonics architecture for modern ultra wide bandwidth wired/wireless communications.

***Course Name: VLSI FABRICATION TECHNOLOGY***
***Course Code: EE648***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | To understand the various materials in the Crystal Level. |
| **CO-2** | To understand the Ion Implantation, Diffusion and various fabrication process of IC |
| **CO-3** | To understand the Thin film deposition and characterization techniques |
| **CO-4** | To understand the various process integration |

**UNIT –I: OVERVIEW AND MATERIALS**
**Introduction** to microelectronic fabrication.
**Semiconductor substrate:** Phase diagram and solid solubility, Crystal structure, Crystal defects, Crystal growth.

**UNIT –II: HOT PROCESSING AND ION IMPLANTATION**
**Diffusion:** Atomistic models of diffusion, Analytic solutions of Fick‘s law, Diffusioncoefficients, Two-step diffusion, Diffusion system.
**Thermal Oxidation:** The Deal-Grove model, the initial oxidation, Oxidecharacterization, Oxidation induced stacking faults, Oxidation systems.
**Ion implantation:** Ion implantation system, Vertical projected range, Channeling effect, Implantation damage, Problems, and concerns.

**UNIT –III: PATTERN TRANSFER**
**Optical lithography:** Overview, Source systems, Contact/proximity printers. Projection printers, Alignment.
**Photoresist:** Contrast curves, Applying and developing photoresist.
**Etching:** Wet etching, Plasma etching, Ion milling, Reactive ion etching, Liftoff.
**Electron Beam Lithography**: Overview, Types of electron beam lithography, Patterning Strategies, Electron beam lithography process.

**UNIT –IV: THIN FILM DEPOSITION AND CHARACTERIZATION TECHNIQUES**
**Physical Vapor Deposition:** Evaporation Systems, Sputtering systems.
**Chemical Vapor Deposition:** CVD system, Advanced CVD systems.
**Epitaxial growth:** Wafer cleaning and native oxide removal, thermal dynamics, Surface reactions, Dopants, Defects in epitaxial growth, MOCVD, MBE, and CBE.
**Characterization Techniques:** XRD, FESEM, TEM, AFM, Raman Spectroscopy, Spectroscopic Ellipsometry, UV-Vis Measurement, Hall Measurement, CV and IV measurement.

**UNIT –V: PROCESS INTEGRATION**
**Contacts and metallization:** Junction and oxide isolation, Si on insulator, Schottky and Ohmic contacts, Multilevel metallization.
**CMOS technologies:** Device behavior, Basic 3 µm technologies, Device scaling.
**Circuit Manufacturing:** Yield, Particle control, Design of experiments, Computer integrated manufacturing.

**Reference Books**
1: Stephen A. Campbell, The Science and Engineering of Microelectronic Fabrication, 2nd edition (Oxford University Press,2001).

**List of Experiments:**
1. Hands-on experience of deposition systems: sputtering system, chemical deposition system. Additionally, wafer processing for device fabrication.
2. Hands-on experience to structural measurement systems: XRD, Raman measurement.

3. Operation of Morphology Measurement Techniques: FESEM, TEM, and AFM.
4. Electrical characterization of the Semiconductor Devices: Hall Measurement, IV and CV.
5. Optical Characterization Techniques: UV-Vis Measurement, Spectroscopic Ellipsometry Measurement.

***Course Name: Semiconductor devices for high speed and high power applications.***
***Course Code: EE650***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the performance parameters of high speed devices and circuits, materials required for high speed devices |
| **CO-2** | Understanding the fundamentals of physical phenomenons in MIS, MOS devices for high speed applications |
| **CO-3** | Knowledge of HEMTS, HBTs |
| **CO-4** | Knowledge of latest technology in high speed and high power III-nitride HEMTs and its application various domains |

**UNIT-I: REVIEW: PERFORMANCE PARAMETERS OF HIGH SPEED DEVICES AND CIRCUITS**
Introduction, basic concepts, transit time of charge carriers, junction capacitances, on-resistances and their dependence on the device geometry and size, carrier mobility, doping concentration and temperature; contact resistance and interconnection/interlayer capacitances, SOI, ECL.

**UNIT-II: MATERIALS REQUIREMENT FOR HIGH SPEED DEVICES AND CIRCUITS**
III –V binary and ternary compound semiconductors (GaAs, InP, InGaAs, AlGaAs etc.), silicon-germanium alloys and silicon carbide for high speed devices, as compared to silicon based devices; crystal structure, dopants and electrical properties such as carrier mobility, velocity versus electric field characteristics of these materials; material and device process technique for III-V and IV – IV semiconductors.

**UNIT-III: PHYSICAL PHENOMENON GOVERNING METAL SEMICONDUCTOR CONTACTS AND METAL INSULATOR SEMICONDUCTOR AND MOS DEVICEs**
Metal semiconductor contacts, interface state density, Schottky barrier diode; thermionic Emission model for current transport and current-voltage (I-V) characteristics; effect of interface states and interfacial thin electric layer on the Schottky barrier height and the I-V characteristics.

**UNIT-IV: MESFETs, HEMTs, HBTs**
Pinch off voltage and threshold voltage of MESFETs; D.C. characteristics; velocity overshoot effects; sub threshold characteristics, short channel effects, hetero-junction devices; MODFET- principle of operation and the unique features of HEMT, InGaAs/InP HEMT; HBT principle of operation, its benefits, GaAs and InP based HBT, the surface passivation for stable high gain high frequency performance, strained layer devices.

**UNIT-V: III-nitride HEMTs**

GaN comparison with other materials, physics of group III-Nitrides, GaN HEMTs, GaN based devices issues and solutions.

**Reference Books:**


1. H. Beneking, High Speed Semiconductor Devices : Circuit aspects and fundamental behavior, Chapman and Hall, London, 1994.
2. C. Y. Chang & F. Kat, GaAs High Speed Devices: Physics, Technology and Circuit Applications, Wiley, NY 1994.
3. S. M. Sze, High Speed Semiconductor Devices, Willey, 1990.
4. Michael Shur, GaAs Devices and Circuits, Plenum Press, NY, 1987.
5. N. G. Einsprush and R. Weisseman, VLSI Electronics: GaAs Microelectronics, Academic Press, NY, 1985.
6. S. K. Ghandhi, VLSI Fabrication Principles, Wiley, NY, 1994.


**List of Experiments:**

1. DC characteristics of HEMTs
2. DC Characteristics of HBTs
3. Power amplifier design using HEMTs
4. Device physics of GaN HEMTs
5. LDMOS characteristics

***Course Name: Quantum Transport in nanoscale FETs.***

***Course Code: EE651***

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the wave particle duality nature of electrons, enegy quantuzation, Hamiltonian etc. |
| **CO-2** | Understanding the Schrodinger equation, graphene structure self-consistent field (SCF) procedure for device simuations with quantum effects |
| **CO-3** | Knowledge of NEGF with scattering parameters for realistic nanotransistor simulations |
| **CO-4** | Knowledge of non-ideal effects present in nanoscale FETs, different types of scattering effects etc. |

**UNIT-I: PRELIMINARY CONCEPTS OF ATOMISTIC VIEW**

Introduction, Energy level diagram, electrons flow, quantum of conductance formula, ballistic conductance, diffusive conductance, coulomb blockade, angular averaging, Drude formula, Ohm’s law.

**UNIT-II: ENERGY BAND**

E(p) or E(k) relation, density of states, number of modes, electron density (n), quantum wells, wires, dots, nanotubes, conductivity vs. electron density (n), quantum capacitance, the nano transistor boundary condition, Quasi-Fermi Levels (QFL's), Landauer formulas, electrostatic potential, Boltzmann Equation, Spin Voltages.

**UNIT-III: SCHRODINGER EQUATION SELF-CONSISTENT SOLUTION**

Hydrogen atom, method of finite differences, wave equation, differential to matrix equation, dispersion relation, counting states, Beyond 1 – D, Basis functions, Graphene, Reciprocal Lattice / Valleys, self-consistent field (SCF) procedure.

**UNIT-IV: NON-EQUILIBRIUM GREEN'S FUNCTION (NEGF) FORMALISM**
Semiclassical model, quantum model, equations, current operator, scattering mechanisms, transmission, resonant tunneling, dephasing, local density of states [LDOS].

**UNIT-V: COHERENT AND NON-COHERENT TRANSPORT IN 2D FETs**
Density matrix, Inflow/outflow, quantum point contact, self-energy, surface Green's function, graphene, Fermi - Golden Rule, inelastic scattering.

**Reference Books:**


1. Supriyo Duttai, Quantum Transport Atom to Transistor, 5th edition, Cambridge University Press, 2005.
2. Mark S. Lundstrom, Jing Guo, Nanoscale transistors Device physics, modelling and simulation, Springer, 2006.
3. Supriyo Dutta, Electronic Transport in Mesoscopic Systems, Cambridge University Press, 1995.
4. Roger T Howe, Charles G Sodini, Microelectronics An integrated approach, Pearson education.
5. Behzad Razavi, Fundamentals of Microelectronics, John Wiley India Pvt. Ltd, 2008.
6. Sundaram Natarajan, Microelectronics – Analysis and Design, Tata McGrawHill, 2007.


**List of Experiments:**

1. Matlab coding and TCAD Simulations of NEGF Formalism
2. Modeling of GNR FETs
3. Quantum simulations of Tunnel FETs
4. Device physics, Subbands, Band diagrams study
5. Heterojunction lattice study

***Course Name: Research Methodology and IPR***
***Course Code: PGC601***
**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understanding the fundamentals of research and its methodology |
| **CO-2** | Choose the appropriate research design and develop appropriate research hypothesis for a research project |
| **CO-3** | Knowledge of manuscript preparation, patents and Intellectual property |
| **CO-4** | Technology transfer and application of IPR in various domains |

| | |
|---|---|
| **Unit I:** | Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations |
| **Unit II:** | Effective literature studies approaches, analysis Plagiarism, Research ethics, |
| **Unit III:** | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and |

| | |
|---|---|
| | assessment by a review committee |
| **Unit IV:** | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. |
| **Unit V:** | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.<br>Patent information and databases. Geographical Indications |
| **Unit VI:** | New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |

**References Textbooks:**


1. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for
2. science & engineering students’”
3. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
4. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for
5. beginners”
6. Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd,2007.
7. Mayall, “Industrial Design”, McGraw Hill, 1992.
8. Niebel, “Product Design”, McGraw Hill, 1974.
9. Asimov, “Introduction to Design”, Prentice Hall, 1962.
10. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “ Intellectual Property in New Technological Age”, 2016.
11. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008

# DEPARTMENT OF APPLIED CHEMISTRY

## ABOUT THE DEPARTMENT:

The Department of Applied Chemistry started in 1976 with the aim to impart education and training to DRDO work force in the area of high energy materials and propellants. Over the years Department has moved on to cater to the need of DRDO and civilian students in order to bring the DRDO achievements closer to our society. The Department's aim is to contribute to our understanding of the chemical world through excellence in observational, theoretical and experimental science and to extend quantitative and other appropriate methodologies to address problems in the fields of applied chemical science. In Applied Chemistry, we are endowed with faculties who are dedicated teachers and distinguished researchers that carry out cutting-edge research in all modern areas of Applied Chemistry, as well as in inter-disciplinary areas like nanoscience and technology, high energy materials, polymer science and technology etc.

The first PhD of DIAT (DU) was from the Department of Applied Chemistry and currently it is amongst the Departments guiding very high number of PhD scholars and research publications in DIAT. In addition to PhD, there are numbers of M. Tech. students carrying their PG education. We provide a vibrant and creative learning environment for our students and researchers. We also participate extensively in R&D for various DRDO labs and industries.

In recent times, the Department has made significant contributions towards revenue generation through grant-in-projects and customized courses.

**Description about the programmes**:

To impart in-depth and intensive training in theory, testing and practice of chemical science especially in Nanoscience Technology, Chemical Science & Technology & High Energy Materials (HEM), Polymers and Composites to the young scientists of DRDO, other agencies of Ministry of Defence and fresh engineers / postgraduates.

The programme covers various disciplines like chemical science & engineering, High Energy materials, polymers and composites, chemistry of nano materials and their applications. The course is suitable for DRDO scientists, service officers and civilians.

**Objective**

- To provide students with a strong technical education for meeting the modern requirements of chemical technological challenges
- To provide an ability to function on multidisciplinary teams
- Thorough grounding and/or awareness and proficiency towards process safety as it pertains to process and unit design.

**Eligibility**

**BE / B.Tech** in any discipline of Engineering, **M.Sc**. in any discipline of Science.

**Qualification**: 55% marks or 5.5 CGPA in the qualifying examination as indicated against the disciplines concerned and valid GATE Score Certificate. The qualification should have been obtained from a recognized (by UGC) University / Deemed University / Institution in India. The candidates who are in the final semester of their degree are eligible to apply; Mark sheet up to the last semester should be enclosed. Provisional certificate in such cases along with Mark sheet of the final semester are required to be submitted before commencement of program.

# M. Tech. in Nano Science and Technology

## Semester I

| Sl. No. | Course Code | Course | Contact Hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | NT-601 | Introduction to Nano Science and Technology | 3 | 1 | 4 |
| 2 | NT-602 | Synthesis of Nanomaterials | 3 | 1 | 4 |
| 3 | NT-603 | Nano materials for Energy and Environmental Objectives | 3 | 1 | 4 |
| 4 | NT-604 | Nanotechnology in Devices | 3 | 1 | 4 |
| 5 | NT 605 | Characterization of Nano Materials | 3 | 1 | 4 |
| 6 | MM-606 | Introduction to Computational Materials Engineering | 3 | 1 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 2 |
| | | **Total** | **20** | **6** | **26** |

## Semester II

| Sl. No. | Course Code | Course | Contact hours/week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | NT-606 | Nanotechnology for Defence Applications | 3 | 1 | 4 |
| 2 | AP-609 | Advanced Sensors | 3 | 1 | 4 |
| 3 | | Elective – I [From Dept. of Applied Chemistry/ Physics/Metallurgy and Materials Engg.] | 3 | 1 | 4 |
| 4 | | Elective – II [From Dept. of Applied Chemistry/ Physics/Metallurgy and Materials Engg.] | 3 | 1 | 4 |
| 5 | | Elective – III | 4 | 0 | 4 |
| 6 | | Elective – IV | 4 | 0 | 4 |
| 7 | PGC-602 | Audit 1 and 2 | 2 | 0 | 0 |
| | | **Total** | **22** | **4** | **24** |

- 04 weeks of industrial practice school during summer vacation for scholarship students (optional)

## Semester III

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | NT-651 | M.Tech. Dissertation Phase I | 28 | | 14 |
| | | **Total** | **28** | | **14** |

**Semester IV**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | NT-652 | M.Tech. Dissertation Phase II | 28 | | 14 |
| | | **Total** | **28** | | **14** |

**List of Electives/ Self Study**

| Sl. No. | Course Code | Course Name |
|---|---|---|
| 1 | MM 610 | Nanomaterials and their applications |
| 2 | MM 612 | Polymer Blends and Nanocomposites |
| 3 | AC 608 | Safety Health and Hazard Management |
| 4 | AC 609 | NBC Warfare (Concepts & Remediation) |
| 5 | AC 614 | Rocket and Gun Propellants |
| 6 | ME 636 | MEMS - Design, Fabrication, and Characterization |
| 7 | NT-607 | Nanobiotechnology |
| 8 | AP-640 | Nanophotonics |
| 9 | Electives from other Department, MOOC/NPTEL courses | |

## Introduction to Nano Science and Technology (NT-601):

- **UNIT I:** Introduction to Nanotechnology, Scientific Revolutions, Nanotechnology and Nanomachines, Chemical bonding & theories (e.g. Valence band & Molecular Orbital), atomic structure- energy – molecular and atomic size and their properties. Forces between atoms and molecules, particles and grain boundaries, surfaces – strong intermolecular forces, Van der Waals and electrostatic forces between surfaces, covalent and coulomb interactions
- **UNIT II:** Solid State Physics (Overview): Amorphous, crystalline, crystalline, polycrystals, symmetry, Unit Cells, Crystal Structures (Bravais Lattices), Crystallographic Planes, Miller Indices, Brillouin, zones, Electronic Properties, Classification of materials: Metal, Semiconductor, Insulator, Band, structure.
- **UNIT III:** Implications of nano size on physical and chemical properties: Density of States, 2D, 1D, 0D, Quantum size effect, large surface to volume ratio, surface functionalization, tenability of properties, : Physical Chemistry of solid surfaces, crystal structures, surface energy, chemical potential, Confinement and transport in nanostructure.
- **UNIT IV:** Nanoscale Phenomenon: Nanoparticles, nano-clusters, nanotubes, nanowires and nanodots. Electronic structure: quantum dots, quantum wires and quantum wells, confinement of electrons energy quantization semiconductor nanocrystals, carbon nanotubes, quantum wells, metal nanostructures, nanofluids.
- **Text Books:**
  Pradeep, T., Nano: The Essentials, McGraw Hill Publishers, Mumbai, 2007.

- **References:**


1. Charles P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology, John Wiley & Sons 2003.
2. Vladimir V. Mitin, Viatcheslav A. Kochelap, Viacheslav Aleksandrovich Kochelap Introduction to Nanoelectronics: Science, Nanotechnology, Cambridge University – 2008
3. Pignataro, B., Tomorrow's Chemistry Today–Concepts in Nano science, Organic Materials, andEnvironmental Chemistry, Wiley-VCH, Royal chemical society, 2008
4. Howard, H., Into The Nano Era: Moore's Law Beyond Planar Silicon CMOS (Vol. 106), Springer Series in Materials Science, Springer-Verlag Berlin, 2004 .


## Synthesis of Nanomaterials (NT-602):

- **UNIT I:** Fundamentals of nucleation and growth: Physical Chemistry of solid surfaces, Crystallization, Interactions between particles.
- **UNIT II:** Top down and bottom up approach of synthesis: Physical and Chemical routes, Physical Route for synthesis of Nanomaterials: Mechanical (high energy ball milling, melt mixing), physical evaporation methods (Plasma method, Pulse Laser method, spray pyrolysis), sputter deposition, Chemical Vapour Deposition, Arc Deposition, Atomic Layer Deposition
- **UNIT III:** Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and coprecipitation; Sol-gel synthesis; Microemulsions or reverse micelles; Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis; Sonochemical synthesis; Photochemical synthesis; Synthesis in supercritical fluids, Langmuir-Blodgett (LB) Method, Biological route of synthesis: using microorganisms, plant extracts, templates, etc.
- **UNIT IV:** Self Assembly Route: Mechanism of Self Assembly , Some Examples of Self Assembly, Self Assembly of Nanoparticles using Organic Molecules, Assembly in Biological Systems, Self Assembly in Inorganic Materials, etc.

- **References:**


1. Suvardhan Kanchi, Shakeel Ahmed, Green Metal Nanoparticles, John Wiley & Sons 2018.
2. George Kyzas, Athanasios C. Mitropoulos, Novel Nanomaterials, Intechopen Limited- 2018.
3. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties &Applications , Imperial College Press, 2004.
4. J.George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005.
5. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001.
6. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.
7. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate(Eds.), Handbook of NanoScience, Engg. and Technology, CRC Press, 2002.


## Nano-materials for Energy and Environmental Objectives (NT 603):

**UNIT I :- INTRODUCTION**

Sustainable energy -Materials for energy -Green house effect -CO2emission -Energy demand and challenges.

**UNIT II:-RENEWABLE ENERGY TECHNOLOGY**

Development and implementation of renewable energy technologies. Nano, micro and meso scale phenomena and devices. Energy conversion, transport and storage. High efficiency Photovoltaic solar cells. High performance thermoelectric systems -Integration and performance of DSSC-Quantum dots based solar cells.

**UNIT III:- NANOMATERIALS IN FUEL CELL AND STORAGE TECHNOLOGY**

Micro-fuel cell technologies, integration and performance for micro-fuel cell systems -thin film and microfabrication methods -design methodologies -micro-fuel cell power sources -Supercapacitors -Specific energy-charging/discharging -EIS analysis.

**UNIT IV:- HYDROGEN STORAGE AND PHOTOCATALYSIS**

Hydrogen storage methods -metal hydrides -size effects -hydrogen storage capacity -hydrogen reaction kinetics -carbon-free cycle-gravimetric and volumetric storage capacities -hydriding/dehydriding kinetics -multiple catalytic effects -degradation of the dye -nanomaterials based photocatalyst design -kinetics of degradation.

**UNIT.V:- EMERGINGTECHNOLOGIES FOR ENVIRONMENTAL REMEDIATION**

Use of nanoparticles for environmental remediation and water treatment-Role of dendrimer-single enzyme-nanoparticle and metalloprotein. Case studies and Regulatory needs.

- **REFERENCES:**


1. Shantanu Bhattacharya, Avinash Kumar Agarwal, T. Rajagopalan, Nano-Energetic Materials, Springer Nature Singapore Pte Ltd. 2019.
2. Xiaoru Wang, Xi Chen, Novel Nanomaterials for Biomedical, Environmental and Energy ... · 2018.
3. Handbook of fuel cells: Fuel cell technology and applications by Vielstich. Wiley, CRC Press, 2003.
4. Hydrogen from Renewable Energy Sources by D. Infield 2004.
5. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.


## Nanotechnology in Devices (NT 604):

**UNIT I:** Basics of Electronic Devices: Maxwell-Boltzmann and Fermi-Dirac distribution, doping, carrier transport mechanisms, - drift, diffusion, thermionic emission, and tunneling; excess carriers, carrier lifetime, recombination mechanisms – SHR, Auger, radiative, and surface. p-n junctions – fabrication, basic operation – forward and reverse bias, DC model, charge control model, IV characteristic, Working principle of BJT anf FET, effect of device size reduction,

**UNIT II:** Nanotechnology in electronic devices: Electron transport phenomenon at nanoscale dimensions, Single electron transistor, Organic electronic Devices, Recent devices, including FinFET, Tunnel FET, and emerging materials, including graphene, and its applications, spintronics

**UNIT III:** Quantum well structures in devices: Lasers, detectors, LEDs etc.

**UNIT IV:** Plasmonics: Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation of surface plasmons, surface Plasmon properties, SPR spectroscopy, Applications of Plasmonics.

**REFERENCES:**


1. Donglu Shi, Nanomaterials and Devices, Elsevier, 2014
2. B.W.Mott, “Micro-Indentation Hardness Testing”, Butterworths, London
3. M. H.Loretto, “Electron Beam Analysis of Materials”, Chapman and Hall, 1984.

**Characterization of Nanomaterials (NT-605):**

**UNIT I:- DIFFRACTION TECHNIQUES**
Concepts of diffraction, scattering and radiation-matter interactions, X-ray diffraction: powder diffraction, phase identification, Scherrer formula, strain and grain size determination

**UNIT II: MICROSCOPY AND IMAGING**
Fundamentals of Imaging: magnification, resolution, depth of field and depth of focus, aberration and astigmatism, Optical microscopy, stereology basics and quantitative analysis,Basic principle and components of SEM: imaging modes, image contrast, illustrative applications,Basic principle and components of TEM: Contrast mechanisms, bright field, dark field, TEM application in crystal defect analysis, Electron diffraction in TEM and its applications

**UNIT III:- SPECTROSCOPIC TECHNIQUES**
X ray Photon Spectroscopy, FTIR , Raman spectroscopy

**UNIT IV: THERMAL ANALYSIS TECHNIQUES**
DSC, DTA, and TGA

**UNIT V: ADVANCED TECHNIQUES**
Dyanamic Light Scattering, nanoindentation, VSM

- **Text/ Reference Books:**


1. Suvardhan Kanchi, Shakeel Ahmed, Green Metal Nanoparticles, John Wiley & Sons 2018.
2. Challa S.S.R. Kumar, Nanotechnology Characterization Tools for Tissue Engineering, Springer Nature – 2019.
3. Sverre Myhra, John C. Rivière , Characterization of Nanostructures, CRC Press – 2012.
4. Elements of X-ray Diffraction, B. D. Cullity, Prentice Hall, 2001
5. Materials Characterization, ASM Handbook Vol 10.
6. Characterization of Materials, Vol 1, Elton N. Kaufmann
7. Solid State Chemistry and its Applications, Anthony R. West, Wiley.


**Nanotechnology for Defence Applications (NT 606):**

**Unit I:** Introduction to nano-energetic materials; Applications of nano materials in ammunition, energetic materials; Nano-thermites

**Unit II:** Nanotechnology in stealth and armor protective system

**Unit III:** Nanomaterials in thermoelectric and piezoelectric sensing

**Unit IV:** Chemical and biological warfare: Nanomaterials in detection and decontamination of CW and BW agents

**Unit V:** Role of Nanotechnology in next generation Warfare: Precision guided munitions, miniaturized vehicles

**References:**


1. Nanotechnology for Defence Applications, Narendra Kumar, Ambesh Dixit, Springer, 2019.
2. Nanotechnology for Chemical and Biological Defense, Margaret Kosal · 2009, Springer
3. Nanotechnology in the Defense Industry: Advances, Innovations and Practical Applications, Madhuri Sharon, Angelica S. L. Rodriguez, Chetna Sharon, Wiley, 2019.

## Nanobiotechnology (NT 607)

**UNIT I:** Introduction, History & Applications 1) Various definitions and Concept of Nano-biotechnology & Historical background. 2) Fundamental sciences and broad areas of Nanobiotechnology. 3) Various applications of Nano-biotechnology 4) Cell – Nanostructure interactions

**UNIT II:** Biological nanoparticles production, surface functionalization- and their Applications plants and microorganism Proteins, DNA based nanostructure

**UNIT III:** Devices based on nanobiotechnology – and their applications, lab on a chip.

**UNIT IV:** Applications of Nanotechnology in Drug: Discovery and Delivery, bioinformatics

**References:**


- Nanobiotechnology: A Multidisciplinary Field of Science, Basma A. Omran, 2020, Springer
- Nanobiotechnology: Concepts, Applications and Perspectives, Christof M. Niemeyer, Chad A. Mirkin · 2006, Wiley-VCH
- Microbial Nanobiotechnology: Principles and Applications, Agbaje Lateef, Evariste Bosco Gueguim-Kana, Nandita Dasgupta · 2021, Springer.


## Nanophotonics (AP 640):

**1.** Electromagnetism in Mixed Dielectric Media

The Macroscopic Maxwell Equations, Electromagnetism as an Eigenvalue Problem, General Properties of the Harmonic Modes, Electromagnetic Energy and the Variational Principle, Magnetic vs. Electric Fields, Scaling Properties of the Maxwell Equations, Discrete vs. Continuous Frequency Ranges

**2**. Symmetries and Solid-State Electromagnetism

Using Symmetries to Classify Electromagnetic Modes, Continuous Translational Symmetry, Discrete Translational Symmetry, Photonic Band Structures, Rotational Symmetry and the Irreducible Brillouin Zone, Mirror Symmetry and the Separation of Modes, Time-Reversal Invariance

**3**. The Multilayer Film: The Multilayer Film, The Physical Origin of Photonic Band Gaps, The Size of the Band Gap, Evanescent Modes in Photonic Band Gaps , Off-Axis Propagation, Localized Modes at Defects, Surface States, Omnidirectional Multilayer Mirrors

**4.** Metamaterial: Definition, Negative-refractive Index materials, Metamaterials as perfect lens and cloaking objects. Geometries of metamaterials.

**5.** Plasmonics: Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation of surface plasmons, surface Plasmon properties, SPR spectroscopy, Applications of Plasmonics.

- **REFERENCES**


**1.** Motoichi Ohtsu · 2011 Progress in Nanophotonics, Springer Heidelberg Dordrecht, London New York – 2011.

2. Hilmi Volkan Demir, Sergey V. Gaponenko Applied Nanophotonics, Cambridge University – 2019.

**3.** Paras N. Prasad · 2004 Nanophotonics, John Wiley & Sons – 2004.

4. Lucas Novotny and Bert Hecht, "Principles of Nano-Optics" ,Cambridge University Press, 2012.

5. Masuhara. H. Kawata. S and Tokunga. F ―NanoBiophotoics", Elsevier Science, 2007.

6. Saleh. B. E. A and Teich. A. C "Fundamentals of Photonics", John Wiley and Sons, NewYork,1993.

7. Prasad. P. N―Introduction to Biophotonics", John Wiley and Sons, 2003.

Ohtsu. M. Kobayashi. K. Kawazoe. T and Yatsui. T. ―Principals of Nanophotonics (Optics and Optoelectronics)" University of Tokyo, Japan, 2003

**Nanomaterial and Their Applications (MM 610):**

**Unit 1:** Overview of Nanostructures and Nanomaterials; Synthesis of Nanomaterials: Types and strategies for synthesis of nanomaterials;

**Unit 2:** Crystalline nanomaterials and defects therein; Hybrid nanomaterials; Multiscale hierarchical structures built out of nanosized building blocks (nano to macro); Nanomaterials in Nature: Nacre, Gecko, Teeth, Nanostructures: Carbon Nanotubes, Fullerenes, Nanowires, Quantum Dots.

**Unit 3:** Cellsresponse to Nanostructures; Surfaces and interfaces in nanostructures, Ceramic interfaces, Super hydrophobic surfaces, Grain boundaries in Nanocrystalline materials, Defects associated with interfaces.

**Unit 4:**Thermodynamics of Nanomaterials; Overview of properties of nanostructures and nanomaterials; Overview of characterization of nanostructures and nanomaterials; Deformation behavior of nanomaterials: Fracture and creep;Nanomechanics and nano-tribology; Electrical, Magnetic and Optical properties;

**Unit 5:** Applications of Nanotechnology in various fields: Defence, Aerospace and Marine Nanotechnology, Renewable energy, solar energy, fuel cells, Reinforcement in Ceramics, Drug delivery, Electronics etc.

- **REFERENCES**

**1** Olena Fesenko, Leonid Yatsenko Nanocomposites, Nanostructures, and Their Applications, Springer Nature Switzerland AG 2019.

2 Zishan Husain Khan, Nanomaterials and Their Applications, Springer Nature Springer Nature Singapore Pte Ltd. 2018.

# DEPARTMENT OF METALLURGICAL & MATERIALS ENGINEERING

## M.Tech. in Materials Engineering

### SEMESTER I

| S.No. | Course Code | Course Name | Contact Hours | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | MM-601 | Concepts in Metal and Ceramic | 3 | 0 | 2 | 4 |
| 2 | MM-602 | Materials Characterization | 3 | 0 | 2 | 4 |
| 3 | MM-603 | Thermodynamics of Materials | 3 | 1 | 0 | 4 |
| 4 | MM-604 | Polymers and Composites Technology | 3 | 0 | 2 | 4 |
| 5 | MM-605 | Physical and Mechanical Metallurgy | 3 | 0 | 2 | 4 |
| 6 | MM-606 | Mathematics for Computational Materials Engineering | 3 | 0 | 2 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 0 | 2 |
| | | **Total** | **20** | **1** | **10** | **26** |

### SEMESTER II

| S.No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | MM 608 | Fatigue, Fracture and Failure Analysis | 3 | 1 | 0 | 4 |
| 2 | MM 609 | Materials Processing | 3 | 0 | 2 | 4 |
| 3 | | Elective I (from Departmental Electives) | 3 | 1 | 0 | 4 |
| 4 | | Elective II (from Departmental Electives) | 3 | 1 | 0 | 4 |
| 5 | | Elective – III (from Open Electives) | 3 | 1 | 0 | 4 |
| 6 | | Elective – IV (from Open Electives) | 3 | 1 | 0 | 4 |
| 7 | PGC-602 | Audit Course | 2 | 0 | 0 | 0 |
| | | **Total** | **20** | **5** | **2** | **24** |

**SEMESTER III**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | MM-651 | M.Tech. Dissertation Phase I | 28 | | 14 |
| | | Total | 28 | | 14 |

**SEMESTER IV**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | MM-652 | M.Tech. Dissertation Phase II | 28 | | 14 |
| | | Total | 28 | | 14 |

**List of Electives:**

| Sr. No. | Course Code | Electives from the Department |
|---|---|---|
| 1. | MM 607 | Design of Materials |
| 2. | MM 610 | Nanomaterial and Their Applications |
| 3. | MM 611 | Non-Destructive Evaluations |
| 4. | MM 612 | Polymer blends and Nanocomposites |
| 5. | MM 613 | Biomaterials |
| 6. | MM 614 | Introduction to Computational Materials Engineering |
| 7. | MM 615 | Magnetism and Magnetic Materials |
| 8. | MM 616 | Design of Materials |
| 9. | MM 617 | Materials for High -Temperature Applications |
| 10. | MM 618 | Advanced Steel Technology |
| 11. | MM 619 | Military Materials |
| 12. | MM 620 | Introduction to Corrosion |
| 13. | MM 621 | Welding Science and Technology |
| 14. | MM 622 | High temperature Corrosion |
| 15. | MM 623 | Corrosion mitigation |
| 16. | MM 624 | Advanced Coating |
| 17. | MM625 | Surface Science and Engineering |
| 18. | MM 626 | Reliability Engineering |
| 19. | MM 627 | Electrical and Electronic Materials |

**Program Outcomes (POs)**

- **PO1:** An ability to independently carry out research /investigation and development work to solve practical problems
- **PO2:** An ability to write and present a substantial technical report/document
- **PO3:** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

**Program Specific Outcomes (PSOs)**

**On completion of M.Tech (Materials Engineering) programme graduates will be able to**

1. **PSO1:** To analyse and tackle the complex and diverse engineering problems by appropriate experimentation and interpretation, and, provide probable solutions by applying principles of Materials engineering in combination to the fundamental knowledge of basic sciences.

2. **PSO2:** To be able to design and device new procedures to arrive at a solution for identifying or troubleshooting problems at fundamental/system/component level.

3. **PSO3:** An ability to work together collaboratively in multidisciplinary teams to tackle multifaceted problems and pursue a bright career in Materials engineering and allied areas by demonstrating professional success at different platforms within industry, governmental bodies such as Defence Research and Development Organization & Tri -services (Army, Navy & Air force), Coast Guard, DGQA, DQA, and Defence Public Sector units.

- **Course Structure:**

**Course Name: Concepts in Metal and Ceramic**

**Course Code: MM 601**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Understanding classifications and characteristics of materials |
| CO-2: | Analysis and properties of crystalline materials |
| CO-3: | Detailed overview of ceramics and their characteristics |
| CO-4: | Cognizance of dielectrics, refractories and their applications |
| CO-5: | Demonstration of Solid state, Sol-Gel, Hydrothermal and Co-precipitation process |

| | **Syllabus Details** |
|---|---|
| Unit I | Introduction, classification of materials; atomic structure, bonding in solids, bonding forces and energies; crystal structure, unit cells, crystal systems, crystallographic points, directions, and planes |
| Unit II | crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids:<br>metallic crystal structure |
| Unit III | ceramic materials, Basic properties, classification of ceramic materials–conventional and advanced, ceramic crystal structure, Defects in ceramics: types of defects, origin of point defects, defects and electron energy levels, defect equilibria in ceramic crystals, Phase equilibria |

| | |
|---|---|
| | in ceramics |
| Unit IV | Dielectrics: Dielectric strength, Loss factor. Equivalent circuit description of linear dielectrics, Power factor, Dielectric polarisation, Polarisation mechanisms, Applications. Refractories: Classification of Refractories, Applications. Glass: Definition of glass, Basic concepts of glass structure, Different types of glasses. Application of glasses. |
| Unit V | Practical: Solid state, Sol-Gel, Hydrothermal and Co-precipitation process |

**Textbooks**

1. *Materials Science and Engineering by William D. Callister, John Wiley & Sons, Inc.*
2. *Elements of Materials Science and Engineering by Lawrence H. van Vlack.*

**Reference Book(s):**

1. *Elements of Ceramics: F.H Norton*
2. *Fundamentals of Ceramics: Barsoum*
3. *Introduction to Ceramics: W.D. Kingery*
4. *Physical Ceramics for Engineers: VanVlack*
5. *Handbook of Ceramics: Editor S. Kumar Ceramic*
6. *Materials for Electronics: R.C. Buchanon*

**Course Name: Materials Characterization**
**Course Code: MM 602**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Illustrate the diffraction techniques and its interpretation. |
| CO-2: | Described several microscopy instruments and their imaging fundamentals |
| CO-3: | Summarized spectroscopy techniques and their applications |
| CO-4: | Understanding of thermal analysis techniques |
| CO-5: | Hands on experience of microscopy techniques and corrosion methods. |

| | **Syllabus Details** |
|---|---|
| Unit I | Diffraction Techniques- Concepts of diffraction, scattering and radiation-matter interactions, X-ray diffraction: phase identification, strain and grain size determination |
| Unit II | Microscopy and Imaging- Fundamentals of Imaging: magnification, resolution, depth of field and depth of focus, aberration and astigmatism, SEM: imaging modes, image contrast, illustrative applications, Basic principle and components of TEM: Contrast mechanisms, bright field, dark field, TEM application in crystal defect analysis, Electro diffraction in TEM, STM and AFM |
| Unit III | Spectroscopic Techniques- Fundamental basis of Spectroscopic analysis EDS and WDS applications, X-ray Photoelectron Spectroscopy and Auger electron spectroscopy |
| Unit IV | Thermal Analysis Techniques- DSC, DTA, TGA and Dilatometry, Electrochemical polarization characterization, Electrochemical Impedance spectroscopy. |
| Unit V | Practical: XRD, TEM, SEM, Cyclic voltammetry, Tafel plot, and Salt Spray, weatherometer, cyclic corrosion test, cathodic protection monitoring, localised corrosion monitoring methods (SECM, SEVT) |

**Textbooks**

1. *Elements of X-ray Diffraction, B. D. Cullity, Prentice Hall, 2001*
2. *Solid State Chemistry and its Applications, Anthony R. West, Wiley.*

**Reference Book(s):**

1. *Materials Characterization, ASM Handbook Vol 10.*
2. *Characterization of Materials, Vol 1, Elton N. Kaufmann*

**<u>Course Name: Thermodynamics of Materials</u>**
**<u>Course Code: MM 603</u>**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Understand the basic principles of thermodynamic concepts |
| CO-2: | Learn the thermodynamic relations among variables and their transformations |
| CO-3: | Demonstrate basics of statistical thermodynamics |
| CO-4: | Analysing free energy equation and curves and its interpretation for single component system |
| CO-5: | Detailed understanding of binary system, phases formation and chemical potential |

| | **Syllabus Details** |
|---|---|
| Unit I | Simple and composite systems, phases, Internal energy, Enthalpy, Entropy, Gibbs Free energy, Specific heat, Laws of thermodynamics, Reversible and Irreversible processes, adiabatic work interaction. |
| Unit II | Generation of Auxiliary Functions: Legendre transforms, Coefficient relations, Maxwell's relations, Thermodynamic relations among state functions variables and its application to solids |
| Unit III | Statistical definition of temperature and entropy, Micro- and Macro-states, Maxwell-Boltzmann distribution, Thermodynamic equilibrium: stable equilibrium states, criteria for equilibrium |
| Unit IV | Free energy of single component system: Free energy as a function of temperature, Clausius-Clapeyron Equation, Driving force for solidification; Equilibrium vacancy concentration and Analysis of Magnetic transitions |

**Textbooks**

1. *David R. Gaskell, Introduction to the Thermodynamics of Materials, Taylor & Francis, 1798*
2. *Ahindra Ghosh, Textbook of Materials and Metallurgical thermodynamics. Prentice Hall of INDIA 2003*

**Reference Book(s):**

1. *R.T. DeHoff, Thermodynamics in Materials Science, McGraw-Hill, Singapore, 1993*
2. *D. A. Porter and K. E. Easterling, Phase transformations in Metals and Alloys, Chapman and Hall, London, 1996*
3. *Taiji Nishizawa, Thermodynamics of microstructures, ASM International*

**<u>Course Name: Polymer and Composite Technology</u>**
**<u>Course Code: MM 604</u>**

| Course Outcomes (CO): | |
|---|---|
| CO-1: | Understanding classifications and characteristics of polymers |
| CO-2: | Analysis of the polymer properties |
| CO-3: | Conception of composite and nanofiller |
| CO-4: | Cognizance of Manufacturing of composites |
| CO-5: | Case studies of polymers and composites for Defence Applications |

| | Syllabus Details |
|---|---|
| Unit I | Polymers: Classification of Polymers, Co-Polymers, Thermoset and Thermoplastics, Crystalline and Amorphous Polymers, Polymerization, Degree of Polymerization, Glass transition temperature, Molecular weight of polymer and its determination by various techniques. |
| Unit II | Physical methods of polymer analysis such as IR, DSC, TGA, XRD etc., Viscoelasticity, Polymer blends and alloys: thermodynamics, morphology and properties |
| Unit III | Composites: Conventional polymer composites, Fiber reinforced composites, Nanofillers and their composites; Recycling of macro and micro polymer composites |
| Unit IV | Composite manufacturing techniques: Solution-cast, Melt-mixing, Extrusion, Compression molding, Resin transfer, Resin infusion, Vacuum casting and electrospinning. |
| Unit V | Defence Applications: Coatings (Superhydrophobic, Self-Healing), Fire retardant, Corrosion Resistant, EMI Shielding, Environmental responsive polymers (Self-healing, Phase change and Shape Memory), Polymer composites in aerospace applications. Service life prediction methodologies of polymers and composites |

**Textbooks**

1. *V.R. Gowariker, Polymer Science, Wiley Eastern, 1995*
2. *F. N. Billmeyer, Textbook of Polymer Science, Wiley Interscience, 1971.*

**Reference Book(s):**

1. *Kumar and S. K. Gupta, Fundamentals and Polymer Science and Engineering, Tata McGraw-Hill, 1978*
2. *Epel, J.N.:Engineering Plastics, Engineering Materials Handbook, ASM International 1988.*
3. *Brydson, A.J. : Plastics Materials, Princeton, N.J., 1966*

**Course Name: Physical and Mechanical Metallurgy**
**Course Code: MM 605**

| Course Outcomes (CO): | |
|---|---|
| CO-1: | Identify the defects in metals and phases in Fe-FeC diagram with TTT and CCT diagrams |
| CO-2: | Analysis of defects transfer in crystal structure |
| CO-3: | Conception of several strengthening mechanisms |
| CO-4: | Cognizance of strength testing in materials and dependent phenomenon |
| CO-5: | Case studies of metallurgy testing techniques |

| | **Syllabus Details** |
|---|---|
| Unit I | Crystal defects/imperfection in Metals, dislocations, burger vectors, dislocations multiplications, dislocation interactions, stacking faults, Phase rule, Phase diagram, Eutectic, Fe-FeC diagram, TTT and CCT diagrams for carbon steel |
| Unit II | Plastic deformation in single crystal, critical resolved shear strength, deformation |
| Unit III | Strengthening mechanisms: Solid solution strengthening, strengthening from grain boundaries, strains hardening, strain ageing, annealing of cold worked materials, strengthening from particles, precipitation hardening |
| Unit IV | Hardness and tensile testing, stress-strain relationships, effect of strain, strain rate and temperature on flow stress, nanoindentation, High temperature deformation and Creep, Superplasticity |
| Unit V | Practical: Metal Polishing and Etching, Optical Microstructural Characterization, Wear and friction, hardness testing |

**Textbooks**

1. *Mechanical Metallurgy, G.E. Dieter, McGraw-Hill book company, 1988*

**Reference Book(s):**

1. *Mechanical behaviour of Materials, Williams F Hosford, Cambridge University press, 2005*
2. *Materials Science and Engineering by William D. Callister, John Wiley& Sons, Inc.*
3. *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*
4. *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.*

**Course Name: Mathematics for Computational Materials Engineering**
**Course Code: MM 606**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Understand the basics of Linear Algebra |
| CO-2: | Recognize the principles of advanced calculus |
| CO-3: | Introduce vector calculus |
| CO-4: | Utilise numerical methods to solve differential equations |

| | **Syllabus Details** |
|---|---|
| Unit I | Algebra of real matrices: Determinant, inverse and rank of a matrix; System of linear equations (conditions for unique solution, no solution and infinite number of solutions); Eigenvalues and eigenvectors of matrices; Properties of eigenvalues and eigenvectors of symmetric matrices, diagonalization of matrices; Cayley-Hamilton Theorem. |
| Unit II | Limit, Continuity and differentiability; Maxima and minima; Partial derivatives; Total derivative. |
| Unit III | Gradient, divergence and curl; Line integrals, and Green's theorem. |
| Unit | Concepts of discretization in space/time, implicit, explicit; Taylor's series; Solution |

| | |
|---|---|
| IV | to ODEs; Classification of second order linear partial differential equations; Method of separation of variables: One dimensional heat equation and two-dimensional Laplace equation. |

**Textbooks**

1. *Advanced engineering mathematics: Kreyszig; Wiley.*
2. *Advanced engineering mathematics: Jain/Iyenger; Narosa*

**Reference Book(s):**

1. *Advanced engineering mathematics: Peter V. O'Neil Cengage Learning*
2. *Advanced engineering mathematics: Alan Jeffery; Academic Press.*

**Course Name: Design of Materials**
**Course Code: MM 607**

| Course Outcomes (CO): | |
|---|---|
| CO-1: | Principles of solid-state diffusion, their equation along with solution. |
| CO-2: | Applications of several mechanical alloys and their phase diagrams |
| CO-3: | Cognizance of phase transformations processes |
| CO-4: | Understanding ceramics and statistics of brittle fracture |
| CO-5: | Demonstration of Solid state, Sol-Gel, Hydrothermal and Co-precipitation process |

| | Syllabus Details |
|---|---|
| Unit I | Diffusion: First and Second law of diffusion, Solution to diffusion equations and error function, Types of diffusion, Kirkendall effect and applications |
| Unit II | Metals and Metal Structures: Generic classes of Metallic alloys and applications, Equilibrium shapes of grains and phases;<br>Case studies in phase diagrams: Soft solders, Zone Refinement of Semiconductors, Bubble free Ice |
| Unit III | Diffusive and Displacive Transformations: Kinetics of nucleation, diffusive and Martensitic phase transformations;<br>Case Studies in Phase Transformations: Fine grain castings, Rapid solidification and amorphous materials;<br>Light alloys: Age-hardening and thermal stability |
| Unit IV | Mechanical properties of Ceramics, Statistics of Brittle fracture: Flaw size and dispersion of strength, Weibull distribution, Design of pressure windows |
| Unit V | Composites: Fibrous, particulate and foamed composites, Improving stiffness, strength and toughness.<br>Case studies in Defence applications: Turbine blades, bullet-proof vests, uses of metal matrix composites and carbon-carbon composites. |

**Textbooks**

1. *Engineering Materials 1 Michael F. Ashby and David R. H. Jones; Butterworth- Heinemann, Elsevier Publications*

2. *Engineering Materials 2 Michael F. Ashby and David R. H. Jones; Butterworth- Heinemann, Elsevier Publications*

**Reference Book(s):**

1. *D. A. Porter and K. E. Easterling, Phase transformations in Metals and Alloys, Chapman and Hall, London, 1996*
2. *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*

**Course Name: Fatigue, Fracture and Failure Analysis**
**Course Code: MM 608**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Detailed introduction to fatigue failure of materials |
| CO-2: | Analyze the effect of fatigue crack propagation and improving fatigue life |
| CO-3: | Conception of fracture mechanics |
| CO-4: | Conceptualize stresses induced during brittle fracture |
| CO-5: | Understanding fracture toughness in metals and alloys |

| | **Syllabus Details** |
|---|---|
| Unit I | Stress cycles, Interpretation of Fatigue Data. Endurance Limit, Effect of Mean Stress on Fatigue, Cyclic Stress-Strain Curve, Low Cycle Fatigue, Plastic Strain & Fatigue Life, |
| Unit II | Effect of Structural Features, Fatigue Crack Propagation, Stress Concentration & Fatigue, Size & Surface Effect, Effect of Metallurgical Variables & Enhancement of Fatigue Life, |
| Unit III | Classification of Fracture, Theoretical Strength of Metals, Griffith Theory of Brittle Fracture, Metallographic features of Fracture, Fractography |
| Unit IV | Dislocation Theory of Brittle Fracture, Effect of Tri-axial Stress, Strain Energy Release Rate, Stress Intensity Factor, |
| Unit V | Fracture Toughness & Design, KIC, CTOD, J-Integral, R-Curve, Toughness of Metals & Alloys. Stress corrosion cracking. |

**Textbooks**

1. *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.*

**Reference Book(s):**

1. *Deformation and fracture mechanics of engineering materials, 4th Ed., R. W. Hertzberg, John Wiley & Sons, 1995.*
2. *Elementary engineering fracture mechanics By David Broek Noordhoff 1974.*
3. *Fatigue and Fracture of Metals, W. M. Murray, John Wiley, 1952.*

**Course Name: Materials Processing**
**Course Code: MM 609**

| Course Outcomes (CO): | |
|---|---|
| CO-1: | Understand the processing of polymers |
| CO-2: | Analyse the processing of ceramics |
| CO-3: | Comprehend the processing of metals |
| CO-4: | Identify the metal forming processes |
| CO-5: | Demonstration of various processing units |

| | **Syllabus Details** |
|---|---|
| Unit I | **Processing of Polymers**- Extrusion, compounding, fiber spinning, injection moulding, compression moulding, Additive manufacturing |
| Unit II | **Processing of ceramics**- Compaction, moulding, sintering, refractory manufacturing processes, glass manufacturing techniques. |
| Unit III | **Processing of Metals**- Casting, Hot working, Cold working, Rolling, Annealing, Forging, Extrusion, |
| Unit IV | Wire drawing, Sheet metal forming, Joining Techniques, Friction stir welding, Powder Metallurgy |
| Unit V | Practical: Metal processing- rolling, annealing; polymer processing-Extrusion and compression molding, electrospinning |

**Textbooks**


1. *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.*
2. *Manufacturing Processes and Materials for Engineers, L. E. Doyle, 1975. Powder*


**Reference Book(s):**


1. *Metallurgy, Applications, Advantages and Limitations, Klar, Erhard, ASM, 1983, Ohio.*
2. *Plastics Processing Data Handbook (2nd Edition), Rosato, Dominick, 1997.*
3. *Plastic Injection Molding: Manufacturing by Douglas M. Bryce, 2007.*
4. *Concise encyclopedia of plastics, Rosato, Marlene G, 2005*
5. *Extrusion: the definitive processing guide and handbook, Giles, Harold F.; Wagner, John R.; Mount, Eldridge M, 2005.*


**Course Name: Nanomaterial and Their Applications**
**Course Code: MM 610**

| Course Outcomes (CO): | |
|---|---|
| CO-1: | Learn the strategies for synthesis of nanomaterials |
| CO-2: | Classification of nanomaterials and analysis of the defects in crystalline nanomaterials |
| CO-3: | Analyze the structure property variation when reduced to nanoscale. |
| CO-4: | Understanding thermodynamics of nanomaterials |
| CO-5: | Case studies of nanomaterials in Defence applications |

| | **Syllabus Details** |
|---|---|

| | |
|---|---|
| Unit I | Overview of Nanostructures and Nanomaterials; Synthesis of Nanomaterials: Types and strategies for synthesis of nanomaterials; |
| Unit II | Crystalline nanomaterials and defects therein; Hybrid nanomaterials; Multiscale hierarchical structures built out of nanosized building blocks (nano to macro); Nanomaterials in Nature: Nacre, Gecko, Teeth; Nanostructures: Carbon Nanotubes, Fullerenes, Nanowires, Quantum Dots. |
| Unit III | Cells response to Nanostructures; Surfaces and interfaces in nanostructures, Ceramic interfaces, Superhydrophobic surfaces, Grain boundaries in Nanocrystalline materials, Defects associated with interfaces; |
| Unit IV | Thermodynamics of Nanomaterials; Overview of properties of nanostructures and nanomaterials; Overview of characterization of nanostructures and nanomaterials; Deformation behaviour of nanomaterials: Fracture and creep; Nanomechanics and nanotribology; Electrical, Magnetic and Optical properties; |
| Unit V | Applications of Nanotechnology in various fields: Defence, Aerospace and Marine Nanotechnology, Renewable energy, solar energy, fuel cells, Reinforcement in Ceramics, Drug delivery, Electronics etc. |

**Textbooks**

1. *T. Pradeep, NANO: The Essentials, Tata McGraw-Hill Publisher, 2007. ISBN-13:978- 0-07-061788-9.*

**Reference Book(s):**

1. *K. Haghi, G. E. Zaikov, Advanced Nanotube and Nanofiber Materials, Nova Science Publishers Inc, 2012*
2. *Vladimir V. Mitin, Viatcheslav A. Kochelap, Michael A. Stroscio, Introduction to Nanoelectronics: Science, Nanotechnology, Engineering, and Applications, Cambridge University Press, 2008*

**Course Name: Non-Destructive Evaluations**
**Course Code: MM 611**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Detailed introduction to handy NDT (Non-destructive techniques) |
| CO-2: | Cognizance of Eddy current and ultrasonic testing |
| CO-3: | Conception of acoustic emission and radiography techniques |
| CO-4: | Understanding automated NDT techniques |
| CO-5: | Case studies on NDT techniques application |

| | **Syllabus Details** |
|---|---|
| Unit I | Visual Inspection, Liquid Penetrant Testing, Magnetic Particle Testing, |
| Unit II | Eddy Current Testing, Ultrasonic Testing, |
| Unit III | Acoustic Emission Technique, Radiography Technique |
| Unit IV | Residual Stress Analysis, In-situ Metallography, Automation and Robot in NDT |
| Unit V | Case study: Grain Size, Weldment and other Structural Components. |

**Textbooks**

1. *Non-destructive Testing of welds, Baldev Raj, C.V. Subramanian and T. Jayakumar, Narosa Publishing House, 2000, Delhi.*

**Reference Book(s):**

2. *International Advances in non-destructive testing, (Ed.) W. J. Mcgonnagle, Gordon and Breach Science Publishers, 1981, NY.*
3. *Non-destructive Testing, Views, Reviews, Previews, (Ed.) L.L. Alston, Oxford University Press, 1970*
4. *Nondestructive Evaluation and quality control, ASM handbook, Volume 17, ASM International*

**Course Name: Polymer Blends and Nanocomposites**
**Course Code: MM 612**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Detailed introduction to polymer blends and nanocomposites with miscible and phase separated thermodynamic aspects |
| CO-2: | Classified polymer blends and composites |
| CO-3: | Conception of nanostructured materials and interface of reinforced materials |
| CO-4: | Demonstrated several processing methods for polymer blends |
| CO-5: | Case studies of polymer nanocomposites in defence applications |

| | **Syllabus Details** |
|---|---|
| Unit I | Introduction to polymer blends and composites, nanostructured materials and nanocomposites Thermodynamical aspects of polymer miscibility, mixing, factors governing miscibility, immiscible polymers and phase separation. Importance of interface on the property development, compatibilizers and compatibilization. |
| Unit II | Blends of amorphous & semi-crystalline polymers, inter-penetrating networks, thermoplastic and thermoset blends, rubber toughened polymers, particulate and fiber reinforced composites. |
| Unit III | Nanostructured materials like nanoclay, carbon nanotubes, graphene, magnetic nanoparticles etc. and polymer nanocomposites. Surface treatment of the reinforcing materials and interface/interphase structures of composites/nanocomposites. |
| Unit IV | Various processing techniques like solution mixing, melt processing. Physical and thermo-mechanical properties of polymer blends, composites and nanocomposites. |
| Unit V | Potential Applications in Defence. |

**Textbooks**

1. *Textbook of Polymer Science, Fred W. Billmeyer (Wiley)*
2. *Polymer alloys and blends by L A Utracki*

**Reference Book(s):**

1. *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

**Course Name: Biomaterials**
**Course Code: MM 613**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Detailed discussion of biomaterials along with applications |
| CO-2: | Elaborate the classification of biomaterials |
| CO-3: | Cognizance of nanobiomaterials |
| CO-4: | Project several utilizations of biomaterials |
| CO-5: | Case studies of biomaterials for medical applications |

| | **Syllabus Details** |
|---|---|
| Unit I | Introduction to biomaterials, Tissue Engineering, Biocompatibility, Biodegradation Biofluids and medical devices, Biostructures |
| Unit II | Ceramic based biomaterials, metallic biomaterials, polymer-based biomaterials, Biofluidic, medical devices, Biostructures |
| Unit III | Nano-biomaterials: Self-assembly of nanomaterials, hydrophilic, hydrophobic and surfaces, biomimicking |
| Unit IV | Medical imaging, electrospinning of scaffold structures, Additive manufacturing of medical devices, biofluidics and biostructure |
| Unit V | Case studies: Lotus leaf, Gecko feet, Nacre/Bone. Application of nanocomposite biomaterials: artificial biomaterials, antidrag coatings, self-cleaning surfaces, sensors, Riboswitches |

**Textbooks**

1. *Biomaterials- An Introduction, Joon Park- Publisher Springer*

**Reference Book(s):**

1. *Biomaterials- Principals and Applications- Joon Park- CRC Press*
2. *Handbook of Biomaterial Properties- Garth Hastings- Springer*
3. *Handbook of Biomaterials Properties- William Murphy- Springer*
4. *Handbook of Biomaterial Properties- Jonathan Black- Chapman and Hall*

**Course Name: Introduction to Computational Materials Engineering**
**Course Code: MM 614**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Understand the basics of programming |
| CO-2: | Implement the analytical and numerical solution to partial differential equations utilised in Materials Engineering |
| CO-3: | Analyze the mesoscopic modelling techniques |
| CO-4: | Understand the principles of data-driven modeling |

| | **Syllabus Details** |
|---|---|
| Unit I | Review the fundamentals and applications of programming in high level languages such as Python / MATLAB and low-level languages such as C / C++ |
| Unit II | Introduction to modeling and simulations: Analytical solution of first-order nonlinear differential equation followed by their numerical solution; Numerical solution of Fickian laws in 1D (using low-level language) and 3D (using advanced solvers); Random Walker model |
| Unit III | Sampling methods to obtain numerical solution and its application to solve ferromagnetism in statistical mechanics; Diffuse-interface mesoscale models: Cahn-Hilliard model |
| Unit IV | Data driven modeling: Supervised and Unsupervised models, Fitting and visualization of multidimensional data; Data analytics using principal component analysis |

**Textbooks**

1. *Introduction to Computational Materials Science – Richard LeSar, Cambridge University Press (2013). ISBN: 9781316614877*

**Reference Book(s):**

1. *Mathematical Methods for Physics and Engineering, 3rd Edition – R.F. Riley, M.P. Hobson, S.J. Bence, Cambridge University Press (2012). ISBN: 9780521139878*
2. *Integrated Computational Materials Engineering (ICME) for Metals – Mark F. Horstemeyer, TMS (2012). ISBN: 9781118022528*
3. *Integrative Computational Materials Engineering : Concepts and Applications of a Modular Simulation Platform – Georg J. Schmitz and Ulrich Prahl, Wiley-VCH Verlag GmbH & Co (2012). ISBN: 9783527330812*

**Course Name: Magnetism and Magnetic Materials**
**Course Code: MM 615**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Brief introduction to moment of magnetic materials |
| CO-2: | Analysis of traditional types of magnetism |
| CO-3: | Conception of effects of magnetism and application |
| CO-4: | Cognizance of material characteristics affecting on magnetism |
| CO-5: | Understand different types of magnetic materials |

| | **Syllabus Details** |
|---|---|
| Unit I | Moment of a current loop, Orbital angular momentum and magnetic moments, Spin magnetic moment, gyromagnetic ratio, Vector atom model |
| Unit II | Classical diamagnetism, Superconductors, Paramagnetic moments, classical paramagnetic. |
| Unit III | Weiss molecular field, Brillouin function and spontaneous magnetization, Curie Weiss law, Magnetocaloric effect, Exchange interaction, Spin waves, Antiferromagnetism and Néel temperature, Exchange Bias effect and applications, |

| | |
|---|---|
| | Ferrimagnetism: Spinel structure and Ferrite moments |
| Unit IV | Uniaxial and Cubic anisotropy, Shape anisotropy, Crystal field effects, Origin of magnetic domains, Equilibrium domain size and domain wall, Néel and Bloch Walls |
| Unit V | Differentiation between Soft and hard magnetic materials, Finemet alloys, Rare earth permanent magnets, Magnetostriction: TERFNOL-D, Multiferroics, Magnetic Anomaly Detection. |

**Textbooks**

1. *Introduction to Magnetic Materials, B. D. Cullity and C. D. Graham; IEEE Press, A. Jon Wiley & Sons Publications*

**Reference Book(s):**

1. *Fausto Florillo, Measurement and Characterization of Magnetic Materials, Elsevier Academic Press, 2004*
2. *Modern magnetic Materials: Principles and applications Robert C. O□Handaley; Wiley-Interscience Publications*
3. *Physics of magnetism and Magnetic materials*
4. *K. H. J. Bushaw and F. R. de Boer; Kluwer Academic Publishers*

**Course Name: Heat-treatment of Metals and Alloys**
**Course Code: MM 616**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Explore several heat treatment processes and TTT curve. |
| CO-2: | Analyse the case hardening heat treatment processes |
| CO-3: | Comprehend the advanced heat treatment methods |
| CO-4: | Identify different heat treatment process for specific metals |
| CO-5: | Demonstration of after effects of heat treatment |

| | **Syllabus Details** |
|---|---|
| Unit I | Steel Heat-Treatment, Annealing, Stress relief annealing, Process Annealing, Normalizing, Spheroidizing, Tempering, Quenching, Hardening, TTT Curve, Hardenability |
| Unit II | Case hardening, carburizing, Nitriding, Boronizing |
| Unit III | Flame hardening, Induction hardening, Laser hardening, Electron beam hardening |
| Unit IV | Heat treatment of Aluminum, Titanium and Magnesium Alloys |
| Unit V | Deformation and annealing. |

**Textbooks**

1. *Heat Treatment Principles & Techniques, TV Rajan, CP Sharma & Ashok Sharma Prentice Hall of India, New Delhi, 2007.*
2. *Metallurgy for Engineers-EC Rollason, 4th Ed, Edward Arnold, UK, 1973.*
3. *Introduction to Physical Metallurgy, S H Avner, TATA Mc-Graw Hill, New Delhi, 2001.*

**Reference Book(s):**

1. *Engineering Physical Metallurgy by Yuri Lakhtin, Moscow, MIR Publishers, 1963.*
2. *Grain boundary migration in metals: thermodynamics, kinetics, applications, G. Gottstein & L. Shvindlerman, Boca Raton (FL), CRC, 1999.*

**Course Name: Materials for High -Temperature Applications**
**Course Code: MM 617**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | An introduction to high temperature materials: Alloys and non-metals and their property requirements |
| CO-2: | Concept of creep and high temperature oxidation behaviour and their mitigation. |
| CO-3: | Case study 1: High speed steels: their application, process and properties |
| CO-4: | Case study 2: Ni based Superalloys as aero-engine applications, their structures and processing |
| CO-5: | Identified advanced structural ceramics for high temperature application |

| | **Syllabus Details** |
|---|---|
| Unit I | Melt processing of Superalloy, Single crystal Superalloy, Processing of Superalloy, Alloying effect. |
| Unit II | Oxide Dispersion Strengthened alloys. Powder Metallurgy |
| Unit III | High temperature deformation, Room and high temperature Wear, Advanced coating materials, High Entropy Alloys |
| Unit IV | Fiber Reinforced Composite Superalloy |
| Unit V | Processing and properties of advanced Structural Ceramics |

**Textbooks**

1. *Superalloys, supercomposites and super ceramics, ed. J. K Tien and T. Caulfield, Academic Press, 1989, Boston.*
2. *High temperature structural materials, R. W. Cahn, Chapman and Hall, 1996, London.*

**Reference Book(s):**

1. *Materials for High Temp. Engg. Applications, G. W. Meetham and M.H. Van de Voorde, Springer, 2000, Berlin.*
2. *Friction, wear and Lubrications, K.C. Ludema, CRC Press, 1996.*
3. *Powder Metallurgy: Science, Technology, and Materials Anish Upadhyaya and G. S. Upadhyaya, Taylor & Francis, 2011*

**Course Name: Advanced Steel Technology**
**Course Code: MM 618**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Comprehend different strengthening mechanisms in steel |
| CO-2: | Introduce low carbon steel and their characteristics |

| | |
|---|---|
| CO-3: | Explore medium and high carbon steel along with their transformations |
| CO-4: | Importance of pearlite microstructures |
| CO-5: | Applications of special steel materials like bainite and case studies for defence applications |

| | **Syllabus Details** |
|---|---|
| Unit I | Strengthening mechanisms: Work hardening, Solid solution strengthening, Grain size refinement, Dispersion strengthening |
| Unit II | **Low Carbon steels:** Austenite to ferrite transformation, High strength low alloys steels, Interstitial free steels, Dual phase and TRIP steels |
| Unit III | **Medium and high carbon steels:** Austenite to pearlite transformation, Ferritic-pearlitic microstructures in medium carbon steels, Austenite to Cementite transformation, **Unit 4:** Fully pearlitic microstructures: Rail steels, high strength steel wires |
| Unit IV | **Fully pearlitic microstructures:** Rail steels, high strength steel wires |
| Unit V | **Special steels: Bainite:** Upper and lower Bainite microstructures, Bainite transformation mechanisms and transition, nanostructured Bainite; Maraging steels, Stainless steel, TWIP steels, Case studies for defence applications. |

**Textbooks**

1. *Steels: Processing, Structure, and Performance, George Krauss; ASM International*

**Reference Book(s):**

1. *Steels: Microstructure and Properties HKDH Bhadeshia and Sir R. Honeycomb; Butterworth-Heinmann, Elsevier Publications*

**Course Name: Military Materials**
**Course Code: MM 619**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | An overview of special materials requirements for military applications. |
| CO-2: | Requirement of materials, their properties and processes for armor protection systems. |
| CO-3: | Discussion of specific required for ammunition applications and their properties and processes. |
| CO-4: | Special alloys and their stringent properties required for building fighter aircraft. |
| CO-5: | Special steels and their process for naval vessels. |

| | **Syllabus Details** |
|---|---|
| Unit I | Overview metallic materials for military application, needs of complex metals and alloys required for modern and sophisticated warfare weapons systems.<br>Conventional alloys for military application: Functional requirements of cartridge case and manufacture, Brass and steel cartridge cases, Cased ammunition. Steel shell bodies – High explosive squash head, Steel guns barrels- Direct fire tank guns, Indirect fire artillery guns, Alloys for military bridges: Mild steel- Bailey |

| | |
|---|---|
| | bridge and heavy girder bridge, Aluminum alloy – Medium girder bridge and BR 90. |
| Unit II | Special Alloys for Armour applications: Rolled Homogeneous Armour steels: Kanchan armour for Arjun tank, Steel armour plate, Aluminum alloy armour for light armoured vehicles, Body armour. |
| Unit III | Alloys for ammunition applications: Ferrous fragmenting projectiles: Cast iron mortar bomb bodies, Steel 155 mm anti-personnel artillery shell body. Conical shaped charge weapon system, Hydrodynamic penetration, Copper charge penetrators. Kinetic energy penetrators: Armour piercing fin stabilised discarding Sabot, Tungsten heavy alloys as long rod penetrator, Recent development |
| Unit IV | Alloys for aerospace applications: Materials required for engine parts, Superalloys for high temperature applications, Single crystal blades made of Ni based super alloys, Aerospace grade low density high strength Ti and Al alloys, Ultra-high-strength steel with the toughness for missile applications. |
| Unit V | Special alloys for naval applications: Special alloys with functional properties: Advanced magnetic materials - Ultra high energy product permanent magnets, emerging materials such as nanomaterials and smart materials |

**Textbooks**

1. *Alistair Doig, Military metallurgy, Maney publishing, 2002*

**Reference Book(s):**

1. *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*
2. *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.*
3. *Paul J Hazell, Armour Materials Theory and Design, CRC Press, 20*

**Course Name: Introduction to Corrosion**
**Course Code: MM 620**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Introduction to thermodynamics of corrosion |
| CO-2: | Identification of electrode kinetics and polarisation |
| CO-3: | Cognizance of mixed potential theory |
| CO-4: | Recognized different forms of corrosion |
| CO-5: | Case studies of environmental factors causing corrosion |

| | **Syllabus Details** |
|---|---|
| Unit I | What is corrosion – definition & fundamentals, Importance & Economic Impact of Corrosion, Thermodynamics of Corrosion, Electrochemical principles of Corrosion, Potential versus pH (Pourbaix) diagrams – Calculation & Construction of E – pH diagrams & its practical use. Copper, Aluminium & general corrosion diagram, Mixed Potential or Evans diagram & its application. |
| Unit II | Electrode Kinetics and Polarization Phenomenon: Electrode – Solution interface – Definition & types of polarization. Exchange current density and polarization relationships. Polarization techniques – corrosion rate determination |

| | |
|---|---|
| Unit III | Mixed Potential concepts and Basics. Mixed potential theory – bimetallic couples. Activation and diffusion controlled mixed electrodes. Origin of electrochemical noise and its application. |
| Unit IV | Forms of Corrosion – Uniform, Localized & Metallurgical influenced – Pitting, Crevice, Galvanic & Intergranular Corrosion, Mechanically Assisted, Environmentally Induced & Microbiologically influenced Corrosion. |
| Unit V | Nernst equation, EMF Series and Galvani Series, Stern-Gary eqn. Mechanical and environmental factors affecting corrosion, materials selection for different Defence applications. Passivity, trans passivity and breakdown, corrosion resistant and high temperature resistant materials. |

**Textbooks**

1. *Mars G. Fontana, Corrosion Engineering, 3rd Ed., McGraw-Hill, Singapore, 1987*

**Reference Book(s):**

1. *H.H. Uhlig and R.W. Revie, Corrosion and its control, 3rd Ed., John Wiley, Singapore, 1991*

**Course Name: Welding Science and Technology**
**Course Code: MM 621**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Analyse the welding processes |
| CO-2: | Understand the physics of welding |
| CO-3: | Correlation of metallurgy and welding |
| CO-4: | Understand the welding of various alloys |
| CO-5: | Analyse the failures in welding and their remedies |

| | **Syllabus Details** |
|---|---|
| Unit I | Classification of welding processes, study of welding arc characteristics, metal transfer during arc welding, heat flow in welding, Chemical reactions in welding, weld pool solidification, effect of welding process parameters on the macro-and micro-structure of weld metal. |
| Unit II | Thermal cycles in the heat affected zone. Phase transformations in the weld metal and the heat affected zone. High power density processes such as laser and electron beam welding. |
| Unit III | Welding metallurgy under high cooling rates. Phenomena of hot-cracking and cold cracking. Residual stresses and distortion during and after welding, Fatigue and fracture of weldments. Sensitized phenomena |
| Unit IV | Application of above principles to welding of carbon and alloy steels, cast irons, stainless steels, aluminum and titanium alloys. Weld decay, problems associated with welding of metals and alloys. Stabilized alloy |
| Unit V | Pre and post welding Heat treatment processes, Failure analysis |

**Textbooks**

1. *K. Easterling, Introduction to Physical Metallurgy of Welding, Butterworths Pub., 1983.*

**Reference Book(s):**

2. *Sindo Kou, Welding Metallurgy, John Wiley & Sons, New York, 1987.*
1. *S.A. David (Ed.), Advances in Welding Science and Technology, American Society for Metals, Ohio, 1986.*

**Course Name: High Temperature Corrosion**
**Course Code: MM 622**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Brief introduction to free energy, partial pressure and related diagrams |
| CO-2: | Analysis of thermodynamics of high temperature gases with metals |
| CO-3: | Conception of effects of defect interaction kinetics |
| CO-4: | Cognizance of corrosion characteristics affecting metals |
| CO-5: | Understand different applications of high temperature corrosion |
| CO-6: | Measurement of degradation of materials in high temperature applications |
| CO-7: | Understanding high temperature corrosion testing |

| | **Syllabus Details** |
|---|---|
| Unit I | Free energy, Partial pressure, Ellingham diagram |
| Unit II | Introduction, high temperature gaseous reaction (dry), single metal-single oxidant systems, aspects of thermodynamics, kinetics, transport properties, scale morphologies, electrochemical emphasis, various forms of high temperature corrosion including molten salt corrosion, thermodynamic phase stability in metal/gas systems-predominance area diagrams; |
| Unit III | Theory of point defects in corrosion products, defect interactions, scale growth kinetics and mechanisms, Wagner's parabolic scale growth process, other types of kinetics laws and mechanisms, morphological aspects in the growth of thick scales. |
| Unit IV | Corrosion product evaporation, analyses of kinetic data; alloy oxidation-kinetics, mechanisms, morphology, hot corrosion of metals and alloys-mechanisms and examples. |
| Unit V | High temperature corrosion in various applications |
| Unit VI | Measurements of High – Temperature Degradation, High Temperature Corrosion & Degradation Processes. |
| Unit VII | High Temperature Corrosion Testing |

**Textbooks**

1. *Per Kofstad, High Temperature Corrosion, Elsevier Applied Science, 1988.*
2. *U.R. Evans, Corrosion and Oxidation of Metals, Arnold Publ., London, 1981.*

**Reference Book(s):**

1. *N. Birks and G.H. Meier, Introduction to Oxidation of Metals, Edward Arnold, London, 1983.*
2. *A.S. Khanna, Introduction to High Temperature Oxidation and Corrosion, ASM International, Materials Park, Ohio, 2002.*
3. *Phase transformation in metals and alloys, Porter and Easterling.*

**Course Name: Corrosion Mitigation**
**Course Code: MM 623**

| Course Outcomes (CO): | |
|---|---|
| CO-1: | Understand importance of protective coating process and their classification |
| CO-2: | Knowledge of the fundamentals and applications of coating techniques |
| CO-3: | Cognizance of factors affecting cathodic and anodic protection |
| CO-4: | Demonstrated corrosion protection in extreme environmental conditions |
| CO-5: | Case studies for Defence Applications |

| | Syllabus Details |
|---|---|
| Unit I | Protective Coatings – Introduction, coatings & Coating Processes, Supplementary protection systems, Surface preparation. Classification of inhibitors, Corrosion inhibition Mechanism, Selection of an inhibitor system |
| Unit II | Requirement of protective coatings, classification of organic and inorganic coatings, metallic coatings, electrodeposition and electroless coatings. Paint coatings for corrosion protection, role of resins, pigment, additives and solvents, Advanced coatings (CVD, ALD and PVD). |
| Unit III | Cathodic and Anodic Protection – principles & classifications, mechanism of Cathodic and anodic protections – influencing factors and Monitoring |
| Unit IV | Corrosion protection in extreme environment such as nuclear irradiation, high pressure etc. |
| Unit V | Case studies relevant to Defence Applications: (Superhydrophobic coatings, anti-barnacles coating, corrosion control of underground pipelines, storage tanks, overhead pipelines, offshore structures, ship hulls, risers, reinforced bars and concrete structures |

**Textbooks**

1. *Corrosion: Environment and Industries, Metals Handbook, Vol. 13c, Park Ohio, 1984, 10th Ed., ASM Metals, Ohio, 1987.*
2. *N.D. Tomashov, Theory of Corrosion and Protection of Metals, Macmillan, 1967.*
3. *M.G. Fontana, Corrosion Engineering, 3rd Ed., McGraw-Hill, 1985. 4. H.H. Uhlig, Corrosion & Corrosion Control, Wiley, 1985.*

**Reference Book(s):**

1. *R. Lambourne and T.A. Strivens, Paint and Surface Coatings, Ellis Horwood D, Chichster, 1987.*
2. *C.G. Munger, Corrosion Prevention by Protective Coatings, NACE Pub., Houston, 1984.*
3. *Surface Finishing, Cleaning & Coatings, ASM Handbook, Vol. 5, 1994.*
4. *J. Biesiek and J. Weber Portcullis, Electrolytic and Chemical Conversion Coatings, Red Hill Press, 1976.*
5. *F.A. Lowenheim, Electroplating: Fundamentals of Surface Finishing, McGraw-Hill, New York, 1978.*

**Course Name: Advanced Coatings**
**Course Code: MM 624**

| Course Outcomes (CO): | |
|---|---|
| CO-1: | Recognized requirements of protective coatings and their classification |
| CO-2: | Reviewed commonly used coating methods |

| | |
|---|---|
| CO-3: | Conception of coating application of material surface |
| CO-4: | Understanding importance of coating to underground surfaces, offshore structures, etc. |
| CO-5: | Case studies on advanced coating application |

| | **Syllabus Details** |
|---|---|
| Unit I | Requirement of protective coatings, classification of organic, polymeric and inorganic coatings, conversion coatings, metallic coatings, electrodeposition and electroless coatings. |
| Unit II | Paint coatings for corrosion protection, role of resins, pigment, additives and solvents. |
| Unit III | Application techniques: Surface preparation and its importance in coating, role of coating selection & design of coating, failure mechanism, maintenance coatings, industrial paint systems, modern paint coating systems and specific examples. |
| Unit IV | Coatings for underground pipelines, storage tanks, overhead pipelines, offshore structures, ship hulls, risers, reinforced bars and concrete structures. Testing and evaluation. TBC, EBC |
| Unit V | Case studies |

**Textbooks**

1. *R. Lambourne and T.A. Strivens, Paint and Surface Coatings, Ellis Horwood D, Chichster, 1987.*
2. *2. C.G. Munger, Corrosion Prevention by Protective Coatings, NACE Pub., Houston, 1984.*

**Reference Book(s):**

1. *3. Surface Finishing, Cleaning & Coatings, ASM Handbook, Vol. 5, 1994.*
2. *4. J. Biesiek and J. Weber Portcullis, Electrolytic and Chemical Conversion Coatings, Red Hill Press, 1976.*
3. *5. F.A. Lowenheim, Electroplating: Fundamentals of Surface Finishing, McGraw-Hill, New York, 1978.*

**Course Name: Surface Science and Engineering**
**Course Code: MM 625**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Represented theory of surface reconstructions and its characteristics |
| CO-2: | Learn the effect of theoretical and experimental evaluation of surface energy of substrate surface structure |
| CO-3: | Demonstrate thermodynamics of solid liquid and solid gas interfaces |
| CO-4: | Analyzed wear mechanisms and their categorization |
| CO-5: | Fundamentals and applications of surface coating techniques |

| | **Syllabus Details** |
|---|---|
| Unit I | Theory of surface reconstructions, electronic properties of surfaces, interfaces and overlayers. Characterisation of surfaces by photons, electrons and ions as probes. |
| Unit II | The effect of substrate surface structure on the overlayer properties. Theoretical and experimental evaluation of surface energies |
| Unit III | Solid-liquid and solid-gas interfaces-surface potentials, colloids, sedimentation, adsorption and reaction on surfaces. Damage of the surfaces by corrosion and wear. |
| Unit IV | Wear mechanisms and categories of wear. Surface modifications by diffusion, heat treatment |

| | |
|---|---|
| | and by coatings, Surface Processing laser, electrons and ions |
| Unit V | Physical and vapour deposition, CVD, ion-implantation, thermal spray coating. |

**Textbooks**

1. *M. Prutton, Surface Physics, 2nd Ed., Clarendon Press, Oxford, 1983.*
2. *A.W. Adamson, Physical Chemistry of Surfaces, 3rd Ed., Wiley, 1976.*

**Reference Book(s):**

1. *K.G. Budinski, Surface Engineering for Wear Resistance, Prentice-Hall, 1988.*
2. *K.H. ZumGahr, Microstructure and Wear of Materials, Elsevier, 1987.*

**Course Name: Reliability Engineering**
**Course Code: MM 626**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1: | Detailed overview of probability theory |
| CO-2: | Assessed fundamentals of FMEA techniques |
| CO-3: | Inspected Design of Experiments analysis of variance technique |
| CO-4: | Investigated future of product liability |
| CO-5: | Cognizance of product development and its application |

| | **Syllabus Details** |
|---|---|
| Unit I | Basic Probability Theory Basic concepts, Rules for combining Probabilities of events, Failure Density and Distribution functions, Bernoulli's trials, Binomial distribution, Expected value and standard deviation for binomial distribution – Examples |
| Unit II | Failure Mode and Effect Analysis (FMEA) Basic Principles and General Fundamentals of FMEA Methodology |
| Unit III | Design of Experiments Analysis of Variance Technique-Strategy of Experimental Design |
| Unit IV | Product Liability and Planning History, Product Safety Law, Product Liability Law, The future of product Liability- Prevention. Degree of Novelty of a Product, Product Life Cycle, Company Goals and Their Effect. Solution Finding Methods- Conventional Methods, Intuitive Methods, Discursive Methods, Methods for Combining Solutions- Examples. |
| Unit V | Product Development Process General Problem-Solving Process- Flow of Work During the Process of Designing, Activity Planning, Timing and Scheduling, Planning Project and Product Costs, Effective Organization Structures- Interdisciplinary Cooperation, Leadership and Team Behaviour. |

**Textbooks**

1. *G. Haribaskaran, Probability, Queuing Theory & Reliability Engineering, Laxmi publications, Second Edition.*
2. *D. H. Besterfield, Glen H. Besterfield and M. Besterfield-Sacre, Total Quality Management, Pearson Publications, Third Edition*

**Reference Book(s):**

1. *E. Walpole, H. Myers and L. Myers, Probability and Statistics for engineering and Scientists, Pearson Publications, Eighth Edition.*
2. *BrendBretsche, Reliability in Automotive and Mechanical Engineering, Springer Publications.*
3. *G. Pahl, W. Bietz, J. Feldhusen and K. H. Grote, Engineering Design a Systematic approach, Springer Publications, Third Edition.*
4. *V. Sankar, System Reliability Concepts, Himalaya Publishing House, 2015.*
5. *Roy Billinton and Ronald N. Allan, Reliability Evaluation of Engineering Systems, Reprinted in India B. S. Publications, 2007.*

   *E. Balagurusamy, Reliability Engineering, Tata McGraw Hill, 200*

**Course Name: Research Methodology and IPR**
**Course Code: PGC-601**

| **Course Outcomes (CO):** | |
|---|---|
| CO-1 | Understanding the fundamentals of research and its methodology |
| CO-2 | Choose the appropriate research design and develop appropriate research hypothesis for a research project |
| CO-3 | Knowledge of manuscript preparation, patents and Intellectual property |
| CO-4 | Technology transfer and application of IPR in various domains |

| | **Syllabus Details** |
|---|---|
| Unit I: | Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations |
| Unit II: | Effective literature studies approaches, analysis Plagiarism, Research ethics, |
| Unit III | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee |
| Unit IV | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. |
| Unit V | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.<br>Patent information and databases. Geographical Indications |
| Unit VI | New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |

**References Textbooks:**

1. *Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"*
2. *Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"*
3. *Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"*
4. *Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.*

5. *Mayall, "Industrial Design", McGraw Hill, 1992.*
6. *Niebel, "Product Design", McGraw Hill, 1974.*
7. *Asimov, "Introduction to Design", Prentice Hall, 1962.*
8. *Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.*
9. *T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008*

**Course Name: Audit Course**
**Course Code: PGC-602**

| | **Syllabus Details** |
|---|---|
| Unit I: | English for Research Paper Writing |
| Unit II: | Disaster Management |
| Unit III | Sanskrit for Technical Knowledge |
| Unit IV | Value Education |
| Unit V | Constitution of India |
| Unit VI | Pedagogy Studies |
| Unit VII | Stress Management by Yoga |
| Unit VIII | Personality Development through Life Enlightenment Skills |

## SCHOOL OF ENERGY AND ENVIRONMENT

### M. Tech. Renewable Energy

The energy obtained through renewable resources such as sunlight, wind, rain, tides, waves and geothermal heat is called Renewable Energy. It is opposite to the fossil fuels, which are being used enormously than they are being replenished. Renewable energy resources exist over wide geographical areas, in contrast to fossil fuels, concentrated in a limited number of countries. Therefore, it is rapidly gaining importance and becoming efficient and cheaper, and their share of total energy consumption is increasing. Deployment of renewable energy and energy efficiency technologies results in significant energy security, climate change mitigation, and economic benefits. Renewable energy technology is also suited to rural and remote areas, where energy is often crucial in human development.

**Stakeholders:**

(iii) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments

(iv) Graduates in the relevant field of science/technology from recognized Universities across the country.

**Eligibility for Students:**

BE/ B.Tech. in Energy/ Mechanical/ Chemical/ Civil/ Environmental/ Computer Science/ Electrical/ Electronics/ Biotechnology/ Full-time M.Sc. in all branches of Chemistry & Physics/ Graduation in any relevant discipline of Science and Engineering.

**Organization:** The M.Tech. programme is of four-semester duration. In each of the first two semesters there are seven theory courses. There will be three continuous evaluation examinations and a final semester examination for every course. At the end of the final semester, the student submits a dissertation and makes a presentation about the work carried out by him/her on the project, which is evaluated by the Internal and External examiners. Course syllabus is updated periodically to keep pace with the contemporary technological advancement.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO1: Graduates will be developing skill set in the field of research in renewable energy sectors.

PEO2: Graduates will acquire interdisciplinary knowledge required to get established as an entrepreneur in renewable energy.

PEO3: Graduates will showcase professional, social and ethical responsibilities in implementing renewable and sustainable energy solutions.

PROGRAMME OUTCOMES (POs)

PO1: An ability to carry out Research and development work to solve practical / industry problems

PO2: An ability to write and present a substantial technical report/document

PO3: An ability to demonstrate mastery over the area as per the specialization of the program which will be beyond the program scheme

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M.Tech (Renewable Energy) program, graduates will be able to

PSO1: Ability to work in contemporary and futuristic renewable energy research and being industry centric.
PSO2: Ability to develop cutting edge technologies for harnessing renewable energy in multi-dimensional applications.

## Credit Structure

**Semester I**

| Sr. No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | SE-601 | Fundamentals of Energy Studies | 3 | 1 | 0 | 4 |
| 2 | SE-602 | Bioenergy Systems | 3 | 1 | 0 | 4 |
| 3 | SE-603 | Hydrogen Energy | 3 | 1 | 0 | 4 |
| 4 | SE-604 | Waste to Energy | 3 | 1 | 0 | 4 |
| 5 | SE-605 | Solar Energy Systems | 3 | 1 | 0 | 4 |
| 6 | SE-606 | Renewable Energy and Environmental Sustainability | 3 | 1 | 0 | 4 |
| 7 | PGC-601 | Research Methodology and IPR | 2 | 0 | 0 | 2 |
| | | **Total** | **20** | **6** | **0** | **26** |

**Semester II**

| Sr. No. | Course Code | Course | Contact Hours/Week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | SE-607 | Wind and Hydro Energy Systems | 3 | 1 | 0 | 4 |
| 2 | SE-608 | Geothermal and Ocean Energy | 3 | 1 | 0 | 4 |
| 3 | | Departmental Elective I | 3 | 1 | 0 | 4 |
| 4 | | Departmental Elective II | 3 | 1 | 0 | 4 |
| 5 | | Elective – III | 3 | 1 | 0 | 4 |
| 6 | | Elective – IV | 3 | 1 | 0 | 4 |
| 7 | PGC- 602 | Audit 1 and 2 | 2 | 0 | 0 | 0 |
| | | **Total** | 20 | 6 | 0 | 24 |

**Semester III**

| Sl. No. | Course Code | Course | Contact Hours/Week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | SE-651 | M.Tech. Dissertation Phase - I | 0 | 0 | 28 | 14 |
| | | **Total** | | | **28** | **14** |

**Semester IV**

| Sl. No. | Course Code | Course | Contact Hours /week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | SE-652 | M.Tech. Dissertation Phase - II | 0 | 0 | 28 | 14 |
| | | **Total** | | | **28** | **14** |

SE-601: **Fundamentals of Energy Studies**

Course Outcomes:

| | |
|---|---|
| **CO-1:** | Understand the domain of Energy Science and Technology and various form of energies |
| **CO-2:** | Know about the Energy related organizations and Government Bodies |
| **CO-3:** | Identify technical details for power plant economics |
| **CO-4:** | Illustrate and classify waste heat recovery systems |
| **CO-5:** | Analyse and understand various biofuels and their characteristics |

Syllabus

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Energy Science & Technology - Forms of Energy – Advantages and Limitations - Mechanical Energy - Chemical Energy and Fuels - Nuclear Energy - Hydro Energy - Renewable Energy –Energy Demand- Comparison of Fuels such as Wood, Charcoal, Coal, Kerosene, Diesel, Petrol, Furnace Oil, LPG, Biogas and Electricity on calorific value and cost basis -Efficiencies of various Energy production. | **9** |
| Unit II | Nodal Agencies for power generation – Ministry of Power – Role – Ministry of New and Renewable Energy Sources – Role – other implementing agencies – Energy Auditing and Management – Energy Conservation Act – Bureau of Energy Efficiency – PCRA – Schemes–Policies – Planning | **8** |
| Unit III | Load Duration Curve –Load factor – Capacity factor – Reserve factor – Demand Factor – Diversity factor –Plant use factor – Location of power plants – Power Plant Economics – Indian Energy Scenario – problems – solutions -power plant sizing based on screening curve method. | **9** |
| Unit IV | Decentralized power generation – concept –Cogeneration – definition – need - application - advantages- classification - saving potentials -Waste heat recovery - Classification- advantages and applications - commercially viable waste heat recovery devices - saving potential – Combined Heat and Power | **9** |
| Unit V | Bio fuels – Edible –Petro crops – Analysis of Indian non-edible oil sources – Example of biodiesel crop – Jatropha curcas – Tree description – Jatropha curcas for rural development – environmental protection – Bio ethanol – production from conventional as well as unconventional sources. - Bio diesel – Technology for production of bio diesel - Transesterification – Process – Usage of Methanol – Glycerine – Storage and Characterization of biodiesel – Biodiesel engine development – modification – Environmental and health effects of biodiesel – R&D in biodiesel – disposal of cake – value addition of byproducts. | **9** |

References:

1. Koushika M.D., "Solar Energy Principles and Applications", IBT publications, 1988.
2. Mital K.M, "Biogas systems: Priciples and Applications", New Age International Publishers (P) Ltd., 1996
3. Venkata Ramana P and Srinivas S.N., “Biomass Energy Systems”, TERI, 1996.
4. Rai, G.D., "Non-Conventional Sources of Energy", Khanna Publishers, Delhi 1995.
5. Rao S, Parulekar B.B, “Energy Technology – Non conventional, Renewable and Conventional” Khanna Publishers, 1999.
6. H.G. Stoll, Least Cost Electrical Utility / Planning, John Wiley & Sons, 1989.

SE-602: **Bioenergy Systems**

Course Objectives:

| | |
|---|---|
| **CO-1:** | Understand current Bio energy status of world and India |
| **CO-2:** | Interpret the technical details of Bio mass energy systems |
| **CO-3:** | Perform classification of different types of stoves and burners |
| **CO-4:** | Analyse the Bio gas plants and technical details of bio gas production |
| **CO-5:** | Identify and explain different Bio mass gasifier systems |

**Syllabus**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Bio Energy Resources, World Bio Energy Potential, India’s Bio Energy Potential, Current Technology and Research Status. | **9** |
| Unit II | Direct Combustion, Technology of Biomass gasification, Pyrolysis and Liquefaction, Bio- Chemical Conversion: anaerobic digestion, alcohol production from biomass, Chemical conversion process: hydrolysis and hydrogenation | **8** |
| Unit III | Traditional Stoves, Energy Efficient Cooking and Space heating Stoves, Metal Stoves Improved Gasifier Stoves, Current Research Status, Pollution due to smoke emissions. | **9** |
| Unit IV | Technology of Bio-gas production, Biogas Plants, Digester types, Digester design, Chemical kinetics and mathematical modeling of bio- methanation process, Dung, Vegetable Waste and Night Soil and Municipal Waste based Bio -gas plants, Bio gas as fuel for transportation, Lighting , Running Dual Fuel Engines, Electricity generation, Bio gas Bottling Plant Technology, Application of Bio gas slurry in agriculture , Design of Biogas for cold climates | **9** |
| Unit V | History, Principle, Design of Bio mass Gasifiers, updraft gasifier, down draft gasifier, zero carbon biomass gasification plants, Gasification of plastic-rich waste, applications for cooking, electricity generation, Gasifier Engines, Operation of spark ignition and compression ignition engine with wood gas, methanol, ethanol and biogas, Biomass integrated gasification/combined cycles systems. Environmental Policy Issues of Bio- Energy systems. | **9** |

References:

1. KC Khandelwal, SS Mahdi, Biogas Technology - A Practical Handbook , Tata McGraw Hill, 1986
2. RC Maheswari, Bio Energy for Rural Energisation , Concepts Publication, 1997
3. J Twidell and T Weir, Renewable Energy Resources, Taylor and Francis (Ed), New York, USA, 2006

4. B Sorensen, Renewable Energy,2nd Ed, Academic press, New York, 2000
5. G Boyle (Ed), Renewable energy: Power for a sustainable future, Oxford, OUP, 1996

SE-603: **Hydrogen Energy**

Course Objectives:

| | |
|---|---|
| **CO-1:** | Understand the basic concepts of hydrogen as a fuel |
| **CO-2:** | Identify different types of fuel and their characteristics |
| **CO-3:** | Analyse and understand technical details of coal and their use as energy source |
| **CO-4:** | Illustrate the classification of gaseous fuels |
| **CO-5:** | Analyse and understand combustion process and emission from different fuels |

Syllabus

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Hydrogen properties, uses, interest in hydrogen as fuel, methods of production, storage, transportation, distribution, hydrogen economy. | **9** |
| Unit II | Basics of fuels: Modern concepts of fuel, Solid, liquid and gaseous fuels, composition, basic understanding of various properties of solid fuels - heating value, ultimate analysis, proximate analysis, ash deformation points; liquid fuels - heating value, density, specific gravity, viscosity, flash point, ignition point (self, forced), pour point, ash composition and gaseous fuels. | **8** |
| Unit III | Coal as a source of energy: Coal reserves – World and India, Coal liquefaction process, various types of coal and their properties, Origin of coal, composition of coal, analysis and properties of coal, Action of heat on coal, caking and coking properties of coal; Processing of coal: Coal preparations, briquetting, carbonization, gasification and liquefaction of coal, Coal derived chemicals. | **9** |
| Unit IV | Natural gas and its derivatives: Classification of gaseous fuels – natural gas and synthetic gases, Natural gas reserves - World and India, properties of natural gas – heating value, composition, and density | **9** |
| Unit V | Principles of combustion: Chemistry and Stoichiometric calculation, thermodynamic analysis, and concept of adiabatic flame temperature; Combustion appliances for solid, liquid, and gaseous fuels: working, design principles and performance analysis | **9** |
| Unit VI | Emissions from fuel combustion systems: Pollutants and their generation, allowed emissions, strategies for emission reduction, Euro and BIS norms for emission, recent protocols | |

References:

1. Fuels & Combustion by Sharma S.P. & Chander Mohan, Tata McGraw Hill Publishing Co. Ltd.
2. Fuels & Combustion by Sarkar Samir, Orient Longman.
3. Fuels and Petroleum Processing by Sharma, B. K, Goel publishing.

SE-604: **Waste to Energy**

Course Objectives:

| | |
|---|---|
| **CO-1:** | Understand the basic concepts of solid waste and disposal systems |
| **CO-2:** | Classify different techniques of waste treatment |
| **CO-3:** | Analyse the process of energy generation from different waste |

| | |
|---|---|
| **CO-4:** | Characterize the rural biomass usage and products/by-products of the process |
| **CO-5:** | Illustrate the various aspects of biomass combustion and processes involved |

Syllabus

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I | Solid Waste -Definitions: Sources, types, compositions; Properties of Solid Waste; Municipal Solid Waste: Physical, chemical and biological property; Collection, transfer stations; Waste minimization and recycling of municipal waste.<br>Landfill method of solid waste disposal; Landfill classification; Types, methods & siting consideration; Layout & preliminary design of landfills: Composition, characteristics, generation; Design of Sanitary Land fill - Movement and control of landfill leachate &gases; Environmental monitoring system for landfill gases. - Gas Recovery – Applications | **9** |
| Unit II | Waste Treatment & Disposal Size Reduction: incineration; Furnace type & design; Types of Incinerators – Fuel Economy - Medical /Pharmaceutical waste / Hazardous waste / Nuclear Waste incineration; Environmental impacts; Measures of mitigate environmental effects due to incineration. | **8** |
| Unit III | Energy Generation from Waste Types: Biochemical Conversion: Sources of energy generation, Industrial waste, agro residues; Anaerobic Digestion: Biogas production; Determination of BOD, DO, COD, TOC, & Organic loading, Aerobic & Anaerobic treatments – types of digester – factors affecting biodigestion - Activated sludge process. Methods of treatment and recovery from the in industrial waste water – Case Studies in sugar, distillery, dairy, pulp and paper mill, fertilizer, tanning, steel industry, textile, petroleum refining, chemical and power plant. | **9** |
| Unit IV | Rural applications of biomass –Combustion - Chulas - improved Chulas- Biomass – Physical - Chemical composition – properties of biomass – TGA – DSC characterization – Ash Characterization - Preparation of biomass – Size reduction – Briquetting of loose biomass-Briequtting machine | **9** |
| Unit V | Thermochemical Conversion -Basic aspects of biomass combustion - heat of combustion - different types of grates - Co combustion of biomass –Gasification - Fixed and Fluidized bed gasifier - Gasification technologies for the selected waste like Rice Husk, Coir pith, Bagasse, Poultry litter etc., - Pyrolysis | **9** |

References:

1. Parker,Colin, &Roberts, Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985
2. Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, Prentice Hall, 2000
3. Manoj Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997
4. Rich, Gerald et.al., Hazardous Waste Management Technology, Podvan Publishers, 1987
5. Bhide AD., Sundaresan BB, Solid Waste Management in Developing Countries, INSDOC, New Delhi,1983.

SE-604: **Solar Energy Systems**

Course Objectives:

| | |
|---|---|
| **CO-1 :** | Understand the technical details of solar radiation |

| | |
|---|---|
| **CO-2 :** | Analyse different ways to utilize the solar energy |
| **CO-3 :** | Examine the ways solar energy proves beneficial in providing thermal comfort in buildings |
| **CO-4 :** | Identify the technical details of solar cells and their performance parameters |
| **CO-5 :** | Explain the applicability of solar photovoltaic systems and their operation |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Solar angles, day length, angle of incidence on tilted surface; Sunpath diagrams; Shadow determination; Extraterrestrial characteristics; Effect of earth atmosphere; Measurement & estimation on horizontal and tilted surfaces; Analysis of Indian solar radiation data and applications. Flat-plate Collectors - Effective energy losses; Thermal analysis; Heat capacity effect; Testing methods; Evacuated tubular collectors; Air flat-plate Collectors: types; Thermal analysis; Thermal drying. Selective Surfaces - Ideal coating characteristics; Types and applications; Anti-reflective coating; Preparation and characterization | **9** |
| Unit II | Concentrating Collector Designs - Classification, Tracking systems; Compound parabolic concentrators; Parabolic trough concentrators; Concentrators with point focus; Heliostats; Comparison of various designs: Central receiver systems, parabolic trough systems; Solar power plant; Solar furnaces - Vapour absorption refrigeration cycle; Water, ammonia & lithium bromide-water absorption refrigeration systems; Solar operated refrigeration systems; Solar desiccant cooling. -Solar Thermal Energy Storage - Sensible storage; Latent heat storage; Thermo-chemical storage. Solar still; Solar cooker: Solar pond. | **8** |
| Unit III | Solar Passive Building - Thermal comfort; Criteria and various parameters; Calculation of solar radiation on buildings; building orientation; Introduction to design of shading devices; Overhangs; Factors that effects energy use in buildings; Ventilation and its significance; Air- conditioning systems; Passive Cooling And Heating Concepts – Passive heating concepts: Direct heat gain, indirect heat gain, isolated gain and sunspaces; Passive cooling concepts: Evaporative cooling, radiative cooling; Application of wind, water and earth for cooling; Shading, paints and cavity walls. | **9** |
| Unit IV | Solar Cell Physics –P-N junction: homo and hetro junctions, Metal-semiconductor interface; Dark and illumination characteristics; Figure of merits of solar cell; Efficiency limits; Variation of efficiency with band-gap and temperature; Efficiency measurements; High efficiency cells, Tandem structure. | **9** |
| Unit V | SPV Applications - Centralized and decentralized SPV systems; Stand alone, hybrid and, grid connected system, System installation, operation and maintenances; Field experience; PV market analysis and economics of SPV systems – Government Schemes and Polices | **9** |

References:

1. Garg H P., Prakash J., Solar Energy: Fundamentals & Applications, Tata McGraw Hill, New Delhi, 1997
2. S P Sukhatme, Solar Energy, Tata McGraw Hill, 2008 11
3. J F Kreider and Frank Kreith, Solar Energy Handbook, McGraw Hill, 2000

4. D Y Goswami, Frank Kreith and J F Kreider,Principles of Solar Engineering, Taylor&
Francis, 1998
5. Tiwari G.N., Suneja S., Solar Thermal Engineering System, Narosa Publishing House, New Delhi, 1997.

SE-606: **Renewable Energy and Environmental Sustainability**

Course Outcomes:

| | |
|---|---|
| **CO-1:** | Understand the importance of environment in energy generation and consumption |
| **CO-2:** | Understand the social and economic impacts of actions in energy & environment |
| **CO-3:** | Analyse current status and possibilities in rural electricity generation & utilization |
| **CO-4:** | Review the various energy & environment related policies from Government |
| **CO-5:** | Explain the applications of renewable energy technologies in rural areas |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Environmental sustainability, Traditional and modern energy use, Methods of accounting the role of traditional energy in the overall energy system. Energy consumption patterns in rural areas. Trends of rural energy consumption, need and development of rural energy data bases (REDB); methodologies for building REDB. Case studies of REDB | **9** |
| Unit II | Integrated Rural Energy Planning (IREP): Origin, implementation, case studies, critique. Socioeconomic and environmental issues of traditional energy use. Health impacts of biomass burning in cookstoves. The debate of black carbon from biomass burning. The energy ladder for cooking. Gender issues in biomass collection and processing. | **8** |
| Unit III | Rural electrification: Overview, current status and future perspectives. Linkages with rural livelihoods, rural industries and social development. Issues of subsidization, last mile access and paying capacity. | **9** |
| Unit IV | Review and critique of various programs of government: National Program for Biogas Development (NPBD), National Program for Improved Cookstoves (NPIC), Village Energy Security Plan (VESP), Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) etc. | **9** |
| Unit V | Use of efficient/appropriate/renewable energy technologies for rural areas.<br>Technologies/products for cooking, water heating, drying, irrigation pumping, small/micro enterprises, lighting, motive power etc | **9** |

References:

1. Report by a Panel of Experts, Rural electrification in Asia and the Far East New York
United Nations, 1963,12
2. B. Kaye and William S: Pintz, Rural electrification issue papersHonolulu: Pacific Islands Development. 2004
3. Chambers, Ann, Distributed Generation: A Non-technical guide, 4th Ed., Penn well,
Oklahoma, 2001

4. Devadas, Planning for Rural Energy System: Part I & II, V Renewable and Sustainable Energy Reviews, 5 (2001), 203-226, 227-270. 5. T.C. Kandpal, H. P. Garg, Financial Evaluation of Renewable Energy Technology, Macmilan, New Delhi, 2003

PGC-601: **Research Methodology and IPR**

Course Outcomes

| | |
|---|---|
| **CO-1:** | Understand the meaning and characteristics of research problems |
| **CO-2:** | Learn how to conduct effective literature survey |
| **CO-3:** | Learn to write technical report and proposals |
| **CO-4:** | Understand about IPR, their importance, and new developments |

Syllabus

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations. | **9** |
| Unit II | Effective literature studies approaches, analysis Plagiarism, Research ethics | **7** |
| Unit III | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee. | **8** |
| Unit IV | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT | **8** |
| Unit V | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. | **7** |
| Unit VI | New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies | **7** |

References:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"

2.Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"

3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"

4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.

5. Mayall, "Industrial Design", McGraw Hill, 1992.

**PGC-602: Audit I and II**

Unit I: English for Research Paper Writing

Unit II: Disaster Management

Unit II: Sanskrit for Technical Knowledge

Unit IV: Value Education

Unit V: Constitution of India

Unit VI: Pedagogy Studies
Unit VII: Stress Management by Yoga
Unit VIII: Personality Development through Life Enlightenment

SE-607: **Wind and Hydro Energy Systems**
Course Outcomes:

| | |
|---|---|
| **CO-1:** | Understand the technical details of wind energy conversion physics |
| **CO-2:** | Analyse the design and performance characteristics of wind turbines |
| **CO-3:** | Examine different hydropower systems |
| **CO-4:** | Illustrate the possibilities in hydro power generations and utilization |
| **CO-5:** | Explain the ocean thermal, geothermal, and thermo-electric energy systems |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Wind Energy Conversion - Wind energy conversion principles; General introduction; Types and classification of WECS; Power, torque and speed characteristics. – Site Selection Criteria– Advantages – Limitations – Wind Rose Diagram – Indian Wind Energy Data – Organizations like NIWE etc., Wind Energy Conversion System - Design – Aerodynamic design principles; Aerodynamic theories; Axial momentum, blade element and combine theory; Rotor characteristics; Maximum power coefficient; Prandlt's tip loss correction | **9** |
| Unit II | Design of Wind Turbine - Wind turbine design considerations; Methodology; Theoretical simulation of wind turbine characteristics; Test methods. Wind Energy Application - Wind pumps: Performance analysis, design concept and testing; Principle of WEG; Stand alone, grid connected and hybrid applications of WECS; Economics of wind energy utilization; Wind energy in India; Case studies. | **8** |
| Unit III | Small Hydropower Systems - Overview of micro, mini and small hydro systems; Hydrology; Elements of pumps and turbine; Selection and design criteria of pumps and turbines; Site selection and civil works. | **9** |
| Unit IV | Speed and voltage regulation; Investment issues load management and tariff collection; Distribution and marketing issues: case studies; Potential of small hydro power in India. – SHP – Renovation and Modernization – Testing Methods. | **9** |
| Unit V | OTEC- Tidal Energy- Geothermal- MHD - Thermionic- Thermoelectric energy conversion system- Fuel Cells – Batteries – Micro Alge – Biodiesel from Alge. | **9** |

References:
1. G L Johnson, Wind Energy Systems, Prentice Hall Inc, New Jersey, 1985.
2. David A. Spera, (Editor) Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering,American Society of Mechanical Engineers; (1994) 13
3. Erich Hau,Wind Turbines: Fundamentals, Technologies, Application and Economics, Springer Verlag; (2000)
4. Paul Gipe , Karen Perez, Wind Energy Basics: A Guide to Small and Micro Wind Systems, Chelsea Green Publishing Company; (1999)
5. J. F. Manwell, J. G. McGowan, A. L. Rogers, Wind Energy Explained , John Wiley & Sons; 1st edition (2002)

SE-608: **Geothermal and Ocean Energy**

Course Outcomes:

| | |
|---|---|
| **CO-1 :** | Understand the basic concepts and technical details of geothermal energy system |
| **CO-2 :** | Analyse the functioning of a geothermal heat pump |
| **CO-3 :** | Illustrate the ocean thermal form of energy and possibilities associated with it |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Introduction of Geothermal Energy, Geothermal Recourses; definition and classification, Hydrothermal System, Hot dry rock system, Geopressured reservoirs, Magma Energy, Dry rock and hot aquifer analysis. utilisation of geothermal resources, Direct utilization; Swimming bathing and balneology, space conditioning, district heating. | **9** |
| Unit II | Geothermal heat pump, basic concept of heat pump, air conditioner, heating and cooling mode in heat pump, Heat pump with geothermal resources; typical GHP loop configuration. | **8** |
| Unit III | Ocean Thermal; Introduction, OTEC history and technology progress, working principle, resources, and site requirement. | **9** |

References:


1. Renewable Energy resources: basic principles and application by Tiwari and Ghosal.
2. Renewable Energy Sources by Boyle.


SE-609: **Fuel and Combustion Technology**

Course Outcomes:

| | |
|---|---|
| **CO-1:** | Understand the characterization of different types of fuels |
| **CO-2:** | Perform classification of petroleum fuel, its products, and gaseous fuels |
| **CO-3:** | Understand and apply the basic principles in combustion and exhaust analysis |
| **CO-4:** | Illustrate the design concept in burner and associated modifications |
| **CO-5:** | Identify various types of furnaces used in energy industries and their performance |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Solid, Liquid and Gaseous Fuels - General: Coal; Family, origin, classification of coal; Analysis and properties; Action of heat on coal; Gasification; Oxidation; Hydrogenation and liquefaction of coal; Efficient use of solid fuels; Manufactured fuels; Agro fuels; Solid fuel handling; Properties related to combustion, handling, and storage. | **9** |
| Unit II | Origin and classification of petroleum; Refining; Properties & testing of petroleum products; Various petroleum products; Petroleum refining in India; Liquid fuels from other sources; Storage and handling of liquid fuels. Types of gaseous fuels: natural gases, methane from coal mines, manufactured gases, producer gas, water gas, biogas, refinery gas, LPG; Cleaning and purification of gaseous fuels. | **8** |
| Unit III | Theory of Combustion Process Stoichiometry and thermodynamics; Combustion | **9** |

| | | |
|---|---|---|
| | stoichiometry: Combustion thermodynamics, burners; Fluidized bed combustion process. Stoichiometry relations; Estimation of air required for complete combustion; Estimation of minimum amount of air required for a fuel of known composition; Estimation of dry flue gases for known fuel composition; Calculation of the composition of fuel & excess air supplied, from exhaust gas analysis; Dew point of products; Flue gas analysis (O2, CO2, CO, NOx, SOx). | |
| Unit IV | Burner Design Ignition: Concept, auto ignition, ignition temperature; Burners: Propagation, various methods of flame stabilization; Basic features and design of burners for solid, liquid, and gaseous fuels. | **9** |
| Unit V | Furnaces: Industrial furnaces, process furnaces, batch & continuous furnaces; Advantages of ceramic coating; Heat source; Distributions of heat source in furnaces; Blast furnace; Open hearth furnace, Kilns; Pot & crucible furnaces; Waste heat recovery in furnaces: Recuperators and regenerators; Furnace insulation; Furnace heat balance computations; Efficiency considerations. | **9** |

References:


1. S.P. Sharma & Chander Mohan, Fuels & Combustion, Tata McGraw Hill Publishing Co.Ltd.,1984
2. J. D. Gilchrist , Fuels, Furnaces & Refractories, Pergamom Press, 1998
3. Blokh A.G, Heat Transmission in Steam Boiler furnaces, Hemisphere Publishing Corpn.,1988
4. Gupta O.P, Elements of Fuels, Furnaces & Refractories, 3rd edition, Khanna Publishers, 1996.
5. Samir Sarkar, Fuels & Combustion, 2nd Edition, Orient Longman, 1990


SE-610: **Integrated Energy Systems**

Course Objectives:

| | |
|---|---|
| **CO-1:** | Understand the need of storage and utilization principles of various energy forms |
| **CO-2:** | Interpret the technical details of magnetic and electrical energy systems |
| **CO-3:** | Analyse the different energy storage systems and their applications |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Energy Storage: Need of energy storage, Different modes of Energy Storage. Potential energy, Pumped hydro storage, KE and Compressed gas system, Flywheel storage, compressed air energy storage, Electrical and magnetic energy storage: Capacitors, electromagnets. Chemical Energy storage, Thermo-chemical, photo-chemical, bio-chemical, electro-chemical, fossil fuels and synthetic fuels, Hydrogen for energy storage, Solar Ponds for energy storage. Electrochemical Energy Storage Systems: Batteries: Primary, Secondary, Lithium, Solid-state and molten solvent batteries, Lead acid batteries, Nickel Cadmium Batteries, Advanced Batteries. Role of carbon nano-tubes in electrodes | **9** |
| Unit II | Magnetic and Electric Energy Storage Systems: Superconducting Magnet Energy Storage (SMES) systems, Capacitor and Batteries, Comparison and application, Super capacitor: Electrochemical Double Layer Capacitor (EDLC), principle of working, structure, performance and application, role of activated carbon and carbon nano-tube. Sensible Heat Storage: SHS mediums, Stratified storage systems, Rock-bed storage systems, Thermal storage in buildings, Earth storage, Energy storage in aquifers, Heat | **8** |

| | | |
|---|---|---|
| | storage in SHS systems, Aquifers storage. | |
| Unit III | Latent Heat Thermal Energy Storage: Phase Change Materials (PCMs), Selection criteria of PCMs, Stefan problem, Solar thermal LHTES systems, Energy conservation through LHTES systems, LHTES systems in refrigeration and air-conditioning systems, Enthalpy formulation, Numerical heat transfer in melting and freezing process. | **9** |
| Unit IV | Some Areas of Application of Energy Storage: Food preservation, Waste heat recovery, Solar energy storage, Green house heating, Power plant applications, Drying and heating for process industries. | **9** |

References:

1. Garg H P., Prakash J., Solar Energy: Fundamentals & Applications, Tata McGraw Hill, New Delhi, 1997
2. S P Sukhatme, Solar Energy, Tata McGraw Hill, 2008
3. J F Kreider and Frank Kreith, Solar Energy Handbook, McGraw Hill, 2000
4. D Y Goswami, Frank Kreith and J F Kreider,Principles of Solar Engineering, Taylor & Francis, 1998
5. Tiwari G.N., Suneja S., Solar Thermal Engineering System, Narosa Publishing House, New Delhi, 1997.

SE-611: **Rural Electrification Technologies**

Course Outcomes:

| | |
|---|---|
| **CO-1:** | Understand the basic concepts of technologies for rural electrification |
| **CO-2:** | Interpret the technical details of electrification process |
| **CO-3:** | Classify the different turbine generator and their usage |
| **CO-4:** | Illustrate the concepts and current status of biomass based electricity generation |
| **CO-5:** | Identify the technical and economic details of power grid. |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Decentralized generation technologies; Costs and choice of technology, Demand and benefits forecasting and program development, Principles of cost-benefit calculations | **9** |
| Unit II | Economic and financial analysis of stand-alone electrification projects, Decentralized versus central station generation, Traditional power systems, Load curves and load curve analysis | **8** |
| Unit III | Basic gas turbine generator concepts; Utility system turbine generators; Mini and micro gas turbine generators; Solar thermal power generation, utility scale photovoltaic (USPV) generation; Wind-powered generation. | **9** |
| Unit IV | Biomass based generation; DG Evaluation: Cost from past, present, and future, basic DG cost analysis, cost Evaluation and schedule of demand. | 7 |
| Unit V | The power grid; DG-Grid interconnection issues, Mini and Micro Grids – Economics– Environmental Factors – Transmission and Regulations | **7** |

References:

1. H. Lee Willis and W.G. Scott: Distributed Power Generation: Planning and Evaluation, Marcel Dekker, 2000.

2. J. J. Burke: Power Distribution Engineering, Fundamentals and Applications, Marcel Dekker, 1994.
3. T. Gonen: Electric Power Distribution System Engineering, McGraw-Hill 1986.
4. M Mohan: Rural electrification for development: policy analysis and applications. Boulder: Westview Press, 1987
5. G. Saunier: Rural electrification guidebook for Asia and the Pacific, Asian Institute of Technology, 1992.

SE-612: **Energy Storage and Transport Systems**

Course Outcomes:

| | |
|---|---|
| **CO-1:** | Understand the requirement and different ways of energy storage |
| **CO-2:** | Identify the different technologies and parameters related to energy storage |
| **CO-3:** | Illustrate the design and application areas of energy storage and modern energy solutions |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Introduction: Necessity of energy storage, different types of energy storage, mechanical, chemical, electrical, electrochemical, biological, magnetic, electromagnetic, thermal, comparison of energy storage technologies Energy Storage Systems: Thermal Energy storage, sensible and latent heat, phase change materials, Energy and exergy analysis of thermal energy storage | 11 |
| Unit II | Electrical Energy storage-super-capacitors, Magnetic Energy storage-Superconducting systems, Mechanical-Pumped hydro, flywheels and pressurized air energy storage, Chemical-Hydrogen production and storage, Principle of direct energy conversion using fuel cells, thermodynamics of fuel cells, Types of fuel cells, AFC, PEMFC, MCFC, SOFC, Microbial fuel cell, Fuel cell performance, Electrochemical Energy Storage- Battery, primary, secondary and flow batteries | 12 |
| Unit III | Design and Applications of Energy Storage: Renewable energy storage-Battery sizing and stand-alone applications, stationary (Power Grid application), Small scale application-Portable storage systems and medical devices, Mobile storage Applications- Electric vehicles (EVs), types of EVs, batteries and fuel cells, future technologies, hybrid systems for energy storage. | 12 |

References:

1. Energy Storage - Technologies and Applications by Ahmed Faheem Zobaa, InTech.
2. Fundamentals of Energy Storage by J. Jensen and B. Sorenson, Wiley-Interscience, New York,
3. Handbook of battery materials by C. Daniel, J. O. Besenhard,Wiley VCH Verlag GmbH & Co. KgaA
4. Electric & Hybrid Vehicles by G. Pistoia, Elsevier B. V.
5. Thermal energy storage: Systems and Applications by Dincer I. and Rosen M. A., Wiley pub.

SE-613: **Energy Auditing and Management**

Course Outcomes:

| | |
|---|---|
| **CO-1 :** | Understand the basics of energy and principles of its conservation and management |
| **CO-2 :** | Analyse and understand different technical terms in energy audit |
| **CO-3 :** | Classify different furnace types, boilers, and performance parameters |

| | |
|---|---|
| **CO-4 :** | Illustrate different electric motor types and technical details of their operation |
| **CO-5 :** | Understand and interpret various environment concerns and various guidelines |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Basics of energy & its various forms: Electricity basics – DC and AC currents, electricity tariff, load management and maximum demand control, power factor. Thermal basics – fuels, thermal energy content of fuels, temperature and pressure, heat capacity, sensible & latent heat, evaporation, condensation, steam, moist air, humidity and heat transfer, units and conversion. -Energy Conservation Act-2001 and its Features. | **9** |
| Unit II | Energy management and audit: Definition, energy audit – need, types of energy audit, energy management (audit) approach – understanding energy costs, benchmarking, energy performance Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments | **8** |
| Unit III | Boilers: Types, combustion in boilers, performance evaluation, analysis of losses, feed water treatment, blow down, energy conservation opportunities. Furnaces: Classification, general fuel economy measures in furnaces, excess air, heat distribution, temperature control, draft control, waste heat recovery. | 8 |
| Unit IV | Electric motors: Types, Losses in induction motors, Motor efficiency, Factors affecting motor performance, Rewinding and motor replacement issues, Energy saving opportunities with energy efficient motors. Energy Efficient Technologies in Electrical Systems: Maximum demand controllers, Automatic power factor controllers, Energy efficient motors, Soft starters with energy saver, Variable speed drives, Energy efficient transformers. | **9** |
| Unit V | Global environmental concerns: United nations framework convention on climate change (UNFCC), Kyoto protocol, conference of parties (COP), clean development mechanism (CDM), prototype carbon fund (PCF), sustainable development | **7** |

References:

1. CB Smith, Energy Management Principles, Pergamon Press, NewYork, 1981
2. Hamies, Energy Auditing and Conservation; Methods, Measurements, Management & Case study, Hemisphere, Washington, 1980
3. D Patrick and S W Fardo, Energy Management and Conservation, Prentice Hall Inc., 1996
4. Thuman A and Mehta D Paul, Handbook of Energy Engineering, The Fairmount Press., 1998
5. Kennedy, Turner and Capehart, Guide to Energy Management, The Fairmount Press., 1996

SE-614: **Energy Modelling and Simulation**

Course Outcomes:

| | |
|---|---|
| **CO-1 :** | Understand the basics concepts in economics of energy |
| **CO-2 :** | Interpret the energy and environment system analysis |
| **CO-3 :** | Understand the methodology to perform energy demand modelling, forecasting |
| **CO-4 :** | Illustrate the economics of different energy forms and their conservartion |
| **CO-5 :** | Perform the cost analysis for project evaluation |

Syllabus:

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I | Macroeconomic Concepts - Measurement of National Output - Investment Planning and Pricing - Economics of Energy Sources - Reserves and Cost Estimation. | 8 |
| Unit II | Multiplier Analysis - Energy and Environmental Input / Output Analysis – Energy Aggregation –Econometric | **8** |
| Unit III | Energy Demand Modeling - Overview of Econometric Methods. Methodology of Energy Demand Analysis - Methodology for Energy Technology Forecasting - Methodology for Energy Forecasting - Sectoral Energy Demand Forecasting. | **9** |
| Unit IV | Solar Energy - Biomass Energy - Wind Energy and other Renewable Sources of Energy - Economics of Waste - Heat Recovery and Cogeneration - Energy Conservation Economics.. | 8 |
| Unit V | Cost Analysis - Budgetary Control - Financial Management - Techniques for Project Evaluation. | **7** |

References:

1. M.Munasinghe and P.Meier Energy Policy Analysis and Modeling, Cambridge University Press 1993
2. W.A.Donnelly The Econometrics of Energy Demand: A Survey of Applications, New York.1987
3. S.Pindyck and Daniel L.Rubinfeld Econometrics Models and Economic Forecasts, 3rd edition MC Graw -Hill, New York 1990
4. UN-ESCAP Sectoral Energy Demand Studies: Application of the END-USE Approach to Asian Countries, New York 1991
5. UN-ESCAP Guide Book on Energy -Environment Planning in Developing Countries: Methodological Guide on Economic Sustainability and Environmental Betterment Through Energy Savings and Fuel Switching in Developing Countries, New York 1996

SE-615: **Smart Grid**

Course Outcomes:

| | |
|---|---|
| **CO-1 :** | Understand the basic concepts and current status of smart grids in India |
| **CO-2 :** | Identify different communication network and technical details |
| **CO-3 :** | Analyse the use of power electronics in smart grid systems |
| **CO-4 :** | Illustrate technologies for improvement of smart grid systems |
| **CO-5 :** | Explain the challenges and possibilities in transmission systems |

Syllabus:

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I | Introduction –driving the move towards Smart Grids globally and in India Smart Grid. Overview of how Indian power market is organised, operated and challenges being faced. Overview of how the Indian GENERATION, TRANSMISSION and DISTRIBUTION business is operated and controlled and some of the challenges being faced. How software can manage generation and optimise generator performance, Software to support integration of renewables, System planning & condition monitoring based maintenance, Forecasting & basic trading, Demand response, Performance management. | **9** |

| | | |
|---|---|---|
| Unit II | Overview of power sector communications, Generic model of communication network needed for Smart-grid, Introduction to different communication technologies available in the market (Latest standards, emphasis on importance of inoperability and standardization of communication protocols), Matrix of different technologies against the smart-grid communication needs in a given utility environment, AMI, AMR & MDA: How it works and how it will help to; reduce peaks manage networks more efficiently and contribute towards smarter grids, Communication Standards IEC6150, Wide Area Situation Awareness (WASA), Network stability and Phasor Measurement Unit (PMU), 6Automation and Integration of Distributed Generation / Renewable Energy, Automation and Micro-grids | **8** |
| Unit III | Distribution Management Systems (DMS) and Meter Data Management (MDM) are improving energy efficiency and security of supply in Distribution Systems, Overview of Power Electronics in Electrical T&D Systems, Power Electronics in emerging Smart Grids, Transmission (DC Super Grids) , Distribution (PE facilitating the integration of, (Distributed Generation, Renewables, Microgrids, Virtual Power Plants (VPP), Storage, Fault Current Limitation, Power Electronics, Super Conducting and Magnetic types id. | **9** |
| Unit IV | Developing technology and systems that will enable grids to work smarter in the future: Storage: Organic and Inorganic Salts & Synthetic Heat Storage, Developing technology and systems that will enable grids to work smarter in the future (Smart Meters, Recording consumption, Advanced payback options for load-management, Communication between the utility and customer’s home (for home automation)), In-home controls, Demand Side Management (DSM).Power Trading & the India Energy Exchange : Encouraging Markets, Regulation enabling grids to work smarter in India, Project Financing: Financial Incentives to Enable Smart Grids in India, Smart Grid Economics: Making Smarter Grids Financially Viable, Planning for Smarter Grids | **9** |
| Unit V | Challenges faced by the Transmission System Developing technology and systems that will enable smarter transmission of bulk energy (Metering, Trading mechanisms, AC – FACTS (Statcom). DC – HVDC, Fault Current Limiters), Challenges faced by the Distribution Networks:( How to be more energy efficient, stable, reliable and environmentally friendly, Reducing losses, Integration of renewables connecting/disconnecting micro-grids and virtual power plants, manage bi-directional energy flows), Developing technology and systems that will enable smarter distribution networks (DC – MVDC, Fault Current Limiters, Others (AC/DC TXs etc)). | **7** |

References:

1. Join Gridwise & Smartgrids groups in LinkedIn http://www.linkedin.com/
2. Sign up to Smart Grid News www.smartgridnews.com
3. USDoE Smart Grid Book
http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf
4. Technology enabling the transformation of India’s power distribution
http://www.infosys.com/newsroom/features/power-sector-report.pdf
5. Gridwise Alliance website http://www.gridwise.org/

SE-616: **Renewable Energy Laboratory**

**Course outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand the application of solar energy and utilisation |
| **CO-2 :** | Understand the application of wind energy and utilisation |
| **CO-3 :** | Analyse the biomass systems |
| **CO-4 :** | Understand the formation of bio-gas system |
| **CO-5 :** | Explain the challenges and advances in Renewable Energy |

Laboratory I:

1. Study on greenhouse effect on solar flat plate collector
2. Estimation of instantaneous efficiency of a solar liquid flat plate collector
3. Study on solar flat plate collector in series and parallel combination
4. Estimation of efficiency of solar air heaters
5. Estimation of efficiency of solar still
6. Performance evaluation of concentrating solar collector
7. Performance evaluation of solar cooker
8. Estimation of efficiency of solar photovoltaic panels
9. Effect of Shadow & tilt angle on solar photo voltaic panel
10. Study on solar photo voltaic panel in series and parallel combination
11. Study on charging characteristics of a lead acid battery using solar photo voltaic panel.
12. Performance Evaluation of Wind Electric Generator
13. Performance Evaluation of Wind Water Pumping System
14. Study on Grid Integration of Wind Electric Generator

Laboratory II:

1. Proximate analysis of solid wastes
2. Calorific value of solid wastes
3. Combustion characteristics of solid wastes
4. Study of Composting of solid wastes
5. Estimation of energy recovery potential of solid wastes
6. Study of refuse derived fuel (RDF)
7. Estimation of BOD, DO level in effluent
8. Estimation of COD level in effluent
9. Evaluation of Fixed Dome biogas plant
10. Evaluation of Floating Drum biogas plant
11. Performance analysis of gasifier
12. Performance analysis various wood stoves
13. Estimation of Calorific Value of Gaseous fuels
14. Characteristics of Fuel Cell
15. Analysis of Non-Edible oil as alternate energy source

SE-628: **Battery and Fuel Cell Technology**

Course Outcomes:

| | |
|---|---|
| **CO-1 :** | Understand the basic concepts and current status of fuel cell technology |
| **CO-2 :** | Identify different parts and thermos-chemistry of fuel cell |

| | |
|---|---|
| **CO-3 :** | Analyse the chemical kinetics of fuel cell |
| **CO-4 :** | Understand the characterization of fuel cell |
| **CO-5 :** | Explain the challenges and advances in fuel cell technology |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Introduction and overview of fuel cell – requirement, history, principle, overview and basic electrochemistry of the fuel cell.<br>Thermodynamics of Fuel Cell- Gibb's free energy, reversible and irreversible losses, fuel cell efficiency, | **9** |
| Unit II | Nernst equation: Effect of temperature, pressure and concentration on Nernst potential, Concept of Electrochemical Potential Components of Fuel cell: Electrolyte, catalyst, bipolar plate/current collector | **8** |
| Unit III | Activation Polarization-electrochemical kinetics, reaction rate, surface coverage, Activation polarization for charge transfer reaction, Butler-Volmer equation, Tafel equation. | **8** |
| Unit IV | Concentration Polarization: Diffusion transport in electrodes, transport through flow channel, concentration polarization, Ohmic polarization: Ionic conductivity and Electronic Conductivity Fuel Cell Characterization: Possible ways of Characterization, IV haracteristics and electrochemical impedance spectroscopy, cyclic voltammetry | **9** |
| Unit V | Comparison of High temperature and low temperature fuel cell, Different types of fuel cell Hydrogen production and storage, safety issues and Cost issues Advances in sold oxide fuel cells | **8** |

References:

1.O 'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, Wiley, N.Y

2. Bard, A. J., L. R., Faulkner, Electrochemical Methods, Wiley, N.Y 3. Basu, S. (Ed) Fuel Cell Science and Technology, Springer, N.Y.

3.Liu, H., Principles of fuel cells, Taylor & Francis, N.Y

4. Electrochemistry of cleaner environments, J OM Bockris , Springer, US

SE-632: **Energy Efficient Materials**

Course Outcomes:

| | |
|---|---|
| **CO-1 :** | Understand the basic concepts alternative material |
| **CO-2 :** | Understand and analyse solar photovoltaic system |
| **CO-3 :** | Analyse the fuel cell technology |
| **CO-4 :** | Illustrate technologies like thermoelectrics and energy harvesting |
| **CO-5 :** | Explain the potential of nuclear based materials |

Syllabus:

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I | Need of Alternative materials, Green Materials, Biomaterials, Natural and synthetic Polymers. | **5** |
| Unit II | Photovoltaic (PV) thin films for solar cells; Organic Solar Cells; dye sensitized solar | **5** |

| | | |
|---|---|---|
| | cells; Thermo photovoltaic (TPV) devices. | |
| Unit III | Fuel cells, the role of the fuel in the operation, performance and degradation of fuel cells; Membrane electrode assemblies for polymer electrolyte membrane fuel cells; | **8** |
| Unit IV | Developments in membranes, catalysts and novel cathode and anode materials; Membranes, adsorbent materials and solvent-based materials for syngas and hydrogen production fuel cells, Batteries, Ultra capacitor; Super capacitors. Thermoelectrics, Novel illumination sources for efficient lighting, Energy saving in buildings. | **10** |
| Unit V | Materials and techniques for energy harvesting; Lithium batteries: Current technologies and future trends. Thermoelectric materials for conversion of heat to electricity.<br>Materials issues for future nuclear energy; Radiation damage, recovery mechanisms, and creep-rupture, modelling and theoretical aspects | **10** |

References:

1. Materials for Renewable and Sustainable Energy (Springer).

# M. Sc. FOOD TECHNOLOGY

## (In association with DFRL, Mysore)

| Semester I | | | | | |
|---|---|---|---|---|---|
| **S. No** | **Course Code** | **Course** | **L** | **T/P** | **Credit** |
| 1 | ACFT 501 | Food Chemistry | 3 | 1 | 4 |
| 2 | ACFT 502 | Food Microbiology | 3 | 1 | 4 |
| 3 | ACFT 503 | Food and Nutrition | 3 | 1 | 4 |
| 4 | ACFT 504 | Principles of food processing and preservation | 3 | 1 | 4 |
| 5 | ACFT 505 | Food Analysis & Sensory Evaluation | 3 | 1 | 4 |
| **Semester II** | | | | | |
| 1 | ACFT 506 | Technology of Fermented Foods | 3 | 1 | 4 |
| 2 | ACFT 507 | Food Standards and Safety Management | 3 | 1 | 4 |
| 3 | ACFT 508 | Technology of Milk & Dairy Products | 3 | 1 | 4 |
| 4 | ACFT 509 | Fundamentals of Food Engineering | 3 | 1 | 4 |
| 5 | Elective I | | 3 | 1 | 4 |
| **Semester III** | | | | | |
| 1 | ACFT 510 | Technology of Fruits, Vegetables and Plantation Crops | 3 | 1 | 4 |
| 2 | ACFT 511 | Technology of Cereals, Pulses and Oil Seeds | 3 | 1 | 4 |
| 3 | ACFT 512 | Technology of Meat, Poultry & Fish Processing | 3 | 1 | 4 |
| 4 | ACFT 513 | Food Packaging Technology | 3 | 1 | 4 |
| 5 | Elective II | | 3 | 1 | 4 |
| **Semester IV** | | | | | |
| 1 | ACFT 541 | Project work | | | 25 |
| | | Total Credits | | | 85 |

(Semester I & II will be conducted at DIAT, Pune and semester III & IV will be conducted at DFRL Mysore)

**Elective I**

| S. No. | Course Code | Course |
|---|---|---|
| 1 | AC-607 | Nano chemical Technology |
| 2 | AC-610 | Recent Advances in Chemistry |
| 3 | DRC-601 | Research Methodology |
| 4 | | Online courses from NPTEL, MOOC |
| 5 | | Open elective from other dept |

**Elective II**

| | | |
|---|---|---|
| 1 | AC-605 | Advanced Analytical Techniques |
| 2 | AC-604 | Chemical Process Design |
| 3 | ACFT 515 | Advanced Food Technology |
| 4 | MS-601 | Introduction to Materials |
| 5 | | Online courses from NPTEL, MOOC |

## DETAILED SYLLABUS

### FOOD CHEMISTRY (ACFT 501)

**Unit-1. General Introduction & scope:** Fundamentals of Chemistry, Physico-chemical and functional properties of various food constituents and importance

**Unit-2. Water:** Physical properties of Water and Ice, Dispersed systems and surface phenomena.

**Unit-3. Carbohydrates**-Classification, structure, sources, Physico-chemical, functional properties of sugars and polysaccharides in foods& their applications.

**Unit-4. Proteins and amino acids**: Classification, structure, sources, physico-chemical, functional properties of proteins &amino acids. Denaturation of proteins. Principles for separation methods. Protein concentrates and isolates. Processing induced physical and chemical changes in Proteins.

**Unit-5. Lipids:** Classification, structure, sources, physico-chemical, functional properties of lipids. Fatty acids- saturated, mono unsaturated and poly-unsaturated. Chemistry of fats and oil and their role.Modifications of lipids.

**Unit-6. Enzymes as biocatalysts** – Classifications, chemistry, classification, mode of action, specificity, assay techniques, isolation and purification, stabilization, enzyme kinetics. Applications of enzymes.

**Unit-7. Vitamins and Minerals:** Classifications, chemistry, structure, biological importance and functions, Role of vitamins in food industry, fortification of foods.

**Unit-8. Anti-nutritional factors & natural toxins:** Types, Chemistry, structure and physico-chemical properties of anti-nutritional factors & natural toxins present in foods.

**Practical**

1. Principles and working of common instruments.
2. Analysis of water with respect to pH, TS, TSS, hardness, chlorine, etc.
3. Estimation of moisture, ash and fats
4. Estimation of proteins by various methods,
5. Estimation of sugars, starch and other polysaccharides
6. Estimation of crude and dietary fibres
7. Estimation of minerals and vitamins
8. Determination of minerals-calcium, phosphorus, iron and vitamins
9. Analysis of lipids-saponification value, acid value and iodine value.

**References**


1. Fennema, O.R.2007. Food Chemistry. Marcel Dekker, CRC Press, New York.
2. Meyer, L.H. 2002. Food Chemistry. CBS publishers and Distributors, New Delhi.
3. Potter, N.N. and Hotchkiss, J.H. (2006), Food Sciences, Fifth edition, CBS publishers and Distributors, New Delhi.
4. Belitz, H.D., Grosch, Werner, Schieberle, Peter 2009. Food Chemistry. Springer Verlag.
5. Salunkhe, O.K. and Kadam, S.S. Eds. 1999. Handbook of World Legumes: Nutritional Chemistry, Processing Technology and.Utilization. Volume I to III. CRC Press, Florida.
6. Salunkhe, D.K. Chavan, J.K., Adsule, R.N. Kadam, S.S. 1992. World Oilseeds: Chemistry, Technology and Utilization, Van Nostrand Reinhold, New York.

## FOOD MICROBIOLOGY (ACFT-502)

**Unit-1. Introduction to Microbiology:** Historical developments, food microbiology and it's scope, structure, growth & nutrition and reproduction of bacteria, yeast, fungi, algae and viruses- A brief account.

**Unit-2. Factors affecting the growth of microorganisms in food** - Intrinsic and extrinsic parameters that affect microbial growth. Cultivation of microorganisms.

**Unit-3. Microbial spoilage of foods:** Different types of spoilage and their controlfor various foods.

**Unit-4. Microorganisms and public health** - Food poisoning, types and importance food poisoning. Bacterial agents of food borne illness; non-bacterial agents of food borne illness - poisonous algae, fungi and food borne viruses - A brief account.

**Unit-5. Physical and chemical factors influencing the destruction** of microorganisms including thermal death time, Z, F and D values. Principles of food preservation; control of water activity.

**Unit-6. Determination of microorganisms and their products in food**: Sampling plan, sample collection, transport and storage, sample preparation for analysis. Microscopic and culture dependent methods.

**Unit-7. Food hygiene and sanitation:** Contamination during handling and processing and its control; indicator organisms; Rapid methods in detection of microorganisms.

**Practical:**

1. Principles and working of common instruments.
2. **Staining techniques**–Monochrome staining, negative staining, gram staining, acid fast staining, spore staining, capsule staining and motility of bacteria.
3. **Pure culture techniques:**Different methods for isolation of pure cultures from spoiled food:
4. **Growth characteristics**:Methods for determination of microbial numbers– direct and plate count; Generation time; various factors influencing microbial growth.
5. **Microbiological quality evaluation of processed food products**: a) Water; b) Milk and milk products. c) Fruits and vegetables. d) Egg, meat and fish products; e) canned/ retort processed food and other commonly consumed processed and street foods.
6. **Pathogenic microorganisms**: Different methods for isolation of pathogenic bacteria and fungi from contaminated foods.

**References**

1. James M.J. (2000) Modern Food Microbiology, 5th Edition, CBS Publishers.
2. Barnart, G.J. (1997) Basic Food Microbiology, CBS Publishers.
3. Adam M.R. & Moss, M.O. (1995) Food Microbiology, New Age International P. ltd.
4. Bibek Ray (1996) Fundamental Food Microbiology, CRC Press~~.~~
5. Waits MJ. 2001. Industrial Microbiology. Blackwell Science.
6. Ward OP. 1989. Fermentation Biotechnology. Prentice Hall.
7. Garbutt J. 1997. Essentials of Food Microbiology. Arnold Heinemann.

## FOOD AND NUTRITION (ACFT 503)

**Unit-1. Introduction to nutrition:** Nutritive value of food, recommended dietary allowance, interrelationship between nutrients, nutritional aspects of carbohydrates, lipids, proteins, vitamins, minerals, fibre, water and electrolyte balance, digestion and absorption of food, energy value of foods, and energy requirements for various conditions, nutrition of infants, children's, adolescents, mother and geriatric nutrition, high altitude nutrition.Military nutrition

**Unit-2. Nutritional requirements & disease control:** Therapeutic nutrition & formulation of special dietary foods; Relation of food and diseases; Deficiencies of essential nutrients; Assessment of nutritional status & RDA; Effect of processing on nutrients; Functional foods with attributes to control cardiovascular diseases, cancer, obesity, ageing etc.,

Nutrition of dietary fibres.Biological value of proteins.Energy value of foods.Techniques of diet and health surveys.Formulation of diets and food products for specific needs.

**Unit-3. Introduction to nutraceuticals:** definitions, synonymous terms, basis of claims for a compounds as a nutraceutical, regulatory issues for nutraceuticals.

**References**


1. Salukhe, O. K. And Kadam, S. S. Eds. 1999. Handbook of world Legumes: Nutritional chemistry, Processing Technology and Utilization Volume I to III. CRC Press
2. Brigelius-Flohe, J and Joost H. G. 2006, Nutritional Genomics; Impact on health and Disease. Wiley VCH.
3. Focus on Nutrition Research, Tony P. Starks, Nova Science, 2006


**PRINCIPLES OF FOOD PROCESSING AND PRESERVATION(ACFT 504)**

**Unit-1. Scope and importance**:Introduction to food processing and preservation. National and international perspectives.Historical development of food processing and preservation.

**Unit-2. Principles of Food Preservation:**Basic principles of food preservation. Drying and Dehydration, Freezing, Ionizing and non-ionizing radiations, Chemical preservation.

**Unit-3. Food processing methods:** Blanching, pasteurization, sterilization, UHT, aseptic processing, canning. Thermal processing and process time calculations.

**Unit-4. Advanced methods of food processing:** Advanced thermal and non-thermal processes. Hurdle Technologies.

Natural preservation methods using sugar, high salt and fermentation.

**Practical**

1: Preparation of intermediate moisture & HT foods,
2: Osmotic dehydration of food
3: Modified and controlled atmosphere packaging,
4: Demonstration of food processing machines.
5: Calculation of *D* and *z* values

**References**


1. Fellows, P. and Ellis H. 1990. Food Processing Technology: Principles and Practice, New York.
2. Potter, N. N. and Hotchkiss, J. H. 1995. Food Science, Springer Science, Fifth Edition


**FOOD ANALYSIS & SENSORY EVALUATION (**ACFT 505)

**Unit-1. Food Component Analysis:** Proximate composition includes protein, fat, moisture ash etc. Analysis of minerals & vitamins & nutritional component. Use of Analytical Techniques in Food Science; Basics, Principles and Applications of UV – Vis Spectrophotometer, Gas Chromatography(GC), High Pressure Liquid Chromatography (HPLC), Atomic Absorption Spectroscopy (AAS), Fourier

Transform Infrared Spectroscopy (FTIR), Differential Scanning Calorimetry (DSC) and Thermo Gravimetric Analysis (TGA). Microwave and IR techniques.

**Unit-2. Introduction to quality attributes of food:**Appearance, flavour, textural factors and additional quality factors. Chemical dimensions of basic tastes- sweet, salt, sour, bitter and umami

**Unit-3.Gustation & Taste perception:**Structure and physiology of taste organs- tongue, papillae, taste buds, salivary glands. Mechanism of taste perception Factors affecting taste quality& evaluation methods foe sensory analysis,Estimation of colour of food by visual /instrumental means.

**Unit-4. Principles and working of common instruments.**

**Practical**

1. Analysis of minerals by using Atomic Absorption Spectroscopy (AAS)/ICP
2. Fatty acid analysis by using GC
3. Determination of vitamins by chromatography
4. Taste evaluation
5. Evaluation of Taste thresholds
6. Taste evaluation by overall acceptability (OAA)

**References**

**1.** Fennema, O.R.2007. Food Chemistry. Marcel Dekker, CRC Press, New York.
**2.** Ranganna. Analysis of food and vegetables, ICAR, New Delhi.
**3.** Sensory Evaluation of Food: Principles and Practices; Harry T. Lawless, Hildegarde Heymann, Springer US, 11-Dec-2013.

## SEMESTER- II

**TECHNOLOGY OF FERMENTED FOODS (**ACFT 506)

**Unit-1. Scope and Importance**: History and Introduction to fermentation Technology, Types of Fermentation, Fermentor Designs.

**Unit-2. Fermentation process:** Media formulations, sterilization, Starter cultures and their maintenance. Factors influencing fermentation process.Downstreamprocess. Primary and secondary metabolites

Fermented food products: Lactic acid fermentation. Ethanol fermentation.Vitamin B-12 fermentation.Soya sauce fermentation.Fermented Dairy products.Wine and Beer fermentation.Vinegar fermentation.Bread making by yeast. Indian traditional foods, pickles, fermented vegetables, Mushroom cultivation, Oriental fermented products, Probiotics.

**Unit-3. GM foods:** Genetically modified microorganisms and foods. Bio-safety, ethics and risk assessment

**Practical**

1. Media preparation and sterilization
2. Fermentation of lactic acid at flask level.
3. Fermentation involving lactic acid bacteria.
4. Identification of simple secondary metabolites such as lactic acid bacteriocins.
5. Fermentation of molasses for ethanol production.

**References**

1. Prescott & Dunn (1992). Industrial Microbiology, 4th Edition. CBS Publishers, NewDelhi.

2. Ward, O.P. (1989). Fermentation Biotechnology- Principles, Process and Products. Prentice Hall Publishers, New Jersey.
3. Stansbury, P.F., Whitakar, A and Hall, S.J. (1995). Principles of Fermentation Technology, Pergamen Press, Oxford.
4. Rehm, H.J., Read, G.B., Puhler, A and Stadler (1999). Biotechnology, Vol. 1-8, VCH Publications.
5. Crueger and Crueger (2000) Biotechnology – A Text book of Industrial Microbiology. IInd edition. Panima Publishing company
6. Bains W. 1993. *Biotechnology from A to Z*. Oxford Univ. Press.
7. Crueger W &Crueger A. 2000. *Biotechnology: A Textbook of Industrial Microbiology*. Madison, USA.
8. Joshi VK & Pandey A. 2003. *Biotechnology Food Fermentation*. Vols. I, II.Education Publ.
9. Knorr D. 2002. *Food Biotechnology*. Marcel Dekker.

**FOOD STANDARDS AND SAFETY MANAGEMENT (**ACFT 507)

**Unit-1. Importance and functions of quality control**: Concept and meaning of food quality and food Safety, food adulteration, food hazards.

**Unit-2. Food laws and regulations –** International and National scenario& law, standards and governing bodies such as FSSAI, USFDA, BIS, AGMARK.Quality management systems in India; Food Safety and Standards Act, 2006; Domestic regulations; various organizations (both global and domestic) dealing with inspection, traceability and authentication, certification and quality assurance.

Sampling procedures and plans, specification of raw materials and finished products, Labeling issues; regulations for waste disposals; Concept of Codex Almentarious/USFDA. Quality assurance, Total Quality Management; GMP/GHP; GLP, GAP; Sanitary and hygienic practices; Quality manuals, documentation and audits, Indian & International quality systems and standards like ISO Overview of ISO, structure, interpretation and case studies of food safety and Quality management.

History, structure, principles, HACCP applications, HACCP based SOPs. Export import policy,; Laboratory quality procedures and assessment of laboratory performance; Applications in different food industries; Food adulteration and food safety.

CASE STUDIES

**References**

1. The training manual for Food Safety Regulators. Vol.II- Food Safety regulations and food safety management. (2011) Food safety and Standards Authority of India. New Delhi.
2. HACCP: A practicalapproach,Mortimre, S., and Wallace, C., (2005) 2$^{nd}$ Ed, Aspen.
3. American Society for Quality by Surak, J.G., and Wilson, S. (2007), 2$^{nd}$ Ed., Quality Press

**TECHNOLOGY OF MILK AND MILKPRODUCTS (**ACFT 508)

**Unit-1. Introduction:**Present status of milk & milk products in India and Abroad; market milk-Composition of milk of various species, quality evaluation and testing of milk, procurement, transportation and processing of market milk, standardization, toning of milk, homogenization, pasteurization, sterilization, storage, transportation and distribution of milk. Cleaning & sanitization of dairyequipments. Special milks such as flavoured, sterilized, recombined & reconstituted toned & double toned. Judging and grading of milk and its products.

**Unit-2. Condensed milk**- Definition, methods of manufacture, evaluation of condensed & evaporated milk; dried milk- Definition, methods of manufacture of skim & whole milk powder, instantization, physiochemical properties, evaluation, defects in dried milk powder.

**Unit-3. Cream-** Definition, classification, composition, cream separation, sampling, neutralization, sterilization, pasteurization & cooling of cream, evaluation, defects in cream;

Butter- Definition, composition, classification, methods of manufacture, theories of churning, evaluation, defects in butter.

**Unit-4. Ice cream-** Definition, composition and standards, nutritive value, classification, methods of manufacture, evaluation, defects in ice cream, and technology aspects of softy manufacture.

**Unit-5. Cheese:** Definition, composition, classification, methods of manufacture, cheddar, Gouda, cottage and processed cheese, evaluation, defects in cheese.

**Unit-6. Indigenous milk products** - Present status, method of manufacture of milk products.

**Unit-7. Milk product processing-** cream, butter oil, cheese, cheese spread, condensed milk, evaporated milk, whole and skimmed milk powder, ice cream, khoa, channa, paneer, fermented milk products. Yoghurt, dahishrikhand and similar products. Drying Theories, Dried milk: Definition and composition, production by drum drying and air spray system; defects; dried milk products–butter-milk powder, whey powder, cream powder, infant milk food. Drying Equipments: Spray Drier, Drum Drier.Novel emerging milk processing techniques. Quality Control in Milk Processing: Tests for evaluation of quality of milk and adulteration.

**Practical**

1. Study on basics of reception of milk at the plant; platform test of milk, physico-chemical, microbiological and sensory analysis of milk and milk products
2. Estimation of fat by Gerbers' method and SNF in milk;
3. Homogenization of milk.
4. Preparation of curd/lassi.
5. Operation of LTLT & HTST Pasteurization;
6. Spray drying of milk.
7. Preparation of special milks;
8. Cream separation.
9. Standardization of milk from cow and buffalo using Pearson's Method.
10. Preparation and evaluation of table butter, ice cream, cheese and indigenous milk product such as *khoa, chhana, paneer, ghee, rosogolla, gulabjamun, shrikhand, lassi, burfi* etc.;
11. Determination of adulterants in milk by milk testing kit.

**References**

1. Aneja RP, Mathur BN, Chandan RC & Banerjee AK. 2002. *Technology of Indian Milk Products*. Dairy India Publ.
2. Walstra P. (Ed.). 2006. *Dairy Science and Technology*. 2nd Ed. Taylor & Francis.
3. Walstra P. 1999. *Dairy Technology*. Marcel Dekker.
4. Dey S.1994. *Outlines of Dairy Technology*. Oxford Univ. Press, New Delhi.
5. Rathore NS *et al.* 2008. *Fundamentals of Dairy Technology - Theory & Practices*. Himanshu Sharma, H, Pandey H, Singh C. 2009. Dairy Science and Technology and Food and Dairy Engineering. CBS Publishers.
6. Spreer E. 1998. Milk and Dairy Product Technology. Marcel Dekker, New York.

## FUNDAMENTALS OF FOOD ENGINEERING (ACFT-509)

**Unit-1. Fundamental Concepts and Definitions :** Introduction to food engineering, Dimensions and units, thermodynamic systems (closed, open and isolated), intensive and extensive properties, equilibrium state, density, specific volume, specific weight, specific heat, enthalpy, entropy, pressure, temperature scales.

**Material Balances:** Principles, process flow diagrams, total mass balance, component mass balance, material balance problems involved in dilution, concentration and dehydration; heat balance calculations.

**Energy Balances:** Principles, energy terms, specific heat of solids and liquids, properties of saturated and superheated steam, heat balances.

**Unit-2. Heat Transfer**

**Conduction:** Fourier's law, thermal conductivity, resistances in series, heat flow through cylinder.

**Convection :** Natural convection and force convection, film coefficient, overall heat transfer coefficients, dimensionless numbers – pandtl number and nusselt and heat transfer from condensing vapours to boiling liquids, heat exchange equipment applied to food insustries – jacketed pans, heaters, coolers – tubular heat exchangers, scrapped surface heat exchangers and plate heat exchangers.

**Radiation:** Stefan-Boltzmann constants. Black bodies. Irradiation of foods. Radiation units and doses for foods, safe limits, irradiation mechanism and survival curve, irradiation of packaging materials.

**Thermal process calculations :** Commercially sterile concept, concept of D, F and Z values, reference F value; effect of temperature on thermal inactivation of micro-organisms, thermal process calculation for canned foods; calculation of processing time in continuous flow systems.

**Evaporation:** Properties of liquid, heat and mass balance, single and multiple effect evaporation, steam economy, heat recovery, efficiency, process calculations, equipment, accessories and systems. Application of evaporators in food industries.

**Unit-3. Mechanical operations :**

**Mixing kneading, and blending:** solid mixing, liquid mixing, classification of equipment and application. Homogenisation.

**Size separation:** filtration theory, constant rate and constant pressure filtration. Classification of filtration equipment – plate and frame filter press, rotary vacuum filters, leaf filters, centrifugal filters and air filters. Sedimentation – sedimentation of solids in liquid and solids in gas – stokes law, centrifulgal separation – equipment and theory.

**Size reduction and classification :** Slicing, dicing, crushing and grinding – laws governing crushing and grinding – classification of equipment and applications. Sieve analysis, standard sieves – types of equipment, vibrating screen, tromels, oscillating, vibrating and planetary equipment.

**Extrusion Cooking :** Theory and applications, extrusion cookers and cold extrusion, single and twin screw extruders, design considerations.

**Unit-4.**

**Distillation :** Vapour-liquid relationships, Raoult's law, Henery's law,boiling point diagram, classification of distillation – batch distillation, steam distillation, vacuum distillation and rectification and their application to food industries.

**Drying :** Theory and Mechanism of drying, moisture and drying rate curves, free moisture content, critical moisture content, equilibrium moisture content, constant and falling rate periods, spray, drum, bin, cabinet, tunnel, vacuum shelf dryer, through flow dryer, fluidized bed dryers, batch and continuous operational, osmotic dehydration, freeze drying and their respective applications in food industries.

**Chilling, refrigeration and freezing:** Shelf life extension requirements for various products, theories, characteristics curve, cooling rate calculations. Chilling and freezing equipment, cryogenics. Freezing – technological principles of freezing operations, freezing systems – direct contact and indirect contact system; influence of freezing rate on food system; freezing time calculations.

**Crystallization:** Solubility, nucleation, super saturation, heat of crystallization, type of crystallization, equipment and applications

**Practicals**

- Mechanical drawing
- Refrigeration plant
- Boiler house
- Pilot plant
- Electrical laboratory
- Instrumentation
- Pumps and Flow meters
- Mass and energy balance
- Determination of water activity
- Heat treatment : pasteurization and sterilization
- Thermal Process calculations
- Canning operations
- Dehydration of fruits and vegetables – drying rate curves
- Numerical Problem based on Mass balance
- Size determination
- Mixing, kneading, blending
- Extrusion products
- Filtration and centrifugation
- Freezing curve

**Recommended Books**

1. R.P. Singh and D.R. Heldman, ‘Introduction to Food Engineering’, Academic Press, INC, London.
2. R.L. Earle, ‘Unit Operations in Food Processing’, Pergamon Press Oxford, U.K.
3. R.T. Toledo, ‘Fundamentals of Food Process Engineering’, CBS Publishers, New Delhi, India.
4. J.C. Batty and S.L. Folkman, ‘Food Engineering Fundamentals’, John Wiley and Sons, New York, U.S.A.
5. J.C. Harper, ‘Elements of Food Engineering’, AVI, Westport, U.S.A.
6. J.G. Brennan, J.R. Butters, N.D. Cowell and A.E.V. Liley, ‘Food Engineering Operations’, Elsevier, New York, U.S.A.
7. Harper, J.C. (1976) Elements of Food Engg., AVI Publ. Co., Westport, Connecticut.

8. Brennan, J.Buffers, J.R., Cowell N.D., Lilly, A.E.V. (1976). Food Engg. Operations, 2nd Ed., Elsevier, New York.
9. Lewis, M.J. (1987). Physical Properties of Foods & Foods Processing Systems, Ellis Horwood, England.
10. Fellows, P.J. (2015). Food processing technology. Elsevier India.
11. Berk, Zeri. (2009). Food process engineering and technology. Elsevier India.
12. Smith, P.G. 'Introduction to Food Process Engineering' Springer, 2005.
13. Gopala Rao, Chandra, 'Essential of Food Process Engineering', BS Publications.


## SEMESTER – III

## TECHNOLOGY OF FRUITS, VEGETABLES & PLANTATION CROPS (ACFT 510)

**Unit-1. Introduction to fruits & vegetables:**History, scope and importance of fruits and vegetables processing and preservation, National and international perspectives.Post harvest technologies of fruits and vegetables.Factors affecting fruits and vegetables preservation (intrinsic and extrinsic factors).Nature and types of spoilage in fruits and vegetables.

**Unit-2. Post harvest Handling & Storage of Fresh Fruits & Vegetables**: Chemical composition; pre and postharvest changes, desirable characteristics of fruits and vegetables for processing.Ripening of climacteric and non climacteric fruits, Maturity indices and standards for selected fruits and vegetables, method of maturity determination, Principles of storage, Types of storage: natural, ventilated low temperature storage, CA and MA storages. Hypobaric storage, pre-cooling and cold storage, Zero energy cool chamber, Physiological disorders: chilling injury and diseases, Factor affecting post harvest losses

**Unit-3. Fruits & vegetables processing**: Role of enzymes in fruits and vegetable processing,Browning in fruits and vegetables, Theory of gel formation, pectin and related compounds,andproductsFermented and non-fermented beverages, Fruit and vegetable, beveragesand fruit based formulations, commodity specific products.

Scope, principle, history, mechanism, advantages and disadvantages of drying and dehydration, methods of dehydration of commercial products, selection of methods based on characteristics of foods to be produced, advantages and disadvantages of different methods. Physical and chemical changes during drying ,control of chemical changes, desirable and undesirable changes. Packaging and storage of dehydrated products.

**Unit-4. Plantation crops:**Importance of plantation crops, chemical composition and processing of tea, coffee, Cocoa and their quality assessment. Instant coffee and tea, monsoon coffee, cocoa beverage.Cocoa processing and chocolate.Spices and volatiles. Minor spices and spice production, processing of spices.

**Practical:**

1. Equipment for fruits and vegetable processing & plant-layout,
2. Preparation of fruit juices, squashes, syrups and ready-to-serve beverages.
3. Canning: of fruits and vegetables.
4. Preparation of jams, jellies, marmalade, preserves, and candies.
5. Preparation of pickles, chutneys.
6.Tomato products
7. Drying of fruits and vegetables,
8. Estimation of caffeine in tea and coffee roasting.
9.Grinding,extraction, blending &packaging of coffee, Pectin determination.
10. Estimation of Browning enzymes,PPO& POD.

11. Determination of salt content.

**References**


1. Dauthy, M.E. 1997. Fruit and Vegetable Processing. International Book Distributing Co. Lucknow, India.
2. Kadar, A. A. 1992. Postharvest Technology of Horticultural Crops. 2nd Ed. University of California.
3. Seymour, G.B., Taylor, J.E. and Tucker, G.A. Ed. 1993. Biochemistry of Fruit Ripening. Chapman and Hall, London.
4. Srivastava, R.P. and Kumar, S. 1998. Fruit and Vegetable Preservation: Principles and Practices. 2nd Ed. International Book Distributing Co. Lucknow.
5. Wildey, R.C. Ed. 1994. Minimally Processed Refrigerated Fruits and Vegetables. Chapman and Hall, London.
6. Wills, R.B.H., McGlasson, W.B., graham, D., Lee, T.H. and Hall, E.G. 1989. Postharvest: An Introduction to the Physiology and Handling of Fruits and Vegetables. BSP Professional Books, Oxford.


**TECHNOLOGY OF CEREALS, PULSES AND OIL SEEDS**(ACFT 511)

General introduction and production and utilization trends; Structure and composition of common cereals, pulses and oilseeds.Postharvest storage of grains.

**Unit-1. Wheat**: Structure, types and physicochemical characteristics; wheat milling - products and by products; factors affecting quality parameters; physical, chemical and rheological tests on wheat flour; additives used in bakery products; flour improvers and bleaching agents; manufacture of bakery products, pasta products and various processed cereal-based foods.

**Unit-2. Rice**: Structure, classification, physicochemical characteristics; cooking quality; rice milling technology; by- products of rice milling and their utilization; Parboiling of rice- technology and effect on quality characteristics; aging of rice - quality changes; processed products based on rice.

**Unit-3. Maize:** Structure, Classification, chemical properties.

**Unit-4. Millets**: Structure, Bajra, Jowar and Ragi etc.

**Unit-5. Bakery:**Bakery and confectionary industry; raw materials and quality parameters; dough development; methods of dough mixing; dough chemistry; rheological testing of dough.Technology for the manufacture of bakery products and the effect of variations in formulation and process parameters on the quality of the finished product; quality consideration and parameters; Staling and losses in baking; machineries used in bakery industry.

**Unit-6. Legumes and oilseeds**: composition, anti-nutritional factors, processing and storage; processing for production of edible oil, meal, flour, protein concentrates and isolates; extrusion cooking technology; snack foods; development of low cost protein foods.

**Practical:**

1. Physical characteristics of grains
2. Texture analysis of grains
3. Oil extraction from oilseed
4. Oil content of oilseeds
5. Free fatty acids, Iodine value
6. Saponification value
7. Peroxide Value
8.Preparation of biscuits
9. Dough rheology

10. Estimation of gluten content, Amylographic studies, Starch damage etc

**Referenc**e


1. Chakrabarty MM. 2003. *Chemistry and Technology of Oils and Fats*. Prentice Hall.
2. Dendy DAV &Dobraszczyk BJ. 2001. *Cereal and Cereal Products*. Aspen.
3. Hoseney RS. 1994. *Principles of Cereal Science and Technology*. 2nd Ed. AACC.
4. Kulp K & Ponte GJ. 2000. *Handbook of Cereal Science and Technology*. 2nd Ed. Marcel Dekker.
5. Lorenz KL.1991. *Handbook of Cereal Science and Technology*. Marcel Dekker.
6. Marshall WE & Wadsworth JI. 1994. *Rice Science and Technology*. Marcel Dekker.
7. Mathews RH. 1989. *Legumes Chemistry, Technology and Human Nutrition*. Marcel Dekker.
8. Salunkhe DK.1992. *World Oilseeds: Chemistry, Technology and Utilization*. VNR.
9. Dubey SC. 2002. *Basic Baking*. The Society of Indian Bakers, New Delhi.
10. Francis FJ. 2000. *Wiley Encyclopedia of Food Science & Technology*. John Wiley & Sons.
11. Manley D. 2000. *Technology of Biscuits, Crackers & Cookies*. 2nd Ed. CRC Press.
12. Pyler EJ. *Bakery Science & Technology*. 3rd Ed. Vols. I, II. Sosland Publ.
13. Qarooni J. 1996. *Flat Bread Technology*. Chapman & Hall.


**TECHNOLOGY OF MEAT, POULTRY AND FISH PROCESSING (**ACFT 512)

**Unit-1. Meat**: Sources of meat and meat products in India, its importance in national economy. Selection of animals for slaughtering, importance of traceability, ante-mortem inspection, grading and safety protocols. Effect of feed, breed and management on meat production and quality.Chemical composition and muscle structure, post-mortem muscle chemistry; meat colour and flavours; meat microbiology and safety.

Modern abattoirs/ meat plants, typical layout and features, design of Ante-mortem handling facilities; hoisting rail and travelling pulley system; stunning methods; Slaughtering of animals and poultry. Steps in slaughtering and dressing; offal handling and inspection; inedible by-products; operational factors affecting meat quality: Rigor mortis, pH changes, colour changes, effects of processing on meat tenderization; abattoir equipment and utilities. Meat quality evaluation, inspection, grading of meat.Mechanical deboning, Meat plant sanitation and safety, By-product utilization.
Chilling and freezing of carcass and meat/poultry; factors responsible for effective chilling and freezing, importance of cold chain facilities, quality changes during chilling and freezing, cold shortening, ripening, DFD and PSE, Factors affecting post-mortem changes - properties and shelf-life of meat.
Processing of meat – pickling, curing and smoking; thermal and non thermal processing methods of preservation – retort processing, different dehydration techniques, high pressure processing, hurdle processing and irradiation.Restructured anddesignedmeatproducts.intermediate moisture and dried meat products; meat plant hygiene – GMP and HACCP; Packaging of meat products.
**Unit-2. Poultry**: classification, composition, preservation methods and processing. Poultry industry in India, measuring the yields and quality characteristics of poultry products, microbiology of poultry meat, spoilage factors; Layout and design of poultry processing plants, Plant sanitation; Poultry meat processing operations, equipment used – Defeathering, bleeding, scalding etc.; Packaging of poultry products, refrigerated storage of poultry meat and by-products
Structure, composition, nutritive value and functional properties of eggs and its preservation by different methods.Processing of egg products. Factors affecting egg quality and measures of egg quality.

Packaging of eggs, egg products, Whole egg powder, Egg yolk products, their manufacture, packaging and storage.

**Unit-3. Fish:**Types of fish, composition, structure, post-mortem changes in fish. Handling of fresh water fish.Canning, smoking, freezing and dehydration of fish.Preparation of fish products, fish sausage and home makings. Commercially important marine products from India; product export and its sustenance; basic biochemistry and microbiology; preservation of postharvest fish freshness; transportation in refrigerated vehicles; deodorization of transport systems; design of refrigerated and insulated trucks; grading and preservation of shell fish; pickling and preparation of fish protein concentrate, fish oil and other by-products.

**Practical**

1. Slaughtering and dressing of meat animals;
2. Study of post-mortem changes;
3. Meat cutting and handling; evaluation of meat quality;
4. Preservation by dehydration, freezing, canning, curing, smoking and pickling of fish and meat;
5. Shelf-life studies on processed meat products;
6. Evaluation of quality of eggs;
7. Preservation of shell eggs;
8. Estimation of meat:bone ratios;
9. Preparation of meat products- barbecued sausages, loaves, burger, fish finger;
10. Application of meat testing kits for quality evaluation.
11. Visit to meat processing plants / modern abattoir

**References**

1. Lawrie, R.A. 2006. Meat Science, 7th Edn. Pergamon Press, Oxford UK.
2. Fidel Toldrá. 2010. Handbook of Meat Processing. Blackwell Publishing, USA.
3. Legarreta IG & Hui Y.H. 2010. Handbook of Poultry Science and Technology, Wiley Publications.
4. Stadelmen, W.J. and Cotterill, O.J., 1995. Egg. Science and Technology. Fourth Edition. by CRC Press.
5. Mead G. 2004. Poultry Meat Processing and Quality, Woodhead Publishing, CRC Press, Boca Raton, New York.
6. Kerry, Kerry &Ledward. 2002. Meat Processing, Woodhead Publishing, CRC Press, Boca Raton, New York.
7. Hui YH. 2001. *Meat Science and Applications*. Marcel Dekker. 32
8. Pearson AM & Gillett TA. 1996. *Processed Meat*. 3rd Ed. Chapman & Hall.
9. Stadelman WJ &Cotterill OJ. 2002. *Egg Science and Technology*. 4th Ed. CBS publications, New Delhi.
10. Bremner H. 2002. Safety and Quality Issues in Fish Processing. Publishing, CRC Press, Boca Raton, New York.
11. Pearson A. M and Dutson T. R. 1995. HACCP in Meat, Poultry, and Fish Processing. Springer Science+Business Media Dordrecht, U.K.

## FOOD PACKAGING TECHNOLOGY (ACFT 513)

**Unit-1. Introduction to food packaging**: Definition, objectives, functions and roles of food packaging, Packaging design and development, Packaging environment, Factors influencing the selection of packaging.

Packaging materials and their properties; Paper: pulping, fibrillation and beating, types of papers. Glass: composition, properties, types of closures, methods of bottle making; Metals: types of cans, tin and aluminium based cans, lacquers; Plastics & polymers used in packaging, their chemical structure and properties.

**Unit-2. Testing of packaging materials**; Mechanical properties their methods of testing and evaluation; Barrier properties of packaging materials: Theoryof permeability, and its measurement, water vapour transmission rate (WVTR) and its measurement, prediction of shelf life of foods using different packaging materials.

Migration from packaging materials, Physical process, Partition Coefficient and sorption process, Determination of migration, food stimulants, Flavour adsorption and sorption, Packaging flavour interaction.

**Unit-3. Different forms of packaging**; rigid, semi rigid and flexible, Liquid and powder filling machines; bottling machines, Form fill seal and multilayer aseptic packaging machines, Packaging Systems and methods, Packaging systems for dehydrated foods, frozen foods, Fats and Oils, dairy products, fresh fruits and vegetables, meat, poultry and sea foods.

Role of packaging in food marketing, aesthetic and graphic design of labels; Coding and marking; nutrition labelling, RFID tag, bar coding, Packaging Laws and regulations, safety aspects of packaging materials; Overall and specific migration, Packaging material residues in food products; Environmental& Economic issues, recycling and waste disposal.

**Practical**

1. Identification and testing of packaging materials, Determination of Grammage, water proofness,
2. Testing of lacquered tin plate sheets;
3. Measurement of tin coating weight; sulphide stain test;
4. Determination of equilibrium moisture content;
5. Grading of glass bottles for alkalinity;
6. Determination of physico – mechanical properties of polymer packaging materials,
7. Determination of water vapour and gas transmission rate of packaging material.
8. Determination of gas composition by Head space analyser.

**References**


1. Robertson, G.L. 2006 Food Packaging: Principles and Practice (2nd ed.), Taylor & Francis.
2. Kadoya T. (Ed). 1990. Food Packaging, Academic Press INC.
3. Mahadeviah M &Gowramma RV. 1996. Food Packaging Materials, Tata McGraw Hill.
4. Gowariker, V.R., Viswanatahan, N. V, Sreedhar, J. 1986, Polymer Science, New Age International (P) Ltd, New Delhi.
5. Ahvenainen, R. (Ed.) 2003, Novel Food Packaging Techniques, CRC Press.
6. Han, J.H. (Ed.) 2005, Innovations in Food Packaging, Elsevier Academic Press.
7. Yam, K. L, Lee, D. S. (Ed.), 2012, Emerging Food Packaging Technologies: Principles and Practice, Woodhead Publishing Ltd.


## ELECTIVE – I

## AC-607: NANO-CHEMICAL TECHNOLOGY

**Unit-1. Introduction:** Definition and concept- dimensionality and size dependent phenomena. 9 Nano and Mesopores materials: Chemistry of size dependent variation in nanomaterials, reactivity etc. Nano-fluids: Basic chemistry of nano-fluids, preparation of nano-fluids, analysis of nano-fluids, applications of nano-fluids. Nanostructures: Chemistry of Quantum dots, nanowires and nanotubes, 2D films. Nano-energetic materials: Introduction, nano-thermites, Advantages and examples, synthesis and thermal properties of nano-thermites. Nano-catalysts: Surface chemistry of nanoparticles, examples, photo-catalysis Polymer nano-composites and hybrid materials: Preparation, Characterization, Applications Nanotechnology for chemical industry: Application in pharmaceuticals, Paint, Coatings, rubber and polymers. Other Topics: Application of nanochemistry/ nanomaterials in civil and defence sector, Characterization of nanoparticles by various analytical techniques

**Unit-2. TRAINING AND PRACTICALS:** Synthesis of metal nanoparticles¬& analysis by particle size distribution and UV-Visible spectroscopy Synthesis of quantum dots and analysis by UV-Visible spectroscopy and Photoluminescence¬ spectroscopy

**TEXT/REFERENCES:-**

1. Nanochemistry: K. Klabunde and Gleb B. Sergeev, Elsevier (2013)
2. Nanotechnology: basic science and emerging technologies – Mick Wilson, KamaliKannangara, Geoff Smith, Michelle Simmons, BurkhardRaguse, Overseas Press(2005).
3. Nanocomposite science and technology, Pulickel M. Ajayan, Linda S. Schadler, Paul V. Braun, Wiley-VCH Verlag, Weihem(2003).
4. Nanotechnology – Edited by Gregory Timp, 1999, Springer
5. Nanocrystal Quantum Dots - Edited by Victor I. Klimov, Second Edition, CRC Press

**<u>RECENT ADVANCES IN CHEMISTRY (AC-610)</u>**

**Unit-1. Introduction: Background and eminent discoveries in Chemical Technology**

**Frontiers in Electrochemistry: Equilibrium properties of electrolytes, electrode potential, electro analytical techniques.**

**Unit-2. Green Chemistry: Principals of green chemistry, sustainability, selected examples of green synthesis.**

**Unit-3. Biochemistry & Biotechnology:** Cell Biology and Physiology, Bioenergetics, Industrial Biotechnology.

**Unit-4. Chemistry of smartmaterials:** Smart materials, their properties, distribution by type chemistry of macromolecules, phase change materials

**TEXT/REFERENCES:**

1. Electrochemistry for Chemists, Sawyer, Sobkowiak, & Roberts, John Wiley, 1995.
2. Concepts in Transition Metal Chemistry, Crabb, Eleanor, Moore, Elaine, Smart, Lesley E.RSC Publishing, 2010
3. Highlights in Bioorganic Chemistry, Carsten Schmuck, HelmaWennemers, Wiley-VCH, 2004.
4. Essentials of Pharmaceutical Chemistry, D. Cairns
5. Intelligent Materials, M. Shahinpoor, H.-J. Schneider, RSC, 2008.

**<u>Research Methodology (DRC-601)</u>**

Introduction, statement of problem, Searching the literature, choice of problem scientific methods in research, E-resources, databases, Execution, analysis and interpretation, Experimental work, design, measurements, Review of published research in the relevant field, plagiarism, Computer Applications, Software tools, simulation tools, Basic statistics and probability distributions, Hypothesis testing, Simulation techniques, Mathematical Modeling, Quantitative Analysis, Technical writing, Report, thesis, Research ethics, Paper Writing, Paper Writing

## ELECTIVE – II

## ADVANCED ANALYTICAL TECHNIQUES (AC-605)

**Unit-1. Instrumental Analysis**: Qualitative analysis, genesis of instrumental analysis, hyphenated techniques Polymeric Techniques: Rheology Techniques, Molecular weight determination

**Unit-2. Thermal Techniques:**ThermoGravimetry (TG), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC)

**Unit-3. Chromatographic Techniques**: Gas Chromatography (GC), High Performance Liquid Chromatography (HPLC), Thin Layer Chromatography (TLC), Ion chromatography. Spectroscopy: Ultra Violet-Visible Spectroscopy UV-VIS, Infra-Red spectroscopy (IR), Nuclear Magnetic Resonance (NMR), Mass spectroscopy, Atomic Absorption Spectroscopy (AAS) Analytical techniques for defence: Types and Implementations. TRAINING AND PRACTICALS: Handling and demonstration of FTIR, UV-visible spectrophotometer, Mass spectrometer, LCMS, HPLC and GC. Analysis of organic compounds by IR and UV-Visible spectroscopy.

**TEXT / REFERENCES:-**

1. Analytical chemistry, 4th edition, G. D. Christian, John Wiley & Sons, New York, (1986).
2. Introduction to Spectroscopy, 4th Edition, D. Pavia, G. Lampman, G. Kriz, J. Vyvyan, Brooks/Crole, 2009.
3. Chromatographic Methods, 5th Edition, A. Braithwaite and F. J. Smith, Chapman and Hall, London (1985).
4. Spectroscopic Identification of Organic Compounds by R. M. Silverstein and G. C. Bassler, 4th edition, Morrill Tevence (1981)
5. Analytical chemistry by G. C. Christian, John Wiley & Sons (1980) Analysis of Explosives by Yitrin&Yinon, Pergamon Press, 1981

## Chemical Process Design (AC-604)

1. A strategy for process synthesis and analysis: The nature of process synthesis and analysis; Engineering Economics; Economic decision making.
2. Cost diagrams and quick screening of process alternatives.
3. Recycle structure of the flow-sheet
4. Separation system;
5. Heat Exchanger networks; Process development for energy harvesting
6. Developing a conceptual design and finding the best flow-sheet: Input information and batch vs. continuous; Input output structure of the flow sheet
7. Computational methods in process design

**TEXT/REFERENCES:-**

1. *Conceptual Design of Chemical Processes*, J. M. Douglas, McGraw Hill, 1988.
2. *Chemical Process Design*, A. C. Dimian, C. S. Bidea, Wiley-VCH, 2008.
3. Computational Methods in Process Simulation, By W. Fred Ramirez, Antony Rowe Ltd. (1997)

**ADVANCED FOOD TECHNOLOGY (ACFT 515)**

**Unit-1. Introduction**, Scope and importance of advanced techniques in food technology, Importance and types of thermal and non thermal processing techniques.

Dielectric heating, Microwave heating, Ohmic heating, Infrared heating, RF heating, Extrusion cooking (Introduction, processing equipment and design, Mode of action, Biological effect and application in food processing).

High hydrostatic pressure in food processing, High intensity pulsed electric field processing, High pressure CO2 processing, Ozone (O3) processing, Electron beam processing, Pulsed light processing, Ultrasonication, Combination processing, Plasma processing, (Introduction, processing equipment and design, Mode of action, Biological effect and application in food processing).

**Unit-2. Application of nanotechnology** in food systems, Introduction and applications in foods human nutrition, preservation, processing. Packaging

**References**


1. Joslyn, M.A. Ed. 1970. Methods in Food Analysis. Academic Press, New York.
2. King, R.D. Ed. 1978. Developments in Food Analysis Techniques-1. Applied Science Publishers Ltd., London.
3. Morris, C.J. and Morris, P. 1976. Separation Methods in Biochemistry 2nd Ed. Pitman Pub., London.
4. Plummer, D.T. 1971. An Introduction to Practical Biochemistry. Mc-Graw Hill Pub. Co., New York.
5. Barbosa-Canovas, G.V., Pothakamury, U.R., Palou, E., Swanson, B.G. 1998. Non Thermal Preservation of Foods. Marcel Dekker, Inc. New York, Basel, Hong Kong.
6. Joslyn, M.A. Ed. 1970.Methods in Food Analysis. Academic Press, New York.
7. Raghuramulu, N., Madhavan Nair, K., and Kalyanasundaram, S. Ed.1983. A Manualof Laboratory Techniques. National Institute of Nutrition, ICMR, Hyderabad.
8. Fellows, P. and Ellis H. 1990. Food Processing Technology: Principles and Practice, New York.
9. Tatiana Koutchma, Larry J. Forney, Carmen I. Moraru, Ultraviolet Light in Food Technology: Principles and Applications, CRC Press, Boca Raotn 2009.
10. Awuah,G. B. Ramaswamy, H. S. ,Tang, J. Radio-Frequency Heating in Food Processing: Principles and Applications, CRC Press, Boca Raotn 2009.
11. Datta, Ashim K. Handbook of Microwave Technology for Food Application, Marcel Dekker Inc. New York 2001.


**INTRODUCTION TO MATERIALS (MS 601)**

**Unit-1.** Introduction, classification of materials; atomic structure, bonding in solids, bonding forces and energies; crystal structure, unit cells, crystal systems, crystallographic points, directions, and planes, crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids: metallic crystal structure, ceramic crystal structure, polymer crystal structure, determination of crystal structure; imperfection in solids: point defects, linear defects, interfacial defects, bulk or volume defects, defects in polymer; phase diagrams: definition and basic concept, phase equilibria, one-component phase diagram, Binary phase diagrams.

**Text/Reference:**


Materials Science and Engineering by William D. Callister, JohnWiley& Sons, Inc. Elements of Materials Science and Engineering by Lawrence H. van Vlack.

# M. Sc. MATERIALS SCIENCE

**Brief Description**:

The Department of Metallurgical and Materials Engineering aims to develop a core competence in teaching and research in the areas of Materials Science/Engineering and its applications to defence technologies and products. Being in defence university, the department offers M. Tech and Ph. D. programs on materials engineering and also engaged in conducting various short-term courses to DRDO and defence officers. The main focus of our research is to investigate the structure-property-performance relationship of various materials for defence applications. To cater the defence need further, department would like to offer M.Sc. program in Materials Science for B.Sc. graduates.

This programme is offered for DRDO employees and officers from Tri-services, defence public sector undertaking, ISRO/DAE personal, industry personal, faculty members from institutes/universities and civilian students. This program is also open to friendly foreign countries.

At present, the Department is equipped with major characterization facilities (few instrument names are mentioned below) such as:

- High Resolution Transmission electron microscope (TEM) with STEM, Lorentz, HAADF and EDAX facilities
- Field emission scanning electron microscope (FESEM) with EDS
- Small angle x-ray scattering (SAXS)
- Physical Property Measuring System (PPMS)
- Wear and friction measurement equipment
- Micro-Hardness Tester
- Brinnel and Rockwell Hardness Tester
- Automatic grinding and polishing machines
- Optical polarizable microscope with image analyzer
- Surface Area Analyzer
- Impedance Analyzer and Electrochemical workstation
- Piezometer
- Corona Poling Unit
- UV-Visible Spectroscopy
- Contact Angle measurement unit

and many materials synthesis facilities also available in the Department such as:

- Spray Pyrolysis set-up
- High-Temperature Furnace
- Centrifuge
- Autoclave
- Vacuum Oven
- Orbital Shaker
- Twin screw extruder
- Plastography
- Two roll mill
- Hydraulic press
- Electro spinning unit
- Homogenizer
- Sonicator

The development of know-how and manufacturing technologies of many strategic and advanced materials like intelligent textiles, biosensors, electrospinning, magnetic materials, engineering adhesives, structural composites, hybrid supercapacitors, functional materials, biomaterials for prosthetics, tissue engineering, plastics processing, piezoelectric materials, super critical foaming technology, additive manufacturing, friction stir processing/welding, crystallographic texture, high entropy alloys, computational materials, batteries etc., are taken up by the faculties and students. The Department is working on many sponsored research projects and the researchers have developed a range of products, including propellers for fuel cells, encapsulated drugs on fibers, magnetic alloys, inorganic oxides for drug delivery, encapsulation and sustained release of anti-cholesterol drugs, polymeric beads and membranes for toxic and heavy metal adsorption (effluent treatment), carbon foams for high-temperature applications and open cell polyurethane foams for automobile applications, development of Ti metal matrix composite, welding of additively manufactured alloys, development of high entropy alloys. Moreover, the Department participates extensively in R&D activities in collaboration with Defence Labs and Establishments of India. International collaborative work is being carried out with Naval Post-graduate School (NPS), California, Crainfield University, UK, Loughborough University, UK, National Ding Hwa University, Taiwan, Weizmann Institute of Science, Israel etc.

**Eligibility:**

The eligibility for the M.Sc. postgraduate programme is B.Sc. or equivalent in any branch of science/mathematics or BE/B.Tech in any branch of Engineering. Also, student should have mathematics subject in 12$^{th}$ standard.

**Organization:**

The programme is of four-semester duration. In each semester (first, second and third semester), students have to undergo 5 courses excluding the last semester. In fourth semester students will have to perform project work. In the third semester, students have the option to choose elective courses. In first, second and third semester, there will be continuous evaluation which may comprise several tests/quizzes (decided by the concerned instructor/s) and a final examination for theory subjects. At the end of the final (fourth) semester, students will submit their thesis before going for final evaluation and present their project work before the expert committee (consists of External / Internal members from various R&D organisations/Institutions / Universities etc.). No credits are counted for attending an audit course.

**Course structure for M.Sc. in Materials Science**

**Semester I**

| Sr. No. | Course Code | Subjects (Theory/Practical) | Contact Hours | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | MS501 | **Structure and Properties of Materials** | 3 | 0 | 2 | 4 |
| 2 | MS502 | **Materials Characterization Techniques** | 3 | 0 | 2 | 4 |
| 3 | MS503 | **Thermodynamics, Kinetics, and Phase Transformations** | 3 | 1 | 0 | 4 |
| 4 | MS504 | **Polymer Synthesis, Manufacturing and Technology** | 3 | 0 | 2 | 4 |
| 5 | MS505 | **Computational Mathematics** | 3 | 1 | 0 | 4 |

**Total credit --20**

**Semester II**

| Sr. No. | Course Code | Subjects (Theory/Practical) | Contact Hours | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | MS506 | **Processing of Metals and Ceramics** | 3 | 0 | 2 | 4 |
| 2 | MS507 | **Principles of Metallurgy** | 3 | 1 | 0 | 4 |
| 3 | MS508 | **Non-destructive Testing** | 3 | 0 | 2 | 4 |
| 4 | MS509 | **Polymer Processing and Rheology** | 3 | 1 | 0 | 4 |
| 5 | MS510 | **Computational Materials Science** | 3 | 1 | 0 | 4 |

**Total credit --20**

**Semester III**

| Sr. No. | Course Code | Subjects (Theory/Practical) | Contact Hours | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | MS511 | **Additive Manufacturing of Materials** | 0 | 0 | 5 | 4 |
| 2 | MS512 | **Composite Materials and Polymer Blends** | 3 | 1 | 0 | 4 |
| 3 | MS513 | **Mini Project** | 3 | 1 | 0 | 4 |
| 4 | | **Elective I** | 3 | 1 | 2 | 4 |
| 5 | | **Elective II** | 3 | 1 | 2 | 4 |

**Total credit -- 20**

**Semester IV**

| Sr. No. | Course Code | Subjects (Theory/Practical) | Contact Hours | | Credits |
|---|---|---|---|---|---|
| | | | L | T/P | |
| 1 | MS541 | **Dissertation** | | 40 | 20 |

**Total credit – 20**

**<u>List of Electives</u>**

| Sr. No. | Course Code | Name of the Course |
|---|---|---|
| **Electives from the Department** | | |
| 1 | MS 514 | Polymer characterization and Testing |
| 2 | MS515 | Nanoscience and Nanotechnology |
| 3 | MS516 | Chemistry of Polymer |
| 4 | MS517 | Biomaterials |
| 5 | MS518 | Functional Materials |

# Since, DIAT adopted choice-based credit system, student can choose any subject from the institute as well as from online platforms (MOOC, SWAYAM etc.) as an elective subject.

**Course Name: Structure and properties of Materials**
**Course Code: MS501**

**Unit I:** Introduction, classification of materials; atomic structure, bonding in solids, bonding forces and energies; crystal structure, unit cells, crystal systems, crystallographic points, directions, and planes,
**Unit II:** Crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids: metallic crystal structure
**Unit III:** Ceramic materials, Basic properties, classification of ceramic materials–conventional and advanced, ceramic crystal structure, Defects in ceramics: types of defects, origin of point defects, defects and electron energy levels, defect equllibria in ceramic crystals
**Unit IV:** Electronic and Magnetic Properties: Free electron theory, Fermi energy, density of states, elements of band theory, semiconductors, Hall effect, dielectric behavior, piezo and ferro-electric behaviour Origin of magnetism in materials, para-, dia-, ferro- and ferri-magnetism
**Unit V:** Thermal and optical properties: Specific heat, heat conduction, thermal diffusivity, thermal expansion, and thermoelectricity, Refractive index, absorption and transmission of electromagnetic radiation, Examples of materials exhibiting the above properties, and their typical/common applications.

**Text Book(s):**

- *Materials Science and Engineering by William D. Callister, JohnWiley& Sons, Inc.*
- *Elements of Materials Science and Engineering by Lawrence H. van Vlack.*

**Reference Book(s):**

- *Elements of Ceramics: F.H Norton*
- *Fundamentals of Ceramics: Barsoum*
- *Introduction to Ceramics: W.D.Kingery*
- *Physical Ceramics for Engineers: VanVlack*
- *Handbook of Ceramics: Editor S. Kumar Ceramic*
- *Materials for Electronics: R.C. Buchanon*

**Course Name: Materials Characterization Techniques**
**Course code: MS502**

**Unit I:** Microscopy: Optical microscopy, concepts of magnification, resolution and depth of focus, types of optical microscopy, sample preparation, SEM: imaging modes, image contrast, illustrative applications, EDS, Basic principle and components of TEM: Contrast mechanisms, bright field, dark field, TEM application in crystal defect analysis, Electron diffraction in TEM
**Unit II:** Diffraction Techniques- Concepts of diffraction, scattering and radiation-matter interactions, X-ray diffraction: phase identification, strain and grain size determination
**Unit III:** Spectroscopic Techniques- Fundamental basis of Spectroscopic analysis, UV-Vis, IR and Raman, X-ray Photon Spectroscopy and Auger electron spectroscopy
**Unit IV:** Thermal Analysis Techniques- DSC, DTA and TGA
**Unit V:** Tensile test, hardness measurement, electrical conductivity, carrier mobility and concentrations.

**Text Book(s):**

- *Elements of X-ray Diffraction, B. D. Cullity, Prentice Hall, 2001*
- *Solid State Chemistry and its Applications, Anthony R. West, Wiley.*

**Reference Book(s):**

1. *Materials Characterization, ASM Handbook Vol 10.*
2. *Characterization of Materials, Vol 1, Elton N. Kaufmann*

C**ourse Name: Thermodynamics, Kinetics, and Phase Transformations**
**Course code: MS503**

**Unit I:** Simple and composite systems, phases, Internal energy, Enthalpy, Entropy, Gibbs Free energy, Specific heat, Laws of thermodynamics, Reversible and Irreversible processes. Generation of Auxiliary Functions: Legendre transforms, Coefficient relations, Maxwells relations, Thermodynamic relations among state functions variables and its application to solids.
**Unit II:** Free energy of single component system: Free energy as a function of temperature, Clausius-Clapeyron Equation, Driving force for solidification.
**Unit III:** Solution thermodynamics: Entropy of mixing, Enthalpy of mixing, Free energy of ideal, regular and real solutions, Chemical potential, Unary and binary phase diagrams and Gibbs free energy.
**Unit IV:** Diffusion: Phenomenology, First and Second law of diffusion, Solution to diffusion equations and error function, Types of diffusion

**Unit V:** Solidification of pure metals and alloys, nucleation and growth, diffusional solid-state phase transformations (precipitation and eutectoid), martensitic transformation

**Text/References**

1. *M. Modell and R.C. Reid, Thermodynamics and its Applications, Prentice-Hall, Englewood Cliffs, New Jersey, 1983.*
2. *H.B. Callen, Thermodynamics and an Introduction to Thermostatics, Jonh Wiley & Sons, New York, 1985.*
3. *R.T. DeHoff, Thermodynamics in Materials Science, McGraw-Hill, Singapore, 1993*
4. *Richard E. Dickerson, Molecular Thermodynamics, W. A. Benjamin, 1969*

**Course Name: Polymer Synthesis, Manufacturing and Technology**
**Course Code: MS504**

**Unit I:** Commodity and general purpose thermoplastics: PE, PP, PS, PVC, Polyesters, Acrylic, PU polymers. Engineering Plastics: Nylon, PC, PBT, PSU, PPO, ABS, Fluoropolymers Thermosetting polymers: Polyurethane, PF, MF, UF, Epoxy, Unsaturated polyester, Alkyds.
**Unit II:** Natural and synthetic rubbers: Recovery of NR hydrocarbon from latex; SBR, Nitrile, CR, CSM, EPDM, IIR, BR, Silicone, TPE,
**Unit III:** Speciality plastics: PEK, PEEK, PPS, PSU, PES etc.
**Unit IV:** Biopolymers such as PLA, PHA/PHB.
**Unit V:** Polymer compounding-need and significance, different compounding ingredients for rubber and plastics (Antioxidants, Light stabilizers, UV stabilizers, Lubricants, Processing aids, Impact modifiers, Flame retardant, antistatic agents. PVC stabilizers and Plasticizers) and their function, use of carbon black, polymer mixing equipments, cross-linking and vulcanization, vulcanization kinetics

**Reference Books:**

- *Textbook of Polymer Science, Fred W. Billmeyer (Wiley)*
- *Polymer alloys and blends by L A Utracki*
- *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

**Course Name: Computational mathematics**
**Course Code: MS505**

**Unit I:** Linear Algebra:
Algebra of real matrices: Determinant, inverse and rank of a matrix; System of linear equations (conditions for unique solution, no solution and infinite number of solutions); Eigenvalues and eigenvectors of matrices; Properties of eigenvalues and eigenvectors of symmetric matrices, diagonalization of matrices; Cayley-Hamilton Theorem.
**Unit II:** Calculus of single and multiple variables:
Limit, Continuity and differentiability; Maxima and minima; Partial derivatives; Total derivative.
**Unit III:** Vector Calculus:
Gradient, divergence and curl; Line integrals, and Green’s theorem.
**Unit IV:** Numerical Solution of Differential Equations:
Concepts of discretization in space/time, implicit, explicit; Taylor’s series; Solution to ODEs; Classification of second order linear partial differential equations; Method of separation of variables: One dimensional heat equation and two-dimensional Laplace equation.

**Text Book(s)**

- *Advanced engineering mathematics: Kreyszig; Wiley.*
- *Advanced engineering mathematics: Jain/Iyenger; Narosa*

**Reference Book(s)**
- *Advanced engineering mathematics: Peter V. O'Neil Cengage Learning*
- *Advanced engineering mathematics: Alan Jeffery; Academic Press*
- *Calculus and analytic geometry: Thomas/Finney; Narosa*
- *Numerical methods for Engineers: Steven C. Chapra and Paymond P. Canale*

**Course Name: Processing of Metals and Ceramics**
**Course Code: MS506**

**Unit I:** Metallic processing: Casting and forming processes, rolling, forging, extrusion, Heat treatment of Ferrous and Aluminium alloys, Mechanical properties of metals
**Unit II:** Processing of ceramics- Preparation of ceramic powder, Compaction, moulding, sintering, refractory manufacturing processes, Mechanical properties of ceramics
**Unit III:** Thin film deposition: evaporation and sputtering techniques, chemical vapour deposition, thin film growth phenomena
**Unit IV:** Practical: Metal processing- rolling and annealing, solgel, co-precipitation

**Text Book(s):**
- *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.*
- *Manufacturing Processes and Materials for Engineers, L. E. Doyle, 1975. Powder 436*

**Reference Book(s)**
- *Metallurgy, Applications, Advantages and Limitations, Klar, Erhard, ASM, 1983, Ohio.*
- *Extrusion: the definitive processing guide and handbook, Giles, Harold F.; Wagner, John R.; Mount, Eldridge M, 2005.*

**Course Name: Principle of Metallurgy**
**Course Code: MS507**

**Unit I:** Phase diagrams, Phase Transformation and Microstructures of Al alloys and steel
**Unit II:** Heat Treatment of steel and Al alloys, TTT and CCT diagram.
**Unit III:** Defects and plastic deformation phenomenon
**Unit IV:** Recovery, Recrystallization and Grain growth
**Unit V:** Strengthening of metals and alloys

**Text/Reference Books:**
- *Introduction to Physical Metallurgy, S H Avner, TATA Mc-Graw Hill, New Delhi, 2001.*
- *Morden Physical Metallurgy, 8th Ed, R.E. Smallman, A.H.W. NGAN, Butterworth Heinemann publications, 2014 417*
- *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986*
- *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors*

**Course Name: Non-Destructive Testing**
**Course Code: MS508**

**Unit I:** Visual Inspection, Liquid Penetrant Testing, Magnetic Particle Testing,
**Unit II:** Eddy Current Testing, Ultrasonic Testing,
**Unit III:** Acoustic Emission Technique, Radiography Technique,
**Unit IV:** Residual Stress Analysis, In-situ Metallography, Automation and Robot in NDT,
**Unit V:** Case study: Grain Size, Weldment and other Structural Components.

**Test Book(s)**

- *Non-destructive Testing of welds, Baldev Raj, C.V. Subramanian and T. Jayakumar, Narosa Publishing House, 2000, Delhi.*

**Reference book(s)**

- *International Advances in non-destructive testing, (Ed.) W. J. Mcgonnagle, Gordon and Breach Science Publishers, 1981, NY.*
- *Non-destructive Testing, Views, Reviews, Previews, (Ed.) L.L.Alston, Oxford University Press, 1970*
- *Nondestructive Evaluation and quality control, ASM handbook, Volume 17,ASM International*

**Course Name: Polymer Processing and Rheology**
**Course Code: MS509**

**Unit I:** Polymer Processing Compression molding, transfer molding, injection molding, blow molding, reaction injection molding, filament winding, SMC, BMC, DMC, extrusion, pultrusion, calendaring, rotational molding, thermoforming, powder coating,
**Unit II:** Rubber processing in two-roll mill, internal mixer.
**Unit III:** Flow of Newtonian and non-Newtonian fluids, different flow equations, dependence of shear modulus on temperature, molecular/segmental deformations at different zones and transitions.
**Unit IV:** Measurements of rheological parameters by capillary rotating, parallel plate, cone-plate rheometer. Visco-elasticity- creep and stress relaxations, mechanical models, control of rheological characteristics through compounding, rubber curing in parallel plate viscometer, ODR and MDR.

**Reference Books:**

- *Commercial Polymer blends by L.A. Utracki*
- *Textbook of Polymer Science, Fred W. Billmeyer (Wiley)*
- *Polymer alloys and blends by L A Utracki*
- *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

**Course Name: Computational Materials Science**
**Course Code: MS510**

**Unit I:** Review of programming in high-level and low-level languages
**Unit II:** Lotka-Volterra Model: Analytical and Numerical Solution; Solving Fick's laws of Diffusion numerically in 1D using low-level language; Diffusion in 3D using advanced solvers; Random Walker model
**Unit III:** Monte Carlo method; Ising Model; Sharp and Diffuse interface models; Phase field method for evolution of microstructure: Cahn-Hilliard and Allen-Cahn model
**Unit IV:** Introduction to Machine Learning: Supervised and Unsupervised models, Fitting and visualization of multidimensional data; Data analytics using principal component analysis

**Text Book(s):**

- *Introduction to Computational Science: Modeling and Simulation for the Sciences, Princeton University Press, A. B. Shiflet and G. W. Shiflet*
- *Introduction to Computational Materials Science – Richard LeSar, Cambridge University Press*

**Reference Book(s):**

- *Computational Materials Engineering: An Introduction to Microstructure Evolution, Elsevier Academic press, K. G. F. Janssens, D. Raabe, E. Kozeschnik, M. A. Miodownik, B. Nestler*
- *David V. Hutton, Fundamentals of Finite Element Analysis*
- *Mathematic physics (V. Balakrishnan)*

- *Numerical Recipes in C(William H. Press, Vetterling, Teutolsky, Flannery)*

**Course Name: Composite Materials and Polymer Blends**
**Course Code: MS511**

**Unit I:** Matrix, reinforcement, types of reinforcing fillers, continuous and discontinuous fibers, carbon, glass, aramid and other fibers, preparation methods and properties, particulate fillers, dispersion and interfacial phenomena, nanofillers, functional fillers.

**Unit II:** Polymer Matrix Composites: Polymer resins – thermosetting resins, thermoplastic resins – reinforcement fibres – rovings -woven fabrics – non woven random mats – various types of fibres. PMC processes – hand lay up processes – spray up processes – compression moulding – reinforced reaction injection moulding – resin transfer moulding – Pultrusion – Filament winding – Injection moulding. Fibre reinforced plastics (FRP), Glass Fibre Reinforced Plastics (GFRP). Mechanics of Composites, basic constitutive equations, rule of mixture, Halpin-Tsai equations etc. Applications of PMC in aerospace, automotive industries

**Unit III:** Metal Matrix Composites: Characteristics of MMC, various types of metal matrix composites alloy vs. MMC, advantages of MMC, limitations of MMC, Reinforcements – particles – fibres. Effect of reinforcement – volume fraction – rule of mixtures. Processing of MMC – powder metallurgy process – diffusion bonding -stir casting – squeeze casting, a spray process, Liquid infiltration In-situ reactions-Interface-measurement of interface properties- applications of MMC in aerospace, automotive industries

**Unit IV:** Ceramic matrix composites, carbon-carbon composites, processing, manufacturing, properties and applications in aerospace and automotive components

**Unit V:** Introduction to polymer blends, nanostructured materials and nanocomposites, Thermodynamics of polymer blends, mixing, factors governing miscibility, immiscible polymers and phase separation. Influence of interface on property of blends and nanocomposites. Compatibilizers and compatibilization. Blends of amorphous & semi-crystalline polymers, inter-penetrating networks, thermoplastic and thermoset blends, rubber toughened polymers, particulate and fiber reinforced composites.

**Text Books:**

- *Mathews F. L. and Rawlings R. D., Composite Materials: Engineering and Science, 1st Edition, Chapman and Hall, London, England, 1994.*
- *Chawla K. K., Composite materials, Second Edition, Springer – Verlag, 1998.*
- *Introduction to Materials Engineering, William Callister*
- *Polymer alloys and blends by L A Utracki*

**References:**

- *Clyne, T. W. and Withers, P. J., Introduction to Metal Matrix Composites, Cambridge University Press, 1993.*
- *Strong, A.B., Fundamentals of Composite Manufacturing, SME, 1989.*
- *Sharma, S.C., Composite materials, Narosa Publications, 2000.*
- *Broutman, L.J. and Krock,R.M., Modern Composite Materials, Addison-Wesley, 1967.*
- *ASM Hand Book, Composites, Vol.21, ASM International, 2001.*

**Course Name: Additive Manufacturing of Materials**
**Course Code: MS 512**
**Unit I:** Basic Introduction
Overview- History- Need classification- Additive Manufacturing Technology in product development- Materials for Additive Manufacturing Technology- Tooling- Applications
**Unit II:** Solid and liquid based additive manufacturing

Classification – Liquid based system- Stereolithography Apparatus (SLA)- Principle, process, advantages and applications – Solid based system- Fused Deposition Modeling- Principle, process, advantages and applications, Laminated object Manufacturing.

**Unit III:** Powder based additive manufacturing

Selective Laser Sintering- Principles of SLS process- Process, advantages and applications, Three-Dimensional Printing – Principle, Process, advantages and applications- Laser Engineered Net Shaping (LENS), Electron Beam Melting.

**Unit IV:** CASE STUDIES

Case studies for metals and alloys, Ceramics and Polymers

**Test Books:**

- *Chua C.K., Leong K.F., and Lim C.C., "Rapid prototyping: Principles and applications". Third Edition, World Scientific Publishers, 2010.*
- *Gebhardt A., "Rapid prototyping", Hanser Gardener Publications, 2003*.

**Reference Books:**

- *Liou L.W. and Liou F.W., "Rapid Prototyping and Engineering applications: A tool box prototype development", CRC Press, 2007.*
- *Kamrani A.K. and Nase E.A., "Rapid Prototyping: Theory and practice: Springer, 2006.*
- *Hilton P.D. and Jacobs P.F., "Rapid Tooling: Technologies and Industrial Applications", CRC press, 2000.*
- *Dougles Bryden, "CAD and Prototyping for Product Design", 2014*

**Course Name: Mini Project**

**Course Code: MS513**

Mini project on selected Topic.

**Course Name: Polymer Characterization and Testing**

**Course Code: MS 514**

**Unit I:** Concept of molecular weight distribution and its significance, concept of average molecular weight, determination of number average, weight average, viscosity average and Z-average molecular weights, polymer crystallinity, analysis of polymers using IR, XRD, thermal (DSC, DMTA, TGA), microscopic (optical and electronic) techniques, Molecular wt. distribution: Broad and Narrow, GPC, mooney viscosity. Polymer solubility and swelling

**Unit II:** Mechanical-static and dynamic, tensile, flexural, compressive, abrasion, endurance, fatigue, hardness, tear, resilience, impact, toughness.

**Unit III:** Conductivity-thermal and electrical, dielectric constant, dissipation factor, power factor, electric resistance, surface resistivity, volume resistivity,

**Unit IV:** swelling, aging resistance, environmental stress cracking resistance, limiting oxygen index. Heat deflection temperature –Vicat softening temperature, Brittleness temperature, Glass transition temperature, Coefficient of thermal expansion, Shrinkage, Flammability, dielectric constant, dissipation factor, power factor.

**Unit V:** Optical Properties - Refractive Index, Luminous Transmittance and Haze, Melt flow index

**<u>Reference Books:</u>**

- *Textbook of Polymer Science, Fred W. Billmeyer (Wiley)*
- *Polymer alloys and blends by L A Utracki*
- *Polymer nanocomposites: processing, characterization, and applications by Josheph*

*H. Koo (McGraw-Hill Nanoscience and Technology)*

**Course Name: Nanoscience and Nanotechnology**
**Course Code: MS515**

**Unit I:** Overview of Nanostructures and Nanomaterials; Synthesis of Nanomaterials: Types and strategies for synthesis of nanomaterials;
**Unit II:** Crystalline nanomaterials and defects therein; Hybrid nanomaterials; Multiscale hierarchical structures built out of nanosized building blocks (nano to macro); Nanomaterials in Nature: Nacre, Gecko, Teeth; Nanostructures: Carbon Nanotubes, Fullerenes, Nanowires, Quantum Dots.
**Unit III:** Cells response to Nanostructures; Surfaces and interfaces in nanostructures, Ceramic interfaces, Superhydrophobic surfaces, Grain boundaries in Nanocrystalline materials,
**Unit IV:** Thermodynamics of Nanomaterials; Overview of properties of nanostructures and nanomaterials; Overview of characterization of nanostructures and nanomaterials
**Unit V:** Applications of Nanotechnology in various fields

**Text Book(s)**
- *T. Pradeep, NANO: The Essentials,Tata McGraw-Hill Publisher, 2007. ISBN-13:978-0-07-061788-9.*

**Reference Book(s)**
- *K. Haghi, G. E. Zaikov, Advanced Nanotube and Nanofiber Materials, Nova Science Publishers Inc, 2012*
- *Vladimir V. Mitin, Viatcheslav A. Kochelap, Michael A. Stroscio, Introduction to Nanoelectronics: Science, Nanotechnology, Engineering, and Applications, Cambridge University Press, 2008*

**Course Name: Chemistry of Polymers**
**Course Code: MS516**

**Unit I:** Chemistry of High Polymers Monomers, functionality, degree of polymerizations, classification of polymers, glass transition, melting transition, criteria for rubberiness.
**Unit II:** Polymerization methods: addition and condensation; their kinetics, metallocene polymers and other newer methods of polymerization, copolymerization, monomer reactivity ratios, and its significance, kinetics, different copolymers, random, alternating, azeotropic copolymerization.
**Unit III:** Block and graft copolymers, techniques for polymerization-bulk, solution, suspension, emulsion.
**Unit IV:** Concept of intermolecular order (morphology) – amorphous, crystalline, orientation states. Factor affecting crystallinity. Crystalline transition. Effect of morphology on polymer properties.

**<u>Reference Books:</u>**
- *Textbook of Polymer Science, Fred W. Billmeyer (Wiley)*
- *Polymer alloys and blends by L A Utracki*
- *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

**Course Name: Biomaterials**
**Course Code: MS517**

**Unit I:** Introduction to biomaterials, Tissue Engineering, Biocompatibility, Biodegradation Biofluids and medical devices, Biostructures
**Unit II:** Ceramic based biomaterials, metallic biomaterials, polymer based biomaterials, Biofluidici, medical devices, Biostructures
**Unit III:** Nano-biomaterials: Self assembly of nanomaterials, hydrophilic, hydrophobic and surfaces, biomimicking

**Unit IV:** Medical imaging, electrospinning of scaffold structures, Additive manufacturing of medical devices, biofluidics and biostructure
**Unit V:** Case studies: Lotusleaf, Gecko feet, Nacre/Bone. Application of nanocomposite biomaterials: artificial biomaterials, antidragcoatings,self-cleaning surfaces,sensors, Riboswitches

**Text Book(s):**
- *Biomaterials- An Introduction, Joon Park- Publisher Springer 423*

**Reference Book(s):**
- *Biomaterials- Principals and Applications- Joon Park- CRC Press*
- *Handbook of Biomaterial Properties- Garth Hastings- Springer*
- *Handbook of Biomaterials Properties- William Murphy- Springer*
- *Handbook of Biomaterial Properties- Jonathan Black- Chapman and Hal*

**Course Name: Functional Materials**
**Course Code: MS518**

**Unit I:** Shape memory and Superelastic alloys: shape memory effect, thermodynamics of martensitic transformation, Stress induced martensite and superelasticity, Ni-Ti and Ni-Al based alloys and their applications.
**Unit II:** Magnetic materials: Soft and hard magnetic materials, remnant magnetic material, rare earth magnets, Finemet alloys.
**Unit III**: Opto-electronic Materials: Optical properties of semiconductors, absorption and emission processes, Electronic materials such as GaAs and GaN.
**Unit IV:** Sensor: Metal oxide based sensors, Principles of operation

**Text/References**
*Shape memory Materials: K. Otsuka and C. M. Wayman; Cambridge University Press*
*Principles of Electronic Materials and Devices: S. O. Kasap; McGraw Hill Publications*

# M.Sc. APPLIED CHEMISTRY

| No | Course Code | Course | L | T/P | Credit |
|---|---|---|---|---|---|
| **SEMESTER I** | | | | | |
| 1 | AC 501 | Inorganic Chemistry-I | 3 | 1 | 4 |
| 2 | AC 502 | Organic Chemistry-I | 3 | 1 | 4 |
| 3 | AC 503 | Physical Chemistry-I | 3 | 1 | 4 |
| 4 | AC 504 | Analytical Chemistry | 3 | 1 | 4 |
| 5 | AC 541 | Applied Chemistry Laboratory-I | 3 | 1 | 2 |
| **SEMESTER II** | | | | | |
| 1 | AC 505 | Inorganic Chemistry-II | 3 | 1 | 4 |
| 2 | AC 506 | Organic Chemistry –II | 3 | 1 | 4 |
| 3 | AC 507 | Physical Chemistry-II | 3 | 1 | 4 |
| 4 | AC 508 | Molecular Spectroscopy-I | 3 | 1 | 4 |
| 5 | AC 509 | Polymer Chemistry | 3 | 1 | 4 |
| 6 | AC 542 | Applied Chemistry Laboratory-II | | 2 | 2 |
| **SEMESTER III** | | | | | |
| 1 | AC 510 | Organometallic Chemistry and Catalysis | 3 | 1 | 4 |
| 2 | AC 511 | Industrial Chemistry | 3 | 1 | 4 |
| 3 | | *Elective I* | 3 | 1 | 4 |
| 4 | | *Elective II* | 3 | 1 | 4 |
| 5 | | *Elective III* | 3 | 1 | 4 |
| 6 | AC 543 | Industrial Chemistry laboratory | | 2 | 2 |
| | | | | | |
| **SEMESTER IV** | | | | | |
| 1 | AC 544 | M.Sc. Project Dissertation | 3 | 1 | 23 |
| | | Credits Total | | | 85 |

## LIST OF ELECTIVE COURSES

| S. No. | Course Code | Course |
|---|---|---|
| 1 | AC-607 | Nano Chemistry |
| 2 | AC-610 | Recent Advances in Chemistry |
| 3 | AC 512 | Molecular Spectroscopy II |
| 4 | AC-513 | Defence Chemistry |
| 5 | MS-501 | Introduction to material science |
| 6 | PGC-601 | Research Methodology |
| 7 | | Online courses from NPTEL, MOOC. SWAYAM |
| 8 | | Open elective from any Department |
| 9 | | Bio-chemistry |
| 10 | | Quantum Chemistry |

## DETAILED SYLLABUS OF SEMESTER -I
## INORGANIC CHEMISTRY-I (AC 501)

### UNIT I: MAIN GROUP ELEMENTS

Hydrides, halides, oxides, oxoacids, nitrides, sulfides – shapes and reactivity. Structure and bonding of boranes, carboranes, silicones, silicates, boron nitride, borazines and phosphazenes. Allotropes of carbon, phosphorous and sulphur. Industrial synthesis of compounds of main group elements. Chemistry of noble gases, pseudo-halogens, and interhalogen compounds. Acid-base concepts and principles

### UNIT II: TRANSITION ELEMENTS

Coordination chemistry – structure and isomerism, theories of bonding. Energy level diagrams in various crystal fields, CFSE, applications of CFT, Jahn-Teller distortion. Electronic spectra of transition metal complexes: spectroscopic term symbols, selection rules, Orgel and Tanabe-Sugano diagrams, nephelauxetic effect and Racah parameter, charge-transfer spectra. Magnetic properties of transition metal complexes. Reaction mechanisms: kinetic and thermodynamic stability, substitution and redox reactions. Metal-metal multiple bond.

### UNIT III: LANTHANIDES AND ACTINIDES

Recovery, Periodic properties, spectra and magnetic properties.

### UNIT IV APPLICATION OF INORGANIC CHEMISTRY IN INDUSTRY

Manufacture of inorganic products on a large scale such as the heavy inorganics (chloralkalis, sulfuric acid, sulfates) and fertilizers (potassium, nitrogen, and phosphorus products)

### TEXT BOOKS:

1. Concise Inorganic Chemistry - J. D. Lee
2. Inorganic Chemistry -Meissler & Tarr
3. Mechanism of Inorganic Reactions – Fred Basolo, Ralph G. Pearson
4. Inorganic Chemistry: Principles of Structure and Reactivity – James E. Huheey

## ORGANIC CHEMISTRY-I (AC 502)

### UNIT I: STEREOCHEMISTRY

Chirality and symmetry of organic molecules with or without chiral centres and determination of their absolute configurations. Relative stereochemistry in compounds having more than one stereogenic centre. Homotopic, enantiotopic and diastereotopic atoms, groups and faces. Stereoselective and stereospecific synthesis. Conformational analysis of acyclic and cyclic compounds. Geometrical isomerism and optical isomerism. Configurational and conformational effects, atrop isomerism, and neighbouring group participation on reactivity and selectivity/specificity.

### UNIT II: REACTION MECHANISMS

Basic mechanistic concepts – kinetic versus thermodynamic control, Hammond's postulate and Curtin-Hammett principle. Methods of determining reaction mechanisms through kinetics, identification of products, intermediates and isotopic labelling. Linear free-energy relationship – Hammett and Taft equations. Nucleophilic and electrophilic substitution reactions (both aromatic and aliphatic). Addition reactions to carbon-carbon and carbon-heteroatom (N and O) multiple bonds. Elimination reactions. Reactive intermediates – carbocations, carbanions, carbenes, nitrenes, arynes and free radicals. Molecular rearrangements.

**UNIT III: ORGANIC SYNTHESIS**

Synthesis, reactions, mechanisms and selectivity involving the following classes of compounds – alkenes, alkynes, arenes, alcohols, phenols, aldehydes, ketones, carboxylic acids, esters, nitriles, halides, nitro compounds, amines and amides. Concepts of multistep synthesis – retrosynthetic analysis, strategic disconnections, synthons and synthetic equivalents. Selectivity in organic synthesis – chemo-, regio- and stereoselectivity. Protection and deprotection of functional groups. Concepts of asymmetric synthesis – resolution (including enzymatic), desymmetrization and use of chiral auxiliaries, organo catalysis. Carbon carbon and carbon-heteroatom bond forming reactions through enolates (including boron enolates), enamines and silyl enol ethers. Stereoselective addition to C=O groups (Cram, Prelog and Felkin-Anh models).

**TEXT BOOK:**

1. Stereochemistry Conformation and Mechanism **-P.S. Kalsi**
2. Stereochemistry of Organic Compounds **- E. L. Eliel**
3. A Guidebook to Mechanism in Organic Chemistry **– Peter Sykes**
4. Organic Chemistry **-Clayden, Greeves, Warren and Wothers**
5. Modern Methods of Organic Synthesis **– William Carruthers, Iain Coldham**
6. Organic Synthesis the disconnection approach **– Stuart Warren**
7. **Advanced organic Chemistry: Jerry March, Wiley &Sons**

## PHYSICAL CHEMISTRY-I (AC 503)

**UNIT I: THERMODYNAMICS**

Brief description of the laws of thermodynamics, Concepts of Entropy and Residual Entropy, Free energy and its Temperature dependence, Thermodynamic Equilibria and Free Energy Functions, Physical Equilibria Involving Phase Transitions, Thermodynamic Maxwell Relations.

**UNIT II: EQUILIBRIUM THERMODYNAMICS**

Partial molar quantities, Determinations of the partial molar quantities, Chemical potential and other thermodynamic functions, Variation of chemical potential with temperature and pressure, Chemical potential for Ideal gas mixture, Thermodynamic Functions of Mixing, Concepts of Fugacity and its determination, non-ideal systems: Excess functions for non-ideal solutions. Gibbs Duhem Margules equation and its applications.

**UNIT III: NON EQUILIBRIUM THERMODYNAMICS**

Thermodynamic criteria for non-equilibrium states, Basic Postulates and Methodology, Onsager's Theory, Phenomenological Laws and Equations, Transformations of the generalized fluxes and forces, Microscopic Reversibility and Onsager's Reciprocal Relations, Entropy Production and entropy flow, Theorem of Minimum Entropy Production, Chemical Reactions, Coupled Reactions and Electro-kinetic Phenomena.

**UNIT IV: STATISTICAL THERMODYNAMICS**

Concept of distribution, corresponding distribution laws (using Lagrange's method of undetermined multipliers). Partition function, calculation of thermodynamic properties in terms of partition function. Applications of partition functions.

**UNIT V: EQUILIBRIUM**

Ideal and Non-ideal solutions, Raoult's Law and Henry's Law, Chemical equilibria. Dependence of equilibrium constant on temperature and pressure. Ionic mobility and conductivity. Debye-Hückel limiting law. Debye-Hückel-Onsager equation. Standard electrode potentials and electrochemical cells. Nernst Equation and its application, relationship between Electrode potential and thermodynamic quantities, Potentiometric and conductometric titrations. Phase rule. Clausius- Clapeyron equation. Phase diagram of one component systems: $CO_2$, $H_2O$, S; two component systems: liquid- vapour, liquid-liquid and solid-liquid systems. Fractional distillation. Azeotropes and eutectics.

**TEXT BOOK:**

1. Chemical Kinetics and Catalysis – Richard Mishel
2. Chemical Kinetics – Keith J Laidler
3. A text book of Physical Chemistry (Vol-V) – K. L. Kapoor
4. Fundamentals of Molecular Spectroscopy – Colin N. Banwell

## ANALYTICAL CHEMISTRY (AC 504)

**UNIT I: CONCEPTS OF ANALYTICAL CHEMISTRY**

Classification of Analytical Methods: An overview of Classical methods, Types of Instrumental methods Selection of an analytical methods and their performance criteria. Concepts of optical methods: Electromagnetic spectrum, transitions, components in optical instruments, sources, description of LASER, wavelength selectors, monochromator functioning, effective band width, detectors and description of diode array type detector. Atomic Absorption Spectrometry: Principle, interferences, use of electro thermal analyser, hydride generator and cold vapour for trace metal analysis.

**UNIT II: MASS SPECTROMETRY**

Fragmentation and rearrangements (including Mc Lafferty rearrangement) of different classes of organic molecules. Isotope effects etc. and basics of HRMS, and its necessity in organic synthetic chemistry field.

**UNIT III: ELECTRO-ANALYTICAL TECHNIQUES**

Heterogeneous electron transfer and concept of capacitive and faradic current. Cyclic volt ammo gram.

**UNIT IV: INSTRUMENTATION**

three-electrode potentiometer and electrodes. Measurements and analyses of the voltammograms. Differential pulse voltammetry and coulometry. Application of cyclic voltammetry in inorganic and organic chemistry.

**UNIT V: FLUORESCENCE SPECTROSCOPY**

Fluorescence energy transfer and its applications to measurement of distances in molecules.

**UNIT VI: THERMAL ANALYSIS**

Thermogravimetric analysis (TGA) and its applications to inorganic and polymer material characterization. Differential scanning colourimetry (DSC) and its application to inorganic materials.

**UNIT VII: CHROMATOGRAPHY**

Fundamental of chromatographic separations, retention time, distribution ratio, K factor. High Performance Liquid Chromatography (HPLC) its application to organic compounds. Gas Chromatography (GC) and its applications to synthesis and environmental fields (with one example each).

**TEXT BOOKS**

1. Analytical Chemistry Skoog and Skoog,
2. NMR Spectroscopy- An Introduction, H. Gunther, John Wiley,1980.
3. Basic One and Two-Dimensional NMR Spectroscopy, H. Friebolin, VCH,1991. Spectroscopic Methods in Organic Chemistry, D. H. Williams andI.Fleming,4$^{th}$ ed., 1988. Spectrometric Identification of Organic Compounds, R.M. Silverstein, G.C.Bassler and T.C. Morrill, John Wiley & Sons,NewYork,5th Ed.1991.
4. Electron Paramagnetic Resonance, Elementary Theory and Practical Applications, Weil, John A, J. R.Bolton, and Wertz, J.E, Wiley-Inter science, New York,(1994).
5. Structural Methods in Inorganic Chemistry, E. A. V. Ebsworth, D.W.H. Rankin, & S.Cradoc k, 2$^{nd}$ Ed.1991,CRC Press, Boca Raton, Florida

**APPLIED CHEMISTRY LABORATORY I (AC-541)**

I. Semi-micro-qualitative analysis of transition metal ions in a mixture by wet test and Spot technique. (Any 2).

II. Synthesis of Inorganic complexes (Any 3)
   1. Potassium tri-oxalato-chromate (III)
   2. Bis(ethylene-di-ammine) copper (II) sulphate
   3. Hexa-ammine nickel (II) chloride/sulphate
   4. Magnesium oxinate
   5. Tris (Acetylacetonato) Iron III

III. Non-Instrumental Experiments (Any Three)
   1. Determination of heat of solution of benzoic acid / salicylic acid by solubility
   2. Study of variation of solubility of calcium sulphate with ionic strength and hence determine the thermodynamic solubility product. (Complexometric titration with EDTA)
   3. Determination of equilibrium constant of the reaction KI + I2 KI3 by distribution method.
   4. Determination of energy of activation of acid catalysed hydrolysis reaction of methyl acetate.

IV. Synthesis and determination of % yield of organic derivative (Any four).
   1. β-Napthyl methyl ether from β-Naphthol
   2. m-dinitrobenzene from Nitrobenzene
   3. Aromatic acid from ester
   4. Benzanilide from aniline

5. p-nitroaniline from Acetanilide
6. p-Bromo acetanilide from aniline
7. Phthalimide from phthalic acid

## SELECTED TEXT BOOKS:


1. Elias, A.J., A Collection of Interesting General Chemistry Experiments, Universities Press, (India) Pvt. Ltd., 2002.
2. Roesky, H. W.; Möckel, K., Chemical Curiosities: spectacular experiments and inspired quotes, VCH, 1996. Hand-outs prepared for the laboratory experiments: collections from various literature sources
3. l.G., Svehla, 'Vogel's Qualitative Inorganic Analysis',6thEdn., Orient Longman New Delhi, l987.
4. V.V., Ramanujam, 'Inorganic Semi-micro Qualitative Analysis', 3rd Edn., National Publishing Company, Madras, l990.
5. A. I. Vogel, Vogel's Text Book of Quantitative Inorganic Analysis, 6th Ed., Pearson Education, 2000.
6. J. D. Woolins, Inorganic Experiments, Wiley-VCH Verlag GmbH and Co., 2003.
7. W. G. Palmer, Experiments in Inorganic Chemistry, Cambridge University Press, 1954.
8. G. Raj, Advanced Practical Inorganic Chemistry,
9. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 and 2, Academic Press, 1967.
10. G. Marr and B. W. Rockette, Practical Inorganic Chemistry, Van Nostrnad Reinhond, 1972.
11. G. Pass and H. Sutcliffe, Practical Inorganic Chemistry, 2nd Ed., Chapman and Hall, 1985.


## DETAILED SYLLABUS OF SEMESTER -II

## INORGANIC CHEMISTRY-II (AC 505)

### UNIT I:. BIO-INORGANIC CHEMISTRY

Occurrence and availability of Inorganic elements in organisms, transport and storage of Inorganic elements, Dose response of an element, biological function of inorganic elements, beneficial and toxic elements, essential and tracemet

Sidrophore, phytosidrophores, ferretin, transferrin, hemosiderine, biomineralization, assembly of advanced materials e.g. calcium phosphate, calcium carbonate, ironbiominerals.

Oxygen transport and storage through hemoglobin and myglobin, Alternative oxygen transport in lower organisms. Photosynthesis: Photochemistry, absorption spectra of photosynthetic pigments, photophosphorylation - energy conversion process Role of Alkali and alkaline earth metals in neuro sensation. Ion Channels, ion pumps, magnesium catalysis of phosphate, ubiquitous regulatory role of calcium. Biological ligands for metal ions: Macrocycle, nucleobase, nucleotides and nucleic acids, coordination of metals by protein. Heme and nonheme protein, oxygen uptake, structure and function of haemoglobin, myoglobin, hemocyanin, hemotherine Principle involved and role of various metals viz. Zn, Fe, Cu and Co; carboxy peptidase, carbonic anhydrase, Alcohol dehydrogenase, Zinc Fingures, other gene regulatory Zinc proteins, cobalomine, mutase activities of coenzyme B12.

**UNIT III: APPLICATION OF BIO-INORGANIC CHEMISTRY**

Medicinal and therapic; metal deficiency and disease, toxic effect of metals, metals used for diagnosis and chemotherapy, gold compound as Anti-Rheumatic agent. Nitrogen cycle; biological nitrogen fixation, metalloenzyme in biological nitrogen cycle, molybdenum nitrogenase, other nitrogenasemodel

**TEXT BOOKS:**

1. The Organometallic Chemistry of the Transition Metals, by Robert H. Crabtree, Wiley 2014
2. Organo transition Metal Chemistry: From Bonding to Catalysis by John F. Hartwig, University Science Books, 2009
3. Organo transition Metal Chemistry, Anthony F. Hill, Royal Society of Chemistry, 1. Tutorial Chemistry Text, 2002. Chapters 1 to 7.
4. Inorganic Chemistry – Principles of Structure & Reactivity, J E Huheey, Elllen A Keiter &
5. Richard L Keiter, IV Edition(2005)

## ORGANIC CHEMISTRY-II (AC 506)

**UNIT I: PERICYCLIC REACTIONS AND PHOTOCHEMISTRY**

Electrocyclic, cycloaddition and sigma tropic reactions. Orbital correlations – FMO and PMO treatments, Woodward-Hoffmann rule. Photochemistry of alkenes, arenes and carbonyl compounds. Photooxidation and photoreduction. Di-π-methane rearrangement, Barton-McCombie reaction, Norrish type-I and II cleavage reaction.

**UNIT II: HETEROCYCLIC COMPOUNDS**

Structure, preparation, properties and reactions of furan, pyrrole, thiophene, pyridine, indole, quinoline and iso quinoline.

**UNIT III: BIOMOLECULES**

Structure, properties and reactions of mono- and di-saccharides, physicochemical properties of amino acids, chemical synthesis of peptides, chemical structure determination of peptides and proteins, structural features of proteins, nucleic acids, lipids, steroids, terpenoids, carotenoids, and alkaloids.

**UNIT IV: EXPERIMENTAL TECHNIQUES IN ORGANIC CHEMISTRY**

Optical rotation (polarimetry). Applications of various chromatographic techniques such as thin-layer, column, HPLC and GC. Applications of UV-visible, IR, NMR and Mass spectrometry in the structural determination of organic molecules.

**TEXT BOOK:**

A Guidebook to Mechanism in Organic Chemistry **– Peter Sykes**

1. Organic Chemistry **-Clayden, Greeves, Warren and Wothers**
2. Modern Methods of Organic Synthesis **– William Carruthers, Iain Coldham**
3. Organic Synthesis the disconnection approach **– Stuart Warren**
4. Pericyclic Reactions – R T Morrison, R N Boyd
5. Organic Photochemistry – James H. Coxon, B. Halton

# PHYSICAL CHEMISTRY-II (AC 507)

## UNIT I: CHEMICAL KINETICS

Elementary, parallel, opposing and consecutive reactions. Steady state approximation. Mechanisms of complex reactions. Unimolecular reactions. Potential energy surfaces and classical, Activated Complex Theory, Potential energy surfaces- attractive and repulsive forces, Chain reactions and oscillatory reactions, Photochemical reactions. Enzyme kinetics: Michaelis-Menten mechanism- single and double intermediates, Enzyme inhibiton- reversibility and products inhibiton, Molecular beams, principle of crossed-molecular beams. Molecular encounters and principle parameters, e.g. Impact parameter, Collision cross-section, Reaction cross section and relation between reaction cross-section and reaction rate (single velocity). Dependence of collisional cross-section on translational energy. Probing the transition state, Dynamics of barrier-less chemical kinetics in solution, dynamics of unimolecular reactions. Luminescence and energy transfer processes, study of kinetics by stopped-flow technique, relaxation method, flash photolysis and magnetic resonance method. Kinetics of solidstate reactions.

## UNIT II: SURFACE CHEMISTRY

Surface tension, Capillary action, Pressure difference across curved surface (Laplace equation), Vapour pressure of droplets (Kelvin equation), Gibbs adsorption isotherm, BET adsorption isotherm, Surface films (Electro-kinetic phenomenon), Catalytic activity at surfaces. Catalysis on metal surfaces, Metal oxide surfaces. General characteristics of catalytic reactions, Acid-base catalysis, Enzyme catalysis, Mechanism and kinetics of enzyme-catalysed reactions, Michaelis-Menten equation, Heterogeneous catalysis, Surface reactions, Autocatalysis and Oscillatory reactions. Surface active agents, Classification of Surface active agents, Co-surfactants, Micellization, Microemulsions, Aggregate structures of surfactants, Critical Micellar Concentration, Surfactant packing parameter, Factors affecting the CMC of surfactants, Counter ion binding to micelles, Hydrophobic interaction, Thermodynamics of micellization, Mass action models, Solubilization and Phase diagram of ternary microemulsion system.

## UNIT III: GROUP THEORY AND SPECTROSCOPY

Symmetry Elements and Symmetry Operations, Point Groups, Representation of Groups, Reducible and Irreducible Representation; Character Tables, Orthogonality Theorem– Its Consequences; Internal coordinates and vibrational modes; symmetry adapted linear combination of atomic orbitals (LCAO-MO); construction of hybrid orbitals using symmetry aspects. Atomic Spectroscopy: The energies of atomic orbitals; Hydrogen atom spectrum; Orbital and spin angular momenta, total angular momentum; the fine structure of hydrogen atom spectrum; the spectra of alkali metal atoms. The spectra of complex atoms: Singlet and triplet states; Russell-Saunders coupling; Term Symbols and selection rules. Energy levels of molecular orbitals, vibronic transitions, vibrational progressions and geometry of excited states, Franck-Condon principle, electronic and Raman spectroscopy of diatomic and polyatomic molecules. Relationship of transition moment integral with molar extinction coefficient and oscillator strength electronic spectra of polyatomic molecules. Electronic spectra of transition metals Emission spectra: radiative and non-radiative decay, internal conversion, spectra of transition, metal complexes, charge-transfer spectra.

## TEXT BOOK:

1.Chemical Applications of Group Theory – F. Albert Cotton

2.Fundamentals of Molecular Spectroscopy – Colin N. Banwell
3. Physical Methods – Russel S. Drago

## MOLECULAR SPECTROSCOPY-I (AC 508)

Basic elements of spectroscopy, Interaction of Radiation with matter, Time dependent perturbation. Einstein coefficients. Integrated absorption coefficients. Transition dipole moments and general selection rules based on symmetry ideas.

### UNIT I: ATOMIC SPECTRA

Characterization of atomic states. Microstate and spin factoring methods. Hund's rules. Derivation of spin and orbital selection rules (based on recursion relations of Legand re polynomials). Spectra of complex atoms. Zeeman and Stark effects.

### UNIT II: INTRODUCTION TO MOLECULAR SPECTROSCOPY

Rotational spectroscopy of diatomic molecules. Rigid rotor approximation. Determination of bond lengths and/ or atomic masses from microwave spectral data. Effect of isotopic substitution. Non-rigid rotator. Classification of polyatomic molecules. Energy levels and spectra of symmetric top molecules and asymmetric top molecules. First order Stark effect.

### UNIT III: ULTRAVIOLET SPECTROSCOPY

Fundamental of electronic transitions, selection rules for allowed and forbidden transitions. Studies of conjugated and extended conjugated systems etc. Woodward rules. Electronic spectra of transition metal complexes.

### UNIT IV: VIBRATIONAL SPECTROSCOPY

Homonuclear and heteronuclear diatomic molecules. Extension to polyatomic linear molecules. Derivation of selection rules for diatomic molecules based on Harmonic oscillator approximation. Force constants and amplitudes. A harmonic oscillator. Overtones and combination bands. Introduction to normal coordinate analysis.

Dissociation energies from vibrational spectral data. Vibration-rotation spectra, P, Q and R branches. Breakdown of the Born-Oppenheimer approximation. Nuclear spin effect.

Symmetry of normal coordinates. Use of Group Theory in assignment of spectra and selection rules for simple molecules.

### UNIT V: INFRARED SPECTROSCOPY

Identification of the criteria for IR active character of molecules, Identification of functional groups, hydrogen bonding etc., metalling and vibrations.

### BOOKS (MOLECULAR SPECTROSCOPY)

1. Introduction to Spectroscopy, Donald Pavia,
2. Spectrometric Identification of Organic Compounds, R. M. Silverstein, G. C. Bassler and T. C. Morrill, John Wiley & Sons, New York, 5$^{th}$ Ed.1991.
3. Electron Paramagnetic Resonance, Elementary Theory and Practical Applications, Weil, John A, J. R. Bolton, and Wertz, J. E, Wiley-Inter science, New York, (1994).

4. Structural Methods in Inorganic Chemistry, E.A.V. Ebsworth, D.W.H. Rankin, & S. Cradock, 2nd Ed.1991, CRC Press, Boca Raton, Florida,
5. Principles of Fluorescence Spectroscopy, Lackowicz, Plenum Press, (New York,1983)
6. Bernath, Spectra of Atoms and Molecules, 1995.
7. Bunker& Jensen, Molecular Symmetry &Spectroscopy,1998.
8. D. W. Williams and Flemming, Spectroscopic methods of organic compound.

## POLYMER CHEMISTRY (AC 509)

### UNIT I: FUNDAMENTAL CONCEPTS

Functionality - principle of polymerisation - addition, condensation polymerisation - ring opening polymerisation - classification - production from coal tar and petrochemicals - Techniques of polymerisation - gas polymerisation, - bulk, solution, suspension and emulsion - melt condensation. Mechanism of polymerisation and general characteristics - free radical - cationic, anionic and coordination polymerisation (Ziegler-Natta catalyst) auto acceleration - Kinetic chain length - degree of polymerisation, kinetics of polymerisation (Detailed study) - copolymerisation.

### UNIT II: POLYMER CHARACTERISATION

Molecular weight, MWD - Mn, Mw, Mv and Mz - end group analysis - viscometry - osmometry - Light scattering - spectral analysis-Thermal properties – Polymer rheology, Electrical properties, Mechanical and dynamic properties - polymer degradation. Phase transitions of polymers, crystallization and glass transition, mechanism of glass transition, methods of determining Tg.

### UNIT III: STUDIES OF INDIVIDUAL POLYMERS

Plastics - polyolefins, polystyrenes, acrylics, polyesters, polyamides, cellulose, polyurethanes, Inorganic polymers, FIR plastics – GR plastics. alkyd resins, epoxy resins - phenolics - Melamine resins - compounding of plastics - rubber - elastomer - vulcanisation, compression mouldings - injection mouldings - lamination. Biopolymers - Biomaterials - medicinal applications of polymers - High temperature and fire-resistant polymers. Polymer concrete - polymer impregnated concrete - conducting polymers - polymeric reagents.

### UNIT IV: GENERAL CHEMISTRY

Technology of Production, Properties and Applications of Chain growth polymers Polyethylene such as HDPE, MDPE, LDPE, LLDPE, HMWPE, UHMWPE, EVA, crosslinked PE, chlorinated PE, Polypropylene (PP), Polyisobutylene (PIB)), Acrylics (PMMA & PAN), Poly-vinyles like PVC, PVDC & CPVC, Polystyrene & Co-polymer (HIPS, SBR, SAN & ABS), Poly(vinyl acetate).

### TEXT BOOKS

1. P.J. Flory, ‘Principles of Polymer Chemistry’, Cornell Press, (Recent Edition).
2. Jr. Billmeyer, ‘Test Book of Polymer Science’, Fred, W. John Wiley & Sons, N. York, l984.
3. Dan Campbell, Richard A. Pethrick, Jim R. White, Polymer Characterization: Physical Techniques, 2nd Edition, CRC Press, 2012.
4. F. Rodrigues, ‘Principles of Polymer Systems’, M. Elpaw Hill Book Company, 2nd Ed., l982.
5. K.J. Saunders, ‘Organic Polymer Chemistry’, Chapman & Hall, London, l973.

6. Sabu Thomas & Dominique Durand, Handbook of Biopolymer-Based Materials: From Blends and Composites to Gels and Complex Networks, Wiley – VCH, 2013.

## APPLIED CHEMISTRY LABORATORY - II (AC 542)

1. pH metry and potentiometry (Any 02)
2. conductometry and precipitation titrations (Any 01)
3. Synthesis of metal oxides nano particles and analysis by UV (Any 02)
4. To determine order of reaction between $K_2S_2O_8$ solution and KI by fractional change method
5. To determine the acidity of water from the given sample solution.
6. Synthesis of organic compounds and determination of MP and % yields, etc. (Any 03)
    1. Bromobenzene to p-nitro bromobenzene
    2. Nitrobenzene to m-dinitrobromobenzene
    3. Benzoin to Benzil
    4. Anthracene to Anthraquinone
    5. Anthracene-Maleic Anhydride adduct
    6. 5,5-diphenylhydantoin from urea and benzyl
    7. Synthesis of inorganic complexes and determination of % yield. (Any 03)
        1. Synthesis of Magnesium oxinate.
        2. Synthesis of Nickel dioxime
        3. Tetramine copper (II) sulphate
        4. Tris(thiourea) copper (I) suplhate

**REFERENCE BOOKS:**


1. Elementary Practical Organic Chemistry Part-I small scale preparations, A.L. Vogel (Longman)
2. Laboratory Manual of organic chemistry, B.B. Dey and M.V. Sitaram revised by T.R Govindachari (Allied Publishers Ltd)
3. D.P. Shoemaker, C.W. Garland & J.W. Nibber, 'Experiments in Physical Chemistry', McGraw Hill 5th Edn., 1989.
4. A. I. Vogel, 'Text book of Practical Organic Chemistry',5thEdn. ELBS, London, l989.
5. B.B. Dey and M.V. Sitharaman, 'Laboratory Manual of Organic Chemistry' Revised by T.R. Govindachari, Allied Publishers Ltd., New Delhi. 4th Revised Edn. l992.


## DETAILED SYLLABUS OF SEMESTER -III
## ORGANOMETALLIC CHEMISTRY AND CATALYSIS (AC 510)

### UNIT I: ORGANOMETALLICS

18-Electron rule, Oxidation state, co-ordination number and geometry. Effect of complexation with different metals (4d and 5d); Alkyls and hydrides: alkyls and aryls (metal alkyls stabilized carbanion, β-elimination, stable alkyls, agostic alkyls, reductive elimination, preparation of metal allyls). metal hydrides: characterization, synthesis, reactions, bridging hydrides.

### UNIT II: SYNTHESIS, BONDING, PROPERTIES & APPLICATIONS OF ORGANOMETALLICS

Pi complexes, synthesis, bonding. Properties and application of alkenes and alkynes, allyls, diene, cyclopentane, dienyl, arenes. Distinctive organometallic Reactions - Addition and abstraction:

Nucleophilic addition to CO, Nucleoplic addition to polynes and polyenyls, nucleophilic abstraction in hydrides, acyls, electrophilic addition and abstraction, single electron transfer and radical reactions, Oxidative – Addition reactions, Insertion reaction – at MC bond & M-H bond, Trans-metallation reaction and Cyclization reaction, Ring Expansion reaction, Condensation reaction, Sigma-pi rearrangement reaction, Ligand & Metal exchange reactions.. Fluxionality and dynamic equilibria,

**UNIT III: TRANSITION METALs/ORGANOMETALLIC IN ORGANIC SYNTHESIS**

Alkene isomerisation, hydrogenation, hydroformylation, hydrocyanation, hydroboration, coupling reaction. Carbon-carbon bond formation through coupling reactions – Heck, Suzuki, Stille, Sonogoshira, Negishi, Kumada, Hiyama, Tsuji-Trost, olefin metathesis and McMurry.

**UNIT-IV: TYPES OF ORGANOMETALLIC REACTIONS**

Homogeneous catalysis –Catalytic applications of organometallic complexes - Alkene hydrogenation, Synthesis gas (H2/CO), Hydroformylation, Mosanto-acetic acid process, Wacker- Schmidt process and Ziegler-Natta catalysis. Bioorganometallic chemistry and surface organometallic chemistry.

**Books:**

1. Organometallics: A concise Introduction, Ch.Elshebroicn and A Salzer, VCH, 2006.
2. Organotransition Metal Chemistry: Applications to Organic Synthesis, S.G. Davies, Pergamon 1982.

## INDUSTRIAL CHEMISTRY (AC 511)

**UNIT I: CHEMICAL INDUSTRY**

Introduction, Chemical production, Raw materials and their sources, Parameters of Chemical Industry, Plant location, Safety, Construction of plant, Management for productivity and creativity, Training for plant procedure and labour, Chemical process technology, Important chemical processes, Classification of chemical reactions, Batch and continuous operations, Industrial chemical reactions, Conversion, Selectivity and Yield

**UNIT OPERATIONS:**

Introduction, Unit operations- Conveying, Crystallization, Distillation, Drying, Evaporation, Filtration, Leaching, Liquid-liquid extraction, Membrane separation, Particle size reduction and enlargements, Solid -solid separation.

**UNIT PROCESSES**

Introduction, Industrial unit processes- Definition and examples of Alkylation, Amination by amino lysis, Calcination, Carbonylation, Double decomposition, Esterification, Halogenation, Hydro formulation, Hydrolysis, Nitration, Oxidation, Polymerisation, Sulphonation.

**UNIT II: AMINATION BY REDUCTION:**

Introduction and definition, Methods of reduction, Metal and acid Reductions, Metal and alkali reductions, Amination by amino-lysis, aminating agents, physical and chemical factors affecting amino lysis, manufacture of aniline by reduction of nitrobenzene, p-phenylenediamine, aniline by continuous ammonolysis.

**UNIT: III ALKYLATION**

a) **INTRODUCTION AND TYPES** of Alkylation, alkylating agents, factors controlling alkylation, equipment for alkylation, alkylation methods for i) Alkyl-aryl sulphonates, ii) Ethylbenzene, iii) Dimethylaniline.

b) **HYDROLYSIS:** Definition and scope, hydrolyzing agents, materials susceptible to hydrolysis, kinetics, thermodynamics and mechanisms of hydrolysis, Equipment for hydrolysis, Technical operations involving hydrolysis.

c) **OXIDATION:** Liquid and vapour phase oxidations, apparatus for Oxidation, technical oxidation of acetaldehyde, iso-propyl alcohol, naphthalene, and naphthalene sulphonic acid.
Esterification: Esterification of organic acids and derivatives, esters by addition, to unsaturated systems, interesterification of lard, technical preparation of ethyl acetate, cellulose acetate, nitroglycerol, polyethyl ether.

d) **HYDROGENATION:** Catalytic hydrogenation, Apparatus, Industrial processes, Hydrogenation of fatty oils, Synthesis of methanol.
Nitration: Introduction, Nitrating reagents, Aromatic nitration, Nitration of paraffinic hydrocarbons, nitrate esters, N-nitro-compounds, process equipment for technical nitration, Mixed acid nitration, Typical Industrial nitration processes.

**TEXT BOOKS**

1. Unit Processes in Organic Synthesis- P. H. Groggins, Tata McGraw-Hill, 5$^{th}$ Edition, New Delhi, 2010.
2. Dryden's Outline of Chemical Technology, M. Gopal Rao, Marshall Sittig East-West Press Pvt. Ltd., 3rd Edition, 2014.
3. Chemical Process Industries- B. Shreve., Tata McGraw Hill, New Delhi, 2012.
4. Comprehensive Industrial Chemistry, P. G. More, Pragati Edition, Meerut, 2010.
5. Encyclopaedia of Chemical Technology, Kirk and Othmer, John Wiley & Sons, 2000
6. Plastics Materials, J. Brydson, Butterworths, 8th Edn., London, 1999.
7. Organic Polymer Chemistry, V. Jain, IVY Publishing House, New Delhi, 2003.

**INDUSTRIAL CHEMISTRY LABORATORY (AC 543)**

1. Synthesis of polymer (Any Two)
2. Determination of saponification value of oil
3. Determine chemical oxygen demand of water sample.
4. Synthesis of Dyes/ Dye intermediate and its degradation (Any Two)
5. Synthesis of Drugs /Drug intermediate (Any two)
6. Characterisation of functional groups by FTIR spectrum (Any three)
7. Demonstration of Column chromatography
8. Synthesis of ceramic by sole gel method
9. Industrial Visit

**TEXT BOOKS:**

1. H.S. Peavy: D.R. Rowe and G. Techbanoglous: Environmental Engineering, McGraw Hill Books Co.
2. R.A. Corbitt: Started Handbook: A Environmental Engineering; McGraw Hill New York.
3. A.M. Martin: Bio-conservation of waste Materials to Industrial Products; (ed), Elsevier, Amsterdam.

4. O.P. Kharbanda and E. A. Stellworthy: Waste Management- towards a Sustainable Society, Gower.
5. E. Mortensen: Introduction to Solid Waste, Lecture Notes to Graduate Diploma in Environmental Engineering, University College, Ireland.
6. R.K. Somasekhar and Mariyengar (ED): Solid Waste Management- Current Status and Stratagies for Future, Allied Publishers, Mumbai.
7. F. A. Henglein; Chemical technology (Pergamon)

## SYLLLABUS OF ELECTIVE COURSES
## MOLECULAR SPECTROSCOPY II (AC 512)

### UNIT I: RAMAN SPECTROSCOPY

Stokes and anti-Stokes lines. Polarizability of molecules. Rotational and Vibrational Raman spectroscopy. Selection rules. Polarization of Raman lines.

### UNIT II: ELECTRONIC SPECTROSCOPY

Diatomic molecules. Selection rules. Breakdown of selection rules. Franck-Condon factors. Dissociation energies. Photoelectron spectroscopy of diatomic (N2) and simple polyatomic molecules (H2O, formaldehyde). Adiabatic and vertical ionization energies. Koopmans' theorem. Qualitative ideas of solvent effects- viscosity, polarity, hydrogen bonding.

### UNIT III: NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY (NMR)

General introduction and definition; chemical shift; spin–spin interaction; shielding mechanism of measurement; chemical shift values and correlation for protons bonded to carbons [aliphatic; olefinic; aldehydic and aromatic] and other nuclei [alcohols; phenols; enols; acids; amines; amides and mercaptans]; chemical exchange; effect of deuteration; complex spin-spin interaction between two; three; four; and five nuclei [first order spectra]; virtual coupling. Stereochemistry; hindered rotation; Karplus curve variation of coupling constant with dihedral angle. Application of $^{1}H$ and $^{13}C$ NMR spectroscopy including COSY, NOESY, NOE techniques in the structural determination of complex organic systems. Application in conformational analysis. Multinuclear NMR of various inorganic and organometallic compounds. Data Interpretation, case studies.

### UNIT IV: ELECTRON SPIN RESONANCE

Electron spin and Magnetic moment, Resonance condition in ESR and significance of 'g' value. ESR spectra of organic free radicals, Mc Connel relation, Electron Exchange reactions, applications of ESR.

### UNIT V: PRINCIPLES OF MOSSBAUER SPECTROSCOPY

Basic principles, a chirality of nucleus, Isomer shifts. Quadrupole and Nuclear Zeeman splittings. Applications in structure determination.

### UNIT VI: ELECTRIC AND MAGNETIC PROPERTIED OF MOLECULES

Polarizability, polarization of a molecule in an electric field (electronic, atomic and orientation polarization), Clausius-Mossotti equation, variation of molar polarization with temperature: Debye equation, bond moments, dipole moments and molecular structure. Magnetic susceptibility, molecular interpretations of diamagnetism and paramagnetism, Ferro, ferri and antiferromagnetic behavior, Curie and Neel temperatures, Measurements of magnetic susceptibility by Faraday and Gouy Technique.

## DEFENCE CHEMISTRY (AC 513)

**UNIT I**

High Energy Materials, Introduction to HEMs, Explosives, Propellants and Pyrotechnics

**UNIT II**

Polymers and Nanocomposite for defence applications

**UNIT III**

High Strength Materials

**UNIT IV**

Nuclear, Chemical and biological agents and their remediation.

**TEXT BOOKS**

1. J P Agrawal: High Energy Materials, Wiley VCH, 2012
2. N. Ramdani: Polymer Nanocomposites for advanced Aerospace and Military Applications, IGI Global, 2019
3. NBC: Nuclear, Biological, and Chemical Warfare on the Modern Battlefield John Norris, Will Fowler, 1997.

## INTRODUCTION TO MATERIALS SCIENCE (MS-501)

**UNIT I: SOLIDS**

Crystalline and Amorphous Solid, Unit cell, Summary of crystal lattices, Reciprocal lattice, Bonding & packing in crystals, Lattice planes, Symmetry elements, Space lattice, Glide planes, Screw Axis, Point groups, space groups and elucidations of representing point groups;

**UNIT II: CRYSTAL DEFECTS AND NON-STOICHIOMETRY IN SOLIDS**

Perfect and imperfect crystals, Intrinsic and extrinsic defects- point defects, line defects and plane defects, Schottky and Frenkel defects, Thermodynamics of Schottky and Frenkel defect formation, F, V & H Colour Centers, Non-stoichiometry in solids and their mathematical calculations.

**UNIT III: FUNCTIONAL PROPERTIES OF SOLIDS**

**(a) ELECTRICAL PROPERTIES:** Dielectric materials, Dielectric properties (dielectric constant and dielectric loss), Dependence of dielectric properties on size, Polarizability, Concepts of ferroelectricity, Pyroelectricity and Piezoelectricity.

**(b) MAGNETIC PROPERTIES:** Classification of materials, Line of forces, Effect of temperature, Magnetic moment calculations, Ferro- and antiferromagnetic ordering, Dependence of magnetic properties on size, Magnetic domains and Hysteresis.

**(c) ELECTRONIC PROPERTIES:** Metals, Insulators, Semiconductors and Superconductors, Density of states, Origin of bands, E-k diagrams, Bonding in solids, Band theory, Intrinsic and extrinsic semiconductors p-n junction.

## UNIT IV: STRUCTURES OF SOLIDS

Perovskite structure (e.g. $CaTiO_3$ and $BaTiO_3$), Spinel structure (e.g. $MgAl_2O_4$), Rutile $TiO_2$ structure, Rock salt NaCl structure, Sphalerite and Wurtzite structures of ZnS, Ruddlesden-Popper type $K_2NiF_4$ (e.g. $Sr_2TiO_4$) and β-$K_2SO_4$ (e.g. $Ba_2TiO_4$) structures

## NANO-CHEMICAL TECHNOLOGY (AC-607)

## UNIT-1. INTRODUCTION

Definition and concept- dimensionality and size dependent phenomena. Nano and Mesopores materials: Chemistry of size dependent variation in nanomaterials, reactivity etc. Nano-fluids: Basic chemistry of nano-fluids, preparation of nano-fluids, analysis of nano-fluids, applications of nanofluids. Nanostructures: Chemistry of Quantum dots, nanowires and nanotubes, 2D films. Nano-energetic materials: Introduction, nano-thermites, Advantages and examples, synthesis and thermal properties of 549 nano-thermites. Nano-catalysts: Surface chemistry of nanoparticles, examples, photo-catalysis Polymer nano-composites and hybrid materials: Preparation, Characterization, Applications Nanotechnology for chemical industry: Application in pharmaceuticals, Paint, Coatings, rubber and polymers. Other Topics: Application of nanochemistry/ nanomaterials in civil and defence sector, Characterization of nanoparticles by various analytical techniques

## UNIT-2. TRAINING AND PRACTICALS

Synthesis of metal nanoparticles¬& analysis by particle size distribution and UV-Visible spectroscopy
Synthesis of quantum dots and analysis by UV-Visible spectroscopy and Photoluminescence¬ spectroscopy

## TEXT/REFERENCES: -

1. Nano-chemistry: K. Klabunde and Gleb B. Sergeev, Elsevier (2013)
2. Nanotechnology: basic science and emerging technologies – Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, BurkhardRaguse, Overseas Press(2005).
3. Nanocomposite science and technology, Pulickel M. Ajayan, Linda S. Schadler, Paul V. Braun, Wiley-VCH Verlag, Weihem(2003).
4. Nanotechnology – Edited by Gregory Timp, 1999, Springer 5. Nanocrystal Quantum Dots - Edited by Victor I. Klimov, Second Edition, CRC Press

## RECENT ADVANCES IN CHEMISTRY (AC-610)

## UNIT-1. INTRODUCTION

Background and eminent discoveries in Chemical Technology Frontiers in Electrochemistry: Equilibrium properties of electrolytes, electrode potential, electro analytical techniques.

## UNIT-2. GREEN CHEMISTRY

Principals of green chemistry, sustainability, selected examples of green synthesis. Unit-3. Biochemistry & Biotechnology: Cell Biology and Physiology, Bioenergetics, Industrial Biotechnology. Unit-4. Chemistry of smartmaterials: Smart materials, their properties, distribution by type chemistry of macromolecules, phase change materials

## TEXT/REFERENCES:

1. Electrochemistry for Chemists, Sawyer, Sobkowiak, & Roberts, John Wiley, 1995.
2. Concepts in Transition Metal Chemistry, Crabb, Eleanor, Moore, Elaine, Smart, Lesley E.RSC Publishing, 2010
3. Highlights in Bioorganic Chemistry, Carsten Schmuck, HelmaWennemers, Wiley-VCH, 2004.
4. Essentials of Pharmaceutical Chemistry, D. Cairns 5. Intelligent Materials, M. Shahinpoor, H.-J. Schneider, RSC, 2008

## QUANTUM CHEMISTRY

**UNIT I: QUANTUM CHEMISTRY-I**

Basic postulates of Quantum mechanics (a brief review). Operators in Quantum mechanics: Linear and Hermitian operators, Commutation of operators. Differential equations, partial differential equations, series solutions and special functions, linear vector spaces, transformation of coordinate matrix, representation of operators, eigenvalue problem, orthonormal sets, Fourier and Laplace transforms. Some exactly soluble problems. Simple harmonic oscillator problem. Calculation of various average values using ladder operators and recursion relations of Hermite polynomials. Angular momentum operators. Eigenvalues and eigenfunctions. First order time-independent perturbation theory for non-degenerate states. Variation theorem, variational methods and their applications. Ground and excited state of helium atom.

**UNIT II: QUANTUM CHEMISTRY-II**

Schrodinger equation for hydrogen atom and its solution, the origin of electronic quantum members and physical significance - radial probability density significance of magnetic quantum number with respect to angular momentum. Hydrogen molecule ion and hydrogen molecule Paulis exclusion principle. Term symbols for electronic state in atoms– LS and JJ coupling. Born Oppenheimer approximation, Variational treatment of hydrogen molecule ion. Mulliken designation of molecular orbitals, wave functions for many electron atoms–Hartres–Fock SCF method, Slater Orbitals.

**Unit III:** Born interpretation. Dirac braket notation. Particle in a box: infinite and finite square wells; concept of tunnelling; particle in 1D, 2D and 3D-box; applications. Harmonic oscillator: harmonic and an harmonic potentials; hermite polynomials. Rotational motion: Angular momentum operators, Rigid rotor. Hydrogen and hydrogen-like atoms: atomic orbitals; radial distribution function. Multi-electron atoms: orbital approximation; electron spin; Pauli exclusion principle; slater determinants. Approximation Methods: Variation method and secular determinants; first order perturbation techniques. Atomic units. Molecular structure and Chemical bonding: Born-Oppenheimer approximation; Valence bond theory and linear combination of atomic orbitals –molecular orbital (LCAO-MO) theory. Hybrid orbitals. Applications of LCAO-MO theory to $H_2$ +, $H_2$ ; molecular orbital theory (MOT) of homo- and heteronuclear diatomic molecules. Hückel approximation and its application to annular $\pi$– electron systems.

**Unit IV: Radioactivity:** Detection of radioactivity, Decay processes, half-life of radioactive elements, fission and fusion processes.

**TEXT BOOKS**

1. I. N. Levine, ‘Quantum Chemistry’, 4th Edn., Prentice Hall India, 2001.
2. A. K. Chandra, Introductory Quantum Chemistry, Tata McGraw Hill 1994.

3. M.S. Gopinathan and V. Ramakrishnan, Group Theory in Chemistry, Vishal Publishers,1988.
4. Methods of Molecular Quantum Mechanics by P.W. Atkins.
5. Cotton, F.A. Chemical Applications of Group Theory, 3rd Edn., John Wiley and Sons, 2003.
6. Physical Chemistry: A Molecular Approach by D.A. Mc Quarrie and J.D. Simon
7. D.A. McQuarrie. Quantum Chemistry, Viva Books Pvt Ltd (2003)
8. Jack Simons, Introduction to Theoretical Chemistry, Cambridge University Press, 2003.
9. P.W. Atkins. Molecular Quantum Mechanics, Oxford University Press (1986)

# M. Sc. PHOTONICS

One of the greatest scientific discoveries of the twentieth century that has led to technological advancement touching all aspects of human life is the LASER. Applications of lasers range from medical applications, communications, and industrial applications to military applications. An understanding of laser technology is essential for an engineer working in many of the present-day cutting-edge technologies. The aim of this program is to train the students in the field of lasers, fiber optics, electro-optics, and photonics that would enable them to meet the challenges in this rapidly developing field.

**Stakeholders:**

1. Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments
2. Graduates in the relevant field of science/technology from recognized Universities across the country.

**Eligibility for Students:**

The candidate should possess Bachelor's degree or equivalent in Physics, Applied Physics, Engineering Physics, Electronic Science, Photonics, Optics, Material Science, Instrumentation Science or any equivalent branch

**OR**

B. Tech. (Any discipline)

**Organization:** The M. Sc. programme is of four-semester duration. In each of the first three semesters there are six theory courses and one laboratory course. There will be three continuous evaluation examinations and a final semester examination for every course. At the end of the final semester, the student submits a dissertation and makes a presentation about the work carried out by him/her on the project, which is evaluated by the Internal and External examiners. Course syllabus is updated periodically to keep pace with the contemporary technological advancement.

## PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

**PEO1:** The M. Sc. in Photonics programme aims at developing skilled human resources in the field of Optics, lasers, Electro-optics and overall Photonics. It will ensure the understanding of applied optics, physics and engineering laser technology, fiber optics, semiconductor photonic devices, laser systems and its various applications, catering to the emerging multidisciplinary problems faced by defence industry and civilization.

**PEO2:** With a focus on the DRDO requirements, the students will be trained to use their knowledge for the benefit of society and made aware of their social duty. This will enable them to pursue career in research, academics and industry.

**PEO3:** At the end of the programme the officer or student should be able to undertake state of the art R&D in lasers and electro-optic systems and competitively work towards development of the latest technology in line with national programmes like Make in India.

PROGRAMME OUTCOMES (POs)

**PO1:** An ability to independently carry out research /investigation and development work to solve practical problems

**PO2:** An ability to write and present a substantial technical report/document

**PO3:** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor's program

**PO4:** Having adaptive thinking and adaptability in relation to environmental context and sustainable development

**PO5:** Having a clear understanding of professional and ethical responsibility

**PO6:** Having a good cognitive load management skill related to project management and finance

PROGRAMME SPECIFIC OUTCOMES (PSOs)

**On completion of M. Sc. (Photonics) programme, graduates will be able to**

**PSO1:** The M. Sc. in Photonics aims at developing a skilled knowledgeable Human task force in the field of Photonics serving the needs of the Defence Research and Development Organization & Tri – services (Army, Navy & Air force), Coast Guard, DGQA, DQA, Defence Public Sector units, in addition to the civilians in general. After completing M. Sc. course, the students develop an ability to carry out independent research in the area of optical devices.

**PSO2:** The dissertation work of the M. Sc. students leads to publications in high impact international journals which trains them in technical documentation and report writing.

**PSO3:** The goal of the M. Sc. in Photonics course is to generate highly competent human resources in the areas of laser development, electro-optic systems, fibre optics, applied optics, and computational photonics.

**Credit Structure**

**SEMESTER I**

| Sl. No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | AM-606 | Mathematical methods | 3 | 1 | | 4 |
| 2 | AP-501 | Quantum Mechanics | 3 | 1 | | 4 |
| 3 | AP -502 | Introduction to Optics & Photonics | 3 | | 1 | 4 |
| 4 | AP -503 | Introduction to Lasers | 3 | | 1 | 4 |
| 5 | AP - 504 | Semiconductor Photonic Devices | 3 | 1 | | 4 |
| 6 | AP - 505 | Photonics Lab -1 | 0 | | 4 | 2 |
| | | **Total** | **15** | **03** | **06** | **22** |

**SEMESTER II**

| Sl. No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | AP-506 | Electronic devices and circuits | 3 | | 1 | 4 |
| 2 | AP-507 | Solid State Physics | 3 | 1 | | 4 |
| 3 | AP -508 | Computational Photonics | 2 | | 2 | 4 |
| 4 | AP -509 | Nanophotonics | 3 | 1 | | 4 |
| 5 | AP - 510 | Electronics and Photonics Lab | 0 | | 4 | 2 |
| 6 | | Elective 1 | 3 | | | 4 |
| | | **Total** | **14** | **02** | **07** | **21** |

**List of Electives**

1. Laser Applications AP-631
2. Tera Hertz Devices and Applications AP-642
3. Free Space Optical Communication AP-643

**SEMESTER III**

| Sl. No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | EE-624 | Digital System Design using FPGA | 2 | | 2 | 4 |
| 2 | AP-623 | Introduction to Fiber Optics | 3 | | 1 | 4 |
| 3 | AP -511 | Non-linear Optics | 3 | 1 | | 4 |
| 4 | AP -512 | Advanced Photonics Lab | 0 | | 4 | 2 |
| 5 | PGC 601 | PGC 601 Research Methodology and IPR | 3 | 0 | | 2 |
| 6 | | Elective II | 3 | | | 4 |
| | | **Total** | **14** | **01** | **07** | **19** |

Elective: II.

1. NPTEL MOOC course
2. AP 513 Introduction to Programming
3. Fabrication Technology AP 603

**SEMESTER IV**

| Sl. No. | Course Code | Course | Contact Hours /week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | AP-520 | Project Phase | | | 40 | 20 |
| | | **Total** | | | | **20** |

## AM 606 Mathematical Methods

| | |
|---|---|
| **CO-1 :** | Will understand and know the analytical techniques to solve the differential equations of specific nature. Also, students will understand the power series representation of various functions like Bessel / Legendre when the given differential equation is not in the standard form. |
| **CO-2 :** | Students will learn Laplace and Fourier transforms techniques of various functions to Solve ODEs further Will be able apply to model physical phenomenon and then solve. |
| **CO-3 :** | Will be able to find rank of a matrix, able to diagonalize a matrix and give the related interpretation, can find the basis and dimension of a vector space, Image and kernel of a linear transformation. |
| **CO-4 :** | Students will learn what is Haar and Shannon wavelets are, and how they are used to represent and transform to apply them in various applications. |

**Texts / References:**

1. Advanced Engineering Mathematics, 10th Ed, 2005, Erwin Kreyszig Wiley Eastern.
2. Linear Algebra and its Applications, 4th Ed., 2008, Gilbert-Strang, Academic press.
3. Applied Linear Algebra & Matrix Analysis, 2007, Thomas S Shores, Springer.
4. Advanced Engineering Mathematics, Peter V. O’Neil Thomson Brooks /Cole
5. Ordinary Differential Equations by Deo and Raghavendra
6. Fourier analysis with Applications of boundary value problems schaum series.
7. Integral Transforms by Goyal and Gupta.

## AP-501 – Quantum Mechanics

**Course Outcomes:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I | **Differential Equations:** Review of solution methods for first order as well as second and Higher order equations, Power Series methods with properties of Bessel functions and Legendre polynomials. | **9** |
| Unit II | **Applications:** Orthogonal Trajectories, Population Growth and Decay, Newton's Law of Cooling, Free Falling Bodies. Simple Harmonic Motion, Damped Motion, Forced Motion, Other Applications in Electronics and Pendulum Problem | **8** |
| Unit III | **Linear Algebra:** General (real) vector spaces, Subspaces, Linear independence, Dimension, Norms, Orthogonal bases and Gram-Schmidt orthogonalization, Linear transformation, Kernel and range, Inverse transformations, Matrices of linear transformations, Change of basis, Similarity , Eigen values and eigen vectors, Diagonalization, Orthogonal diagonalization and symmetric matrices, Quadratic forms. | **9** |
| Unit IV | **Transform Techniques:** Over View of Laplace Transforms – Inverse Laplace Transforms – Fourier transform: Flourier integral formula – Fourier transform – Inversion theorem for complex Fourier transform – Fourier Sine and Consine transforms – Inversion formulae – Finite Fourier sine and Cosine Transform – Inversion formulae – | **9** |

| | | |
|---|---|---|
| Unit V | Application of transform techniqes to solutions of differential equations, integral equations and boundary value problems. Wavelets – The Haar wavelets – A wavelets expansion – Multiresolution analysis with Haar Wavelets – General construction of wavelets and multiresolution analysis - Shannon wavelets. | **9** |

| | |
|---|---|
| **CO-1 :** | Understand the basic concepts of quantum mechanics Physics |
| **CO-2 :** | Interpret the physical meaning of formulation in quantum mechanics |
| **CO-3 :** | Examine different 1D problems in quantum mechanics |
| **CO-4 :** | Illustrate the implementation to 1 electron atoms |
| **CO-5 :** | Explain Quantum mechanics to Lasers |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I | Historical Origin of Quantum mechanics: Thermal radiation, Plank's postulates, Black body radiation, stationary states, correspondence principle, Bohr Atom, shortcomings of old quantum theory. | **9** |
| Unit II | The Schrödinger equation, Statistical interpretation, probability, normalization, momentum, The uncertainty principle | **6** |
| Unit III | Time Independent Schrödinger: stationary states, infinite square well, harmonic oscillator, free particle, delta function potential, finite square well | **9** |
| Unit IV | Formalism: Hilbert's space, observables, eigen function of Hermitian operator, statistical interpretation, Dirac notation | **6** |
| Unit V | One electron atoms: solution of Schrödinger equation in 3D, eigen values, quantum numbers, and degeneracy, orbital angular | **8** |
| Unit VI | Quantum statistics: indistinguishability and quantum statistics, quantum distribution functions, Boltzmann distribution as an approximation to quantum distributions, Introduction to Quantum Optics, Coherent States | **8** |

**References Textbooks:**


1. Quantum Mechanics, John Powell, Bernd Crasemann, Narosa Publishing House
2. Quantum Mechanics, Leonard Schiff, Mc-Graw Hill Book Company
3. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing
4. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing
5. Quantum Mechanics by B H Bransden and C J Joachain Pearson Publishing


**AP-502 –** Introduction to Optics and Photonics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of optical electronics |
| **CO-2 :** | Analyze the working principle of ME Theory, EO, MO and AO effects |
| **CO-3 :** | Examine the working mechanism of different types of Optical components, EO, MO and AO effects |
| **CO-4 :** | Illustrate the practical use of Optical components, EO, MO and AO effects |
| **CO-5 :** | Summarize different applications of optical electronics devices |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Fundamentals of Photonics and Optics:** Wave equation, Plane waves, Applications of photonics, Reflection and Refraction of plane waves, Fresnel Equations, Wave propagation in different mediums, propagation of Electromagnetic waves in Uniaxial and biaxial crystals, the dielectric constant tensor and the 'index ellipsoid' | **9** |
| Unit II: | **Polarisation of light and Basic optical components:** Electromagnetic theory of light, Dielectric media, Monochromatic EM waves, Absorption and dispersion, Polarisation of light, Jones Calculus, Poincare sphere. Polarisers, Quarter, Half, and Full waveplates, Beam splitters: polarizing and non-polarizing, wavelength filters, dichroic mirrors, Lenses. | **10** |
| Unit III | **Electro-optics:** Basic principles: Pockel and Kerr effects, Electro-optic devices: modulators, switches, and scanners, E.O. effect in liquid crystals; LCDs and SLMs, Applications. | **9** |
| Unit IV | **Acousto-optics:** Strain waves in solids and liquids, the strain-optic tensor; theory of Raman-Nath and Bragg diffraction; small-angle and large-angle Bragg diffraction. Accousto-optic devices: Modulators, deflectors, scanners, interconnections, and acoustooptictunable filters. | **10** |
| Unit V | **Magneto-optics**: Principles, Faraday effect, Gyrotropic permittivity, Kerr rotation and Kerr ellipticity, Applications. | **6** |

**References Textbooks:**


1. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press,1989. References
2. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006.
3. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
4. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000.
5. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
6. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988.
7. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.


**AP-503 –** Introduction to Lasers

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of laser technology |
| **CO-2 :** | Analyze the working principle of lasers |
| **CO-3 :** | Examine the laser radiation beams |
| **CO-4 :** | Illustrate and construct the practical laser systems |
| **CO-5 :** | Summarize different types of laser systems and its working principals |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Light-matter interaction:** Interaction of radiation with atomic systems, Einstein's coefficients, spontaneous emission, stimulated emission, Linewidth of the laser | 10 |

| | | |
|---|---|---|
| Unit II: | **Lasers Oscillation**: Theory of laser oscillation; Threshold condition, Rate equation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output power, Pumping techniques. | 10 |
| Unit III | **Laser Resonators and Gaussian Beams**: The Ray Matrix, Resonator Stability, Paraxial Wave Equation, Gaussian Beams, ABCD Law for Gaussian Beams, Gaussian Beam Modes, Hermite–Gaussian and Laguerre–Gaussian Beams, Resonators for He–Ne Lasers, Diffraction, Diffraction Theory of Resonators, Beam Quality. | 10 |
| Unit IV | **Laser Systems 1:** Solid-state lasers, Gas lasers, | 8 |
| Unit V | **Laser Systems 2:** Fiber laser and amplifiers | 8 |
| | | |

**Reference Book:**


1. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
2. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
3. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988
4. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
5. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).


## **AP-504 –** Semiconductor Photonic Devices

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand the basics of Optical Physics |
| **CO-2 :** | Interpret all the optical properties and processes in semiconductors and dielectrics |
| **CO-3 :** | Examine the working mechanism of different kinds of LEDs and LASERs |
| **CO-4 :** | Illustrate the implementation of Modulation and Switching Devices |
| **CO-5 :** | Explain different types of photodiodes and photodetectors |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Review of Optical Physics:** Energy Bands of Direct and Indirect Semiconductors, Semiconductor Optoelectronic materials, Density of States, Fermi-level, PN Junction, Homo and Hetero Junction, Quantum Wells. Electron-hole pairs | **9** |
| Unit II: | **Light Emitting Diodes:** The electroluminescence Process, LED materials, Device configuration and Efficiency, LED structures, LED performance characteristics, Frequency response and Modulation bandwidth. LEDs for display and Lighting. | **9** |
| Unit III | **Semiconductor Lasers:** Junction Laser Operating Principles, Threshold Current, Heterojunction Laser, Distributed Feedback Lasers and Distributed Bragg Reflector, Ring Lasers: Single and Double, Master Oscillator Power Amplifier. | **9** |

| | | |
|---|---|---|
| | VCSELS and Laser Diode Arrays. | |
| Unit IV | **Modulation and Switching Devices:** Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator. | **9** |
| Unit V | **Photodetectors:** Types of photodetectors, Photoconductors, Junction photodiode, PIN photodiode and APD, Quantum Well IR Detectors, Detectors for long wavelength operation, Wavelength selective detection, Coherent detection. CCDs (EMCCD, ICCD) and Photonic Integrated Circuits. **Photo multiplier tubes (PMT),** Superconducting Nano-wire based detector, | **9** |

**References Textbooks:**

1. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).
2. G. Ghione, Semiconductor Devices for High-Speed Optoelectronics, Cambridge University Press (2009)
3. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communication, Oxford University Press (2007), 6th Ed., Ch.15-17.
4. G. Keiser, Optical Fiber Communications, McGraw-Hill Inc., 3rd Ed. (2000), Ch.4, 6.
5. J. Singh, Semiconductor Optoelectronics: Physics and Technology, McGraw-Hill Inc. (1995).
6. J. M. Senior, Optical Fiber Communication: Principles and Practice, Prentice Hall of India, 2nd Ed. (1994), Ch.6-8.
7. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17, and 18.
8. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021).

## **AP-505 –** Photonics Laboratory I

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | To understand basic electronics |
| **CO-2 :** | To interprete characteristics of the devices |
| **CO-3 :** | Examine the working of basic electronic components |
| **CO-4 :** | Illustrate working of optical components |
| **CO-5 :** | Explain difference in diode and Laser characteristics |

**Syllabus:**

| **Syllabus Details** | **Hrs** |
|---|---|
| Photonics<br>Michelson Interferometer: Setting up Michelson interferometer using a highly monochromatic laser source, evaluation of laser wavelength by fringe counting.<br>Determination of the Electrical and Optical Characteristics of LED and Laser diode.<br>Designing of Optical Window, Concave and Convex Lens<br>Detection of polarisation states using polarisation components like polarizers, waveplates etc.<br>Analysis of various light source spectra using OSA.<br>Determination of the refractive index profile of a multimode and single mode fiber by the transmitted near field scanning technique and measurement of NA.<br>Macro and Microbending loss in optical fibers and its application<br>Measurement of Photodiode characteristics<br>Study of Fraunhofer diffraction pattern of a rectangular and circular aperture. | 48 |

| | |
|---|---|
| . Optisystem Training Modules | |

**AP-506 –** Electronic Circuits and Devices

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | Basics of semiconductor and Introduction to Diodes:<br>The energy band theory of crystals, Intrinsic and Extrinsic semiconductors. P-N Junction diode as a Rectifier, Photo-Diode, Filters using Diode, Clipping & clamping circuits, LED, Zener diode | 8 |
| Unit II | Transistors and Oscillators<br>Basics of Transistor, Transistor characteristics and applications, basics of oscillators and multivibrators (IC555 as timer). | 10 |
| Unit III | Field Effect Transistor<br>Structure and working of: JFET, I-V characteristics and parameters (Pinch off voltage, trans conductance, drain resistance, amplification factor); MOSFET (construction and application only) Applications: FET as Voltage Variable resistance (VVR), switch, memory cell, DRAM | 10 |
| UNIT IV: | OPAMPS & Multivibrators<br>Idea op-amplifier characteristics, Block diagram, Basic Inverting & non inverting amplifier, Basics of oscillator, Basics of Timer IC 555 as astable multivibrator. | 10 |
| UNIT V: | Sequential circuits and Counters<br>RS, Clocked RS, JK, Master Slave JK, D Flip flop, Counter-synchronous, asynchronous, up-down counter, modulo-N counter, Decade counter (IC 7490); shift register (IC 7495), ring counter | 8 |

**Reference Books:**

1. Millman's Integrated Electronics - Analog and Digital Circuit and Systems | 2nd Edition by Jacob Millman, Christos Halkias, Chetan Parikh
2. Electronic Principles | 7th Edition by Albert Malvino , David J. Bates

**AP-507 –** Solid State Physics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand the basic concepts of Solid State Physics |
| **CO-2 :** | Interpret the physical meaning of formulation in Condensed Mateer |
| **CO-3 :** | Examine different Structure related properties |
| **CO-4 :** | Study the Electronic and magnetic properties of solids |
| **CO-5 :** | Develop skills to solve physics problems |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Crystal Structure and Diffraction:**<br>Real lattices, packing fraction, reciprocal lattices, Brillouin zones. Diffraction by crystals - Ewald sphere construction, Bragg condition in k-space. Geometric | 8 |

| | | |
|---|---|---|
| | structure factor and atomic form factor. Point defects, line defects and dislocations. | |
| Unit II: | **Lattice Dynamics:** Vibrations of crystals with mono-atomic and diatomic basis. Brillouin zones. Optical modes and acoustic modes. Quantization of elastic waves. Phonon momentum. Neutron scattering by phonons. Phonon heat capacity. Phonon density of states. Einstein and Debye theories , thermal conductivity. | 10 |
| Unit III | **Electronic Band Structure in Crystals**: Drude theory of metals. Quantum free electron model of metals (Sommerfeld model). Nearly free electron theory. Brillouin zones. Electron effective mass. Density of states and band gap. Kronig-Penney model. Bloch theorem. Crystal momentum. Qualitative distinction between semiconductors and metals. Fermi surface of metals. Hall effect. | 10 |
| Unit IV | **Dielectric and Magnetic Properties of Solids:** Macroscopic electric field and local electric field in solids. Polarizability and dielectric constant. Claussius-Mossotti relation. Dielectric-Ferroelectric phase transition. Landau theory. Piezoelectricity. | 10 |
| Unit V | **Magnetism** – Diamagnetism, Langevin equation. Pauli paramagnetism in metals. Paramagnetism –Curie law. Ferromagnetism. Quantum mechanical nature of ferromagnetic interaction. Anti-ferromagnetic and ferromagnetic order. | 8 |

**Reference Books:**

1. Introduction to Solid State Physics, Charles Kittel (John Wiley and Sons.).
2. Solid State Physics, A. J. Dekkar (Prentice Hall).
3. Solid State Physics, N. W. Ashcroft and N. D. Mermin (CBS Publishing Asia Ltd.).

## **AP-508 –** Computational Photonics

**Course Objectives:**

| | |
|---|---|
| **CO-1 :** | Understand the simulation methos of photonics devices and fiber Optics |
| **CO-2 :** | Study on mode solution method of photonics devices |
| **CO-3 :** | Study on beam propagation method for Photonics devices |
| **CO-4 :** | Study on FDTD method for photonics band gap |
| **CO-5 :** | Understanding the recent advance in photonics Devices |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | Unit-1<br>**Mode Solver Method:** Theory of fully vectorial mode solvers in 2D and 3D structures, low-index polymer waveguides, high-index silicon (SOI) and GaAs/AlGaAs waveguides, buried, etched (rib, ridge), and diffused geometries commonly used in opto-electronics slot waveguides, slanted-wall and graded structures, plasmonic and microwave waveguides, | 9 |
| Unit II: | Unit-2<br>**Beam Propagation Method:** Theory and working of beam propagation method, Tutorials on MMI couplers, optical gratings, co-directional couplers or polarization converters. | 9 |
| Unit III | Unit-3 | 9 |

| | | |
|---|---|---|
| | **FDTD Method:** Theory and working of FDTD method, Tutorials on photonics band gap simulation: 2D and 3D of different crystal lattices. | |
| Unit IV | Unit-4<br>**Fiber Optics Modeling:** Simulation and modeling of single mode and multimode optical fiber using mode solver, FBG and Chirped FBG synthesis, photonic crystal fiber simulation | 9 |
| Unit V | **Nanodesign:** Mask designing for nanofabrication of different device geometry | 9 |
| Unit VI | **Introduction to Finite Element Method** | 3 |

Reference Books:


1. S. Sujecki, Photonics Modelling and Design, CRC Press, 2015.
2. K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000.
3. A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method. Norwood, MA: Artech House, 1995.


**AP-509 –** Nanophotonics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarization to the concept of Metamaterials |
| **CO-2** | Illustration of Optical Properties in Metamaterials |
| **CO-3** | Examine Surface Plasmon Resonance |
| **CO-4** | Analyze Photonic Bandgap Crystals in different dimensions |
| **CO-5** | Understanding the Importance of Silicon Photonics and Its Applications |

**Syllabus:**

| **Units Divisions** | **Syllabus Details** | **Hours** |
|---|---|---|
| Unit I | Basics of Nanophotonics: Photons and electrons, Quantum confinement effects, 2D, 1D, 0D structures, their growth and properties | **9** |
| Unit II: | **Metamaterials:** Definition of Metamaterials (MTMs) and Left-Handed (LH) MTMs, **Fundamentals of LH MTMs** Left-Handedness from Maxwell's Equations | **9** |
| Unit III: | **Metamaterial in Optics:** Optical Properties of Metal-Dielectric Composites, Optical Magnetism, Negative-refractive Index, Perfect lens and Cloaking objects. | **9** |
| Unit IV | **Surface Plasmon Resonance:** Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation od surface plsmons, surface Plasmon properties, SPR spectroscopy | **9** |
| Unit V | **Photonic band gap crystals:** Photonics Band-Gap: Introduction to Photonics crystal, Photonic Band Structures, One dimensional, Photonic crystal: Origin of Photonics Band Gap, Size of the band gap, Evanescent Modes in Photonics Band gaps, Two-dimensional Photonic crystal: Two-dimensional Bloch States, Square Lattices (Dielectric Columns and Veins), Three-dimensional Photonic crystal: Three-dimensional lattices, | **12** |

**References Textbooks:**

1. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, Christophe Caloz,Tatsuo Itoh, John Wiley and Sons,2006
2. Optical Metamaterials, Fundamentals and Applications, Wenshan Cai Vladimir Shalaev, Springer, 2010.
3. John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade,Photonic Crystal: Molding Light Flow of Light, Princeton University Press, 2008.
4. Graham T. Reed and Andrew P. Knights, Silicon Photonics: An Introduction, JohnWiley and Sons Ltd, 2004
5. Metamaterials: Physics and Engineering Explorations, Nader Engheta Richard W. Ziolkowski, Wiley and Sons,2006
6. Negative-Refraction Metamaterials Fundamental Principles and Applications, G. I. Eleftheriades K. G. Balmain,Wiley and Sons,2005

## **AP-510 –** Electronics and Photonics Laboratory II

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand basic logic circuits |
| **CO-2 :** | Analyze the working of A/D and D/A convertors |
| **CO-3 :** | Illustrate the working Holography |
| **CO-4 :** | Examine the losses in fiber optical communication |
| **CO-5 :** | Interprete the working of fiber lasers |

**Syllabus:**

| Syllabus Details | Hrs |
|---|---|
| Electronics:<br>To study the I-V Characteristics of Diodes (Simple and Zener Diode)<br>To study the I-V Characteristics of Transistors in CB, CE, CC modes (NPN and PNP Transistors)<br>To study the I-V Characteristics of MOSFETs<br>To study the Half, Full, and Bridge rectifier<br>To study the Voltage and Current regulation with a fixed load<br>To study the Clipping and clamping Circuit<br>To study the Characteristics of 741 OPAMPs<br>To analyze the inverting and non-inverting amplifier<br>To Design Active filters | 20 hrs |
| Photonics:<br>Beam Width, Divergence, and $M^2$ measurement of He-Ne/Diode Laser with and without collimation lens.<br>Fiber optic link design<br>Measurement of attenuation and dispersion in optical fibers<br>Fiber to Fiber splicing and splicing loss measurement.<br>Setting up of Mach-Zender interferometer<br>Design of driver circuit for LED and Laser diode<br>Characterization of Erbium Doped Fiber Amplifier<br>Design of signal conditioning circuits for Photodetectors | 28 hrs |

## EE-624 – DIGITAL SYSTEM DESIGN USING FPGAs

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Familiarized with the design of Combinational and Synchronous and Asynchronous Sequential Circuits. Gave an Overview of PLDs and PALs |
| **CO-2 :** | Covered basic introduction of VHDL and the basic language elements. Various Combinational and Sequential circuits were designed using VHDL |
| **CO-3 :** | In-depth analysis of Faults and testability in digital systems including modelling and detection |
| **CO-4 :** | Interfacing various sensors and reading/writing to/from various file formats. Implementing various modulation schemes |
| **CO-5 :** | Design of a RISC CPU, data and control path components. Introduction to various floating/fractional/fixed-point arithmetic operations. Implementing Data encryption/Decryption system, Error correction, communication modules, BERT |

**Syllabus:**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I: | **Digital system design techniques:**<br>Combinational Circuit Design - Synchronous Sequential Circuit Design - Mealy and Moore model - State machine design - Analysis of Synchronous sequential circuit - State equivalence - State Assignment and Reduction - Analysis of Asynchronous Sequential Circuit - flow table reduction – races - state assignment - Design of Asynchronous Sequential Circuit - Designing with PLDs – Overview of PLDs – ROMs - EPROMs – PLA – PAL - Gate Arrays – CPLDs and FPGAs, Designing with ROMs - Programmable Logic Arrays - Programmable Array logic. | 12 |
| Unit II: | **IIVHDL basics and computation module designs:** Introduction to VHDL - Behavioral modeling - Data flow modeling - Structural modeling - Basic language elements– Entity – Architecture - Configurations – Arrays declaration - Subprograms & operator overloading - Packages & libraries – Advanced Features - Model simulation - Realization of combinational and sequential circuits using VHDL – Registers – Flip flops - counters – Shift registers – Multiplexers - sequential machine – Multiplier – Divider, ALU, MAC, CORDIC, Introduction to Synthesis. | 6 |
| Unit III | **Fault modeling, detection and test pattern generation algorithms:**<br>Introduction to testing – Faults in Digital Circuits – Modeling of faults – Logical Fault Models – Fault detection – Fault Location – Fault dominance – Logic simulation – Test generation for combinational logic circuits – Testable combinational logic circuit design - Introduction to Design for Testability - BIST.. | 6 |
| Unit IV | **Digital system design with real-time I/O interface:**<br>Sensors interface - uni-polar & bi-polar A/D converter - D/A converter interface - display devices interface - RS232, USB, Ethernet, VGA interface - RF data link - high voltage switch control - realy/AC/DC motor & buzzer control - PWM signal generation - PS/2 key-board & matrix keypad interface – digital camera interface, arbitrary data/signal generation – sensor data acquisition and writing/reading to/from .xlsx and .doc file - implementation of modulation schemes | 12 |
| Unit V | **Contemporary designs and solutions:** | 10 |

| | | |
|---|---|---|
| | Design of data path components, Control path components - Design of a simple RISC CPU - Debugging using Embedded Logic Analyzers - Audio codec (AC97) interface – Test-bench design - ChipScope Pro Analyzer - introduction to floating/fractional/fixed-point arithmetic operations - Xilinx Sys-Gen tools - MATLAB/VHDL interface with Sys-Gen tools -BERT interface – implementation of DPCM, data encryption/decryption system, EC techniques, communication modules design, DA based computations. | |

**LIST OF EXPERIMENTS:**

| SL No | NAME OF EXPERIMENTS |
|---|---|
| 01. | The Basic FPGA Design Flow<br>To understand use of Xilinx ISE<br>To understand Xilinx Synthesis Technology or XST.<br>Familiarization of Xilinx Vivado Design Tools. |
| 02. | Familiarization of FPGA Boards<br>Xilinx FPGA Boards (Virtex 6,Kintex7)<br>Implementation of Full adder, ALU , Memory and FIFO on FPGA |
| 03. | Fault Detection Logic Implementation on FPGA<br>1. Stuck at Fault 2.Memory BIST |
| 04. | Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analyzers. |

**REFERENCE TEXT BOOKS:**


1. Jesse H. Jenkins, "Designing with FPGAs and CPLDs", Prentice Hall, NJ,1994
2. Fundamentals of Logic Design – Charles H. Roth, 5th ed., Cengage Learning.
3. Kevin Skahill, "VHDL for Programmable Logic", Addison -Wesley, 1996
4. Z. Navabi, "VHDL Analysis and Modeling of Digital Systems", McGRAW-Hill, 1998
5. Digital Circuits and Logic Design – Samuel C. Lee , PHI
6. Smith, "Application Specific Integrated Circuits", Addison-Wesley, 1997
7. P.K. Lala, “Digital Circuit Testing and Testability”, Academic Press, 2002


## AP-623 – Introduction to Fiber Optics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understand the basics concepts of Fiber Optic Communication |
| **CO-2** | Understand all the sub-components of Fiber Optics |
| **CO-3** | Examine the working mechanism of Fiber Optics |
| **CO-4** | Illustrate the practical implementation of Fiber Optic Communication |
| **CO-5** | Summarize different applications of Fiber Optic Communication |

**Syllabus:**

| **Units Divisions** | **Syllabus Details** | **Hours** |
|---|---|---|
| Unit I: | **Optical Fibers:** Light Propagation in Optical Fibers, Optical fiber Modes and | **10** |

| | | |
|---|---|---|
| | Configurations, Mode Theory for Circular waveguides, SM and GI Fibers, Fiber Materials, PhC fibers, Fiber fabrication.<br>**Optical Fibers Characteristics:** Fiber Attenuation, Absorption losses, scattering losses, Radiation losses, Bending losses, Measurement of losses, Dispersion in fibers, Effect of dispersion in the communication link, Dispersion reduction, and compensation techniques. | |
| Unit II: | **Power Launching and Coupling:** Source to Fiber launching and Launching Schemes for Coupling Improvements. Fiber to Fiber joints, Laser coupling to SM fiber, Fiber splicing, Optical Fiber Connector.<br>**Optical Receivers:** Basic Concepts, Common Photodetectors, Receiver Design, Receiver Noise, Coherent Detection, Receiver Sensitivity, Sensitivity Degradation, Receiver bandwidth, and Performance | **9** |
| Unit III | **Fiber Amplifier:** Optical Amplification in rare-earth-doped fibers, Types of Fiber Amplifiers, EDFA, Amplifier Noise, Optical SNR, System Application, Raman Amplifiers, Wideband Optical Amplifier | **9** |
| Unit IV | **Optical Fiber Sensors:** Introduction, Classification and Types of Optical Fiber Sensors, Sensor Modulation techniques, Fiber Bragg Grating Sensors: Principle and Applications. | **9** |
| Unit V | **Overview of Optical Fiber Communication:** Lightwave communications, Optical Spectrum Bands, and Visible Units, Network Information rate and WDM concepts. Key Elements of fiber optics system, Standards for Optical fiber communications. | **9** |

**References Textbooks:**


1. A.K. Ghatak & K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press 1998
2. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008
3. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998
4. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998
5. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988


## **AP-511 –** Non-linear Optics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of nonlinear process |
| **CO-2 :** | Analyse the optical response of NLO devices |
| **CO-3 :** | Examine the working principle of different NLO devices |
| **CO-4 :** | Illustrate the application of NLO for ultrashort pulse generation |
| **CO-5 :** | Understand the quantum optics |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Nonlinear optics basics**: Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients | **8** |
| Unit II: | **Second order nonlinear effects**: Second harmonic generation, Phase matching condition, Various phase matching techniques, Characterization of second order nonlinear optical materials, Periodically poled materials and their applications in | **10** |

| | | |
|---|---|---|
| | nonlinear optical devices. | |
| Unit III | Sum and difference frequency generation, Optical parametric amplification (OPA) and oscillation (OPO), Analysis of OPA and OPO; practical device configurations and applications. Spantaneous Parametric Down Conversion (SPDC) | **8** |
| Unit IV | **Third order non linear effects**: Third harmonic generation, Four wave mixing and Self-phase-modulation Optical Kerr effect, Self-focusing, Optical Solitons; Optical phase conjugation and Optical bistability. Stimulated Raman Scattering and Stimulated Brilluoin Scattering. | **10** |
| Unit V | **Ultrafast Optics**: Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Nonlinear Schrödinger equation, Supercontinuum generation. | **8** |
| | **Applications of Nonlinear optics, Raman Amplifiers, Nonlinear fiber optics and devices** | **4** |

## AP-512 – Laboratory -III

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Characterization of Fiber Optics Devices |
| **CO-2 :** | Analyse the optical multiplexing techniques and its device performance |
| **CO-3 :** | Examine the working principle of different electro-optic and magneto-optic effects |
| **CO-4 :** | Illustrate the different beam characterization methods |
| **CO-5 :** | Understand the design of different spectroscopic systems |

**Syllabus:**

| Syllabus Details | Hrs |
|---|---|
| Characterization of Fiber Bragg grating<br>Power budget analysis using Optical Time Domain Reflectometer (OTDR)<br>Study of Time Division Multiplexing of digital signals<br>Study of a Wavelength Division Multiplexing(WDM) in optical fiber link<br>Study of Add/drop multiplexer<br>Study of Bit error rate and Eye pattern analysis<br>Setting up a Free space Laser Communication experiment link<br>Measurement of third order nonlinear optical coefficient using Z-scan<br>Study of Faraday effect<br>Design of a fiber optic sensor<br>Line coding and decoding, voice coding<br>Measurement of insertion loss of an isolator, coupler and multiplexer<br>Beat length measurement in birefringent fibers.<br>Laser Raman Spectroscopy Experiments<br>Holography<br>**Note: Any 12 experiments are mandatory** | 48 hrs |

## PGC-601 – Research Methodology and IPR

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understanding the fundamentals of research and its methodology |
| **CO-2 :** | Choose the appropriate research design and develop appropriate 3 hypotheses for a research |

| | |
|---|---|
| | project |
| **CO-3 :** | Knowledge of manuscript preparation, patents and Intellectual property |
| **CO-4 :** | Technology transfer and application of IPR in various domains |

**Syllabus:**

| **Units Divisions** | **Syllabus Details** |
|---|---|
| Unit I: | Meaning of research problem, Sources of the research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of the research problem.Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations |
| Unit II: | Effective literature studies approach, analysis Plagiarism, Research ethics, |
| Unit III | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee |
| Unit IV | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process ofPatenting and Development: technological research, innovation, patenting, development.International Scenario: International cooperation on Intellectual Property. Procedure forgrants of patents, Patenting under PCT. |
| Unit V | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.<br>Patent information and databases. Geographical Indications |
| Unit VI | New Developments in IPR: Administration of Patent System. New developmentsin IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |

**References Textbooks:**


1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for
2. science & engineering students'"
3. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
4. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for
5. beginners"
6. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
7. Mayall, "Industrial Design", McGraw Hill, 1992.
8. Niebel, "Product Design", McGraw Hill, 1974.
9. Asimov, "Introduction to Design", Prentice Hall, 1962.
10. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.
11. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008


**List of Electives**

**Elective Course Content for Semster -II**

**AP-631 – Laser Applications**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarize to a variety of applications on lasers |

| | |
|---|---|
| **CO-2** | Interpret how laser-based metrological techniques work |
| **CO-3** | Understand laser spectroscopy applications |
| **CO-4** | Investigate various methods of how a laser can be used for defence applications |
| **CO-5** | Summarize different applications of lasers |

**Syllabus:**

| Units | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Laser Metrology: Laser** for measurement of distance, length, velocity, acceleration; rotation sensing; RLG and FOG. | **6** |
| Unit II | **Laser Spectroscopy:** IR absorption Spectroscopy, Laser Raman spectroscopy, Laser induced breakdown spectroscopy (LIBS), laser-induced fluorescence (LIF), Tunable diode laser spectroscopy (TDLS), Terahertz spectroscopy, Photoacoustic spectroscopy, Instrumentation in laser spectroscopy, Isotope Separation & Enrichment. Bio-Medical Application of Lasers | **12** |
| Unit III | **Holography:** Holographic interferometry and applications; Holography for non – destructive testing – Holographic components | **6** |
| Unit IV | **Industrial Application of Laser:** Laser cutting, Laser welding, Laser drilling, Laser marking, Photolithography, Laser-based unmanned ground vehicles | **9** |
| Unit V | **Defence Applications:** Low power laser applications including Laser Range finders-LRF (DPSSL, Eye Safe & High PRF) & Laser Target Designators; Dazzlers, Laser Warning receivers, Infrared counter measures, Laser Guidance; Laser-based navigation; Laser-based imaging; Laser-based remote sensing: Laser radar, laser radar seekers, LIDAR basic concept and applications | **12** |

## AP-642 – Terahertz Devices and Applications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of terahertz technology |
| **CO-2** | Analyze the working principle of different types of terahertz signal sources |
| **CO-3** | Examine the working mechanism of different types of terahertz detectors |
| **CO-4** | Illustrate the practical implementation of fabrication of components and circuits for terahertz systems |
| **CO-5** | Summarize different applications of terahertz technologyfor imaging, sensing and communications |

**Syllabus:**

| Units | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Basics of Terahertz Technology:** Electromagnetic radiation and propagation fundamentals, Introduction to terahertz technology, Background, Terahertz gap, Key technological issues for terahertz technology, Advantages and limitations of terahertz waves, Material properties at mm and sub-mm frequencies | **9** |
| Unit II | **Terahertz Sources:** Terahertz sources based on electronics: Diodes, transistors, resonant tunnelling diodes, vacuum electronics; Terahertz sources based on | **9** |

| | | |
|---|---|---|
| | photonics: Non-linear crystals, quantum cascade lasers, plasma-based source; Terahertz sources based on optoelectronics: Photomixer, photoconductive antenna and its types; Noises at terahertz frequencies in different sources | |
| Unit III | **Terahertz Detectors:** Terahertz detectors based on electronics: HOT electron bolometer, Heterodyne SIS receivers: Theory and Design, Superconducting tuning circuitries, HEB heterodyne receivers: Theory and Design, Terahertz MMICs: Theory and Design, Terahertz detectors based on photonics | **9** |
| Unit IV | **Terahertz Components:** Terahertz components: Metamaterials and plastic fibers, HEMT cryogenic amplifiers: Theory and Design, Antennas, Filters, Waveguides, Beam Splitter, Beam Combiner, Polarizer, Mirrors, Isolator, Circulator, Cameras, Fabrication Technologies, Metamaterial THz devices, Spintronic THz components. | **9** |
| Unit V | **Terahertz Applications:** Terahertz applications: Time domain Colinear and Non-colinear terahertz spectroscopy, Optical-pump-THz-probe Spectroscopy, Terahertz Imaging, Terahertz sensing and analysis, Terahertz wireless communication, Terahertz remote-sensing, 3D terahertz tomography system, Industrial applications, Space Communication, Cutting-edge terahertz technologies | **9** |

**References Textbooks:**

1. A. Rostami, H. Rasooli, H. Baghban, Terahertz Technology: Fundamentals and Applications, Germany, Springer, 2011.
2. R. E. Miles, P. Harrison, D. Lippens, Terahertz Sources and Systems “, Dordrecht: Kluwer, Springer, 2000.
3. K. Sakai, Terahertz Optoelectronics, Springer, 2004.
4. H.-J. Song, T. Nagatsuma, Handbook of Terahertz Technologies, Devices and applications, Pan Stanford Publishing Pte. Ltd., 2015.
5. D. Saeedkia, Handbook of Terahertz Technology for Imaging, Sensing and Communications, Woodhead Publishing, 2013.

## AP-643 – Free Space Optical Communications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of Free Space Optical Communication |
| **CO-2** | Understand all the sub-components |
| **CO-3** | Examine the working mechanism of FSOC |
| **CO-4** | Illustrate the practical implementation of FSOC |
| **CO-5** | Summarize different applications of FSOC such as VLC/UWOC |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Introduction FSOC/OWC,** Basic Link configuration of FSOC, various application areas of FSOC, Indoor Channel modelling, various link configurations, Artificial light interference effects in indoor channel. | **9** |

| | | |
|---|---|---|
| Unit II: | **Channel Modelling -Outdoor channel,** Atmospheric channel loss related issues, Atmospheric turbulence effects, Measurement of $C_n^2$ , Various atmospheric turbulence models, Effects of atmospheric turbulence on laser beam propagation, Realization of atmospheric effects on OWC test beds | **9** |
| Unit III | **Modulation Techniques:** Importance of modulation in FSO, various modulation formats, selection criteria for modulation, basic modulation schemes OOK,PPM, PIM, DH-PIM, BPSK etc. and error propagation<br>**FSO link Performance under atmospheric turbulence:** performance of FSO link in various modulation formats, comparison across the modulation formats, the turbulence-induced penalty in FSO link, Link budget analysis, Power budget analysis | **11** |
| Unit IV | **Mitigation techniques:** introduction, aperture averaging, various diversity techniques, spatial diversity, time diversity coding techniques, adaptive optics and other techniques. | **9** |
| Unit V | **Laser beam Tracking, pointing & acquisition:** Acquisition and Tracking systems, System description, Acquisition methodology, tracking and pointing control system, RF cross-link system design, link equation Intoduction to Free Space Quantum Optical Communication | **10** |

**References Textbooks:**

1. Arun K. Majumdar, Free-Space Laser Communications Principles and Advances. Springer Publications
2. Hemani Kaushal, Free Space Optical Communication. Springer Publication
3. J. Franz and V.K. Jai, Optical Communication Systems. Narosa Publications
4. Morris Katzman, Laser Satellite Communications. Prentice Hall Inc 1991
5. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K. Jha

**<u>Elective Course Content for Semster -III</u>**

## AP-603 – Technology and Packaging of MEMS systems

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Students to be able to understand concepts involved in MEMS |
| **CO-2 :** | Students to understand the technologies involved in MEMS fabrication and packaging, their advantages and limitations |
| **CO-3 :** | Students to be able to understand working principles in micro sensors and actuators |
| **CO-4 :** | Students to become capable of conceptualizing the design of a microsystem |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Evolution of Microsystems:** Concept & History of Micro systems & MEMS, Benefits of Micro Systems, Comparison between Microsystems & microelectronics, Multidisciplinary nature of microsystems development. | **2** |
| Unit II: | **Scaling Laws in Miniaturization:** Introduction to scaling, geometric scaling, | **4** |

| | | |
|---|---|---|
| | scaling in rigid body dynamics, scaling in electrostatic forces, scaling in electromagnetic Electricity, scaling in fluid mechanics, Scaling in Heat Transfer. | |
| Unit III | **Engineering, Science & Materials for Microsystems**: Atomic structure, Crystal Structures, Bonding in materials, Ionization, Doping in Semiconductors, Diffusion Process, Plasma Physics, Electrochemistry, Silicon as a substrate material for MEMS, Compounds of silicon, Si Piezo resistors, other Piezo electric materials, GaAs, Polymer, Materials used in packaging | **8** |
| Unit IV | **Fabrication of Microsystems**: Photolithography, Ion Implantation, Diffusion, Oxidation, chemical & physical vapor deposition, Epitaxial growth of films, Chemical etching, Plasma etching. | **8** |
| Unit V | **Micromachining processes:** Bulk Micromachining**,** Surface Micromachining, The LIGA Process. | **4** |
| Unit VI | **Working principles of microsystems:** Microsensors: Acoustics wave sensors, Biomedical & Bio sensors, Chemical Sensors, Optical Sensors, Pressure Sensors, Thermal Sensors.<br>MEMS with Microactuators: Microgripper, Micromotors, Micro valves, Micro pumps, Micro accelerometer<br>Microfluidics | **8** |
| Unit VII | **Microsystem packaging:** Levels in microsystem packaging, Interfaces in Microsystem packaging, Essential packaging technologies, 3-d Packaging, assembly of Microsystems. Multi User MEMS Program (MUMPs) | **4** |

| **Lab Assignments** | | **Hrs** |
|---|---|---|
| Lab 1 | To study the etching process in silicon | 4 |
| Lab 2 | Thin film deposition and analysis | 4 |
| Lab 3 | 3D Printing | 4 |

**References Textbooks:**

1] Tai-Ran Hsu, ‘MEMS & Microsystem, Design and Manufacture’,McGraw Hill, 2012
2] Physics of Semiconductor Devices by S.M. Sze,Wiley Publications(2006)
3] Mark J Jackson, Micro and Nano-manufacturing , Springer; First Edition, (2006)ISBN
4] Zheng Cui,Micro-nanofabrication: Technologies and Applications, Springer First Edition (2006),ISBN-10:3540289224
5] R. Kassing, P. Petkov,W.Kulish, C. Popov., Functional Properties of Nanostructured Materials. Springer (ISBN: 978-1-4020-4595-0 (Print) 978-1-4020-4594-3(Online)

## AP-513 – Introduction to programming

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Learn a language, Python, for expressing computations |
| **CO-2 :** | Develop an informal understanding of computational complexity |
| **CO-3 :** | Examine the process of moving from an ambiguous problem statement to a computational formulation of a method for solving the problem |

| | |
|---|---|
| **CO-4 :** | Illustrate the useful set of algorithmic and problem reduction techniques |
| **CO-5 :** | Use computational tools (including simple statistical, visualization, and machine learning tools) to model and understand data |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | Introduction to Python & Simple Numerical Programs<br>Installing Python and Python IDEs, Basic elements of Python, Variables and assignment, branching programs, strings and input, loops, Simple codes, approximate solutions, Floats, Newton–Raphson | 12 |
| Unit II: | Functions, scoping, and abstraction<br>Functions, Scoping, Using functions to modularize code, Functions as objects, | 6 |
| Unit III | Structured types and mutability<br>Ranges and iterables,Strings, Tuples, Ranges, and Lists, SETS, Dictionaries | 6 |
| Unit IV | Recursion, global variables, modules and files, classes<br>Fibonacci Numbers, Palindromes, Global Variables, modules, files, testing and debugging, Abstract data types and classes, some important complexity classes | 12 |
| Unit V | Object-oriented programming, algorithms, data structures, Plotting<br>Search algorithms, sorting algorithms, Matplotlib | 10 |

**References Textbooks:**

1. Introduction to Computation and Programming Using Python, by John V Guttag, MIT Press

**<u>Any MOOC course from NPTEL equivivalent to at least 3 credits or higher</u>**

# M. Sc. TECH PHOTONICS

One of the greatest scientific discoveries of the twentieth century that has led to technological advancement touching all aspects of human life is the LASER. Applications of lasers range from medical applications, communications, and industrial applications to military applications. An understanding of laser technology is essential for an engineer working in many of the present-day cutting-edge technologies. The aim of this program is to train the students in the field of lasers, fiber optics, electro-optics, and photonics that would enable them to meet the challenges in this rapidly developing field.

**Stakeholders:**

(i) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments

(ii) Graduates in the relevant field of science/technology from recognized Universities across the country.

**Eligibility for Students:**

The candidate should possess Bachelor's degree or equivalent in Physics, Applied Physics, Engineering Physics, Electronic Science, Photonics, Optics, Material Science, Instrumentation Science or any equivalent branch

**OR**

B. Tech. (Any discipline)

**Organization:** The M. Sc. Tech. programme is of six-semester duration. In each of the first three semesters there are six theory courses and one laboratory course. The fourth semester is having one mini-project along with four theory courses and one laboratory course. There will be three continuous evaluation examinations and a final semester examination for every course. Half yearly evaluation of the final year project takes place at the end of the fifth semester. At the end of the final semester, the student submits a dissertation and makes a presentation about the work carried out by him/her on the project, which is evaluated by the Internal and External examiners. Course syllabus is updated periodically to keep pace with the contemporary technological advancement.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

**PEO1:** The M. Sc. Tech. in Photonics programme aims at developing skilled human resources in the field of Optics, lasers, Electro-optics and overall Photonics. It will ensure the understanding of applied optics, physics and engineering laser technology, fiber optics, semiconductor photonic devices, laser systems and its various applications, catering to the emerging multidisciplinary problems faced by defence industry and civilization.

**PEO2:** With a focus on the DRDO requirements, the students will be trained to use their knowledge for the benefit of society and made aware of their social duty. This will enable them to pursue career in research, academics and industry.

**PEO3:** At the end of the programme the officer or student should be able to undertake state of the art R&D in lasers and electro-optic systems and competitively work towards development of the latest technology in line with national programmes like Make in India.

PROGRAMME OUTCOMES (POs)

**PO1:** An ability to independently carry out research /investigation and development work to solve practical problems

**PO2:** An ability to write and present a substantial technical report/document

**PO3:** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor's program

**PO4:** Having adaptive thinking and adaptability in relation to environmental context and sustainable development

**PO5:** Having a clear understanding of professional and ethical responsibility

**PO6:** Having a good cognitive load management skill related to project management and finance

PROGRAMME SPECIFIC OUTCOMES (PSOs)

**On completion of M. Sc. Tech. (Photonics) programme, graduates will be able to**

**PSO1:** The M. Sc. Tech. in Photonics aims at developing a skilled knowledgeable Human task force in the field of Photonics serving the needs of the Defence Research and Development Organization & Tri – services (Army, Navy & Air force), Coast Guard, DGQA, DQA, Defence Public Sector units, in addition to the civilians in general. After completing the course, the students develop an ability to carry out independent research in the area of optical devices.

**PSO2:** The dissertation work of the M. Sc. Tech. students leads to publications in high impact international journals which trains them in technical documentation and report writing.

**PSO3:** The goal of the M. Sc. Tech. in Photonics course is to generate highly competent human resources in the areas of laser development, electro-optic systems, fibre optics, applied optics, and computational photonics.

## Credit Structure

1.

| Sl. No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | AM-606 | Mathematical methods | 3 | 1 | | 4 |
| 2 | AP-501 | Quantum Mechanics | 3 | 1 | | 4 |
| 3 | AP -502 | Introduction to Optics & Photonics | 3 | | 1 | 4 |
| 4 | AP -503 | Introduction to Lasers | 3 | 1 | | 4 |
| 5 | AP - 504 | Semiconductor Photonic Devices | 3 | 1 | | 4 |
| 6 | AP - 505 | Photonics Lab -1 | | | 4 | 2 |
| | | **Total** | **15** | **04** | **05** | **22** |

**SEMESTER II**

| Sl. No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | AP-506 | Electronics Devices and Circuits | 3 | | 1 | 4 |
| 2 | AP-507 | Solid State Physics | 3 | 1 | | 4 |
| 3 | AP -508 | Computational Photonics | 2 | | 2 | 4 |
| 4 | AP -509 | Nanophotonics | 3 | 1 | | 4 |
| 5 | AP - 510 | Electronics and Photonics Lab | | | 4 | 2 |
| 6 | AP-631 | Laser Applications | 3 | 1 | | 4 |
| | | **Total** | **14** | **03** | **07** | **22** |

**SEMESTER III**

| Sl. No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | EE-624 | Digital System Design using FPGA | 2 | | 2 | 4 |
| 2 | AP-623 | Introduction to Fiber Optics | 3 | | 1 | 4 |
| 3 | AP -511 | Non-linear Optics | 3 | 1 | | 4 |
| 4 | AP -512 | Advanced Photonics Lab | 0 | | 4 | 2 |
| 5 | PGC 601 | PGC 601 Research Methodology and IPR | 3 | 0 | | 2 |
| 6 | | Elective I | 3 | | | 4 |
| | | **Total** | **14** | **1** | **7** | **20** |

**Elective: I**

1. NPTEL MOOC course
2. AP 513 Introduction to Programming
3. Fabrication Technology AP 603

**SEMESTER IV**

| Sl. No. | Course Code | Course | Contact Hours /week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | AP 641 | High Power Lasers | 3 | 1 | | 4 |
| 2 | AP-642 | Tera Hertz Devices and Applications | 3 | 1 | | 4 |
| 3 | AP 643 | Free Space Optical Communication | 3 | 1 | | 4 |
| | | Elective II | 4 | | | 4 |
| 4 | AP 524 | Mini Project | | | | 4 |
| | | **Total** | **13** | **3** | | **20** |

**Elective: II**

1. Machine Learning AP 608

2. MOOC NPTEL

**SEMESTER V**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | P | |
| 1 | AP-525 | Project Phase I | | 28 | 14 |
| | | **Total** | | | |

**SEMESTER VI**

| Sl. No. | Course Code | Course | Contact Hours /week | | Credits |
|---|---|---|---|---|---|
| | | | L | P | |
| 1 | AP-526 | Project Phase I | | 28 | 14 |
| | | **Total** | | | |

## AM 606 Mathematical Methods

| | |
|---|---|
| **CO-1 :** | Will understand and know the analytical techniques to solve the differential equations of specific nature. Also, students will understand the power series representation of various functions like Bessel / Legendre when the given differential equation is not in the standard form. |
| **CO-2 :** | Students will learn Laplace and Fourier transforms techniques of various functions to Solve ODEs further Will be able apply to model physical phenomenon and then solve. |
| **CO-3 :** | Will be able to find rank of a matrix, able to diagonalize a matrix and give the related interpretation, can find the basis and dimension of a vector space, Image and kernel of a linear transformation. |
| **CO-4 :** | Students will learn what is Haar and Shannon wavelets are, and how they are used to represent and transform to apply them in various applications. |

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I | **Differential Equations:** Review of solution methods for first order as well as second and Higher order equations, Power Series methods with properties of Bessel functions and Legendre polynomials. | **9** |
| Unit II | **Applications:** Orthogonal Trajectories, Population Growth and Decay, Newton's Law of Cooling, Free Falling Bodies. Simple Harmonic Motion, Damped Motion, Forced Motion, Other Applications in Electronics and Pendulum Problem | **8** |
| Unit III | **Linear Algebra:** General (real) vector spaces, Subspaces, Linear independence, Dimension, Norms, Orthogonal bases and Gram-Schmidt | **9** |

| | | |
|---|---|---|
| | orthogonalization, Linear transformation, Kernel and range, Inverse transformations, Matrices of linear transformations, Change of basis, Similarity , Eigen values and eigen vectors, Diagonalization, Orthogonal diagonalization and symmetric matrices, Quadratic forms. | |
| Unit IV | **Transform Techniques:** Over View of Laplace Transforms – Inverse Laplace Transforms – Fourier transform: Flourier integral formula – Fourier transform – Inversion theorem for complex Fourier transform – Fourier Sine and Consine transforms – Inversion formulae – Finite Fourier sine and Cosine Transform – Inversion formulae – | **9** |
| Unit V | Application of transform techniqes to solutions of differential equations, integral equations and boundary value problems. Wavelets – The Haar wavelets – A wavelets expansion – Multiresolution analysis with Haar Wavelets – General construction of wavelets and multiresolution analysis - Shannon wavelets. | **9** |

**Texts / References:**


1. Advanced Engineering Mathematics, 10th Ed, 2005, Erwin Kreyszig Wiley Eastern.
2. Linear Algebra and its Applications, 4th Ed., 2008, Gilbert-Strang, Academic press.
3. Applied Linear Algebra & Matrix Analysis, 2007, Thomas S Shores, Springer.
4. Advanced Engineering Mathematics, Peter V. O'Neil Thomson Brooks /Cole
5. Ordinary Differential Equations by Deo and Raghavendra
6. Fourier analysis with Applications of boundary value problems schaum series.
7. Integral Transforms by Goyal and Gupta.


## AP-501 – Quantum Mechanics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand the basic concepts of quantum mechanics Physics |
| **CO-2 :** | Interpret the physical meaning of formulation in quantum mechanics |
| **CO-3 :** | Examine different 1D problems in quantum mechanics |
| **CO-4 :** | Illustrate the implementation to 1 electron atoms |
| **CO-5 :** | Explain Quantum mechanics to Lasers |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I | Historical Origin of Quantum mechanics: Thermal radiation, Plank's postulates, Black body radiation, stationary states, correspondence principle, Bohr Atom, shortcomings of old quantum theory. | **9** |
| Unit II | The Schrödinger equation, Statistical interpretation, probability, normalization, momentum, The uncertainty principle | **6** |
| Unit III | Time Independent Schrödinger: stationary states, infinite square well, harmonic oscillator, free particle, delta function potential, finite square well | **9** |

| | | |
|---|---|---|
| Unit IV | Formalism: Hilbert's space, observables, eigen function of Hermitian operator, statistical interpretation, Dirac notation | **6** |
| Unit V | One electron atoms: solution of Schrödinger equation in 3D, eigen values, quantum numbers, and degeneracy, orbital angular | **8** |
| Unit VI | Quantum statistics: indistinguishability and quantum statistics, quantum distribution functions, Boltzmann distribution as an approximation to quantum distributions, Introduction to Quantum Optics, Coherent States | **8** |

**References Textbooks:**


1. Quantum Mechanics, John Powell, Bernd Crasemann, Narosa Publishing House
2. Quantum Mechanics, Leonard Schiff, Mc-Graw Hill Book Company
3. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing
4. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing
5. Quantum Mechanics by B H Bransden and C J Joachain Pearson Publishing


**AP-502 –** Introduction to Optics and Photonics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of optical electronics |
| **CO-2 :** | Analyze the working principle of ME Theory, EO, MO and AO effects |
| **CO-3 :** | Examine the working mechanism of different types of Optical components, EO, MO and AO effects |
| **CO-4 :** | Illustrate the practical use of Optical components, EO, MO and AO effects |
| **CO-5 :** | Summarize different applications of optical electronics devices |

**Syllabus:**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I: | **Fundamentals of Photonics and Optics:** Wave equation, Plane waves, Applications of photonics, Reflection and Refraction of plane waves, Fresnel Equations, Wave propagation in different mediums, propagation of Electromagnetic waves in Uniaxial and biaxial crystals, the dielectric constant tensor and the 'index ellipsoid' | **9** |
| Unit II: | **Polarisation of light and Basic optical components:** Electromagnetic theory of light, Dielectric media, Monochromatic EM waves, Absorption and dispersion, Polarisation of light, Jones Calculus, Poincare sphere. Polarisers, Quarter, Half, and Full waveplates, Beam splitters: polarizing and non-polarizing, wavelength filters, dichroic mirrors, Lenses. | **10** |
| Unit III | **Electro-optics:** Basic principles: Pockel and Kerr effects, Electro-optic devices: modulators, switches, and scanners, E.O. effect in liquid crystals; LCDs and SLMs, Applications. | **9** |
| Unit IV | **Acousto-optics:** Strain waves in solids and liquids, the strain-optic tensor; theory of Raman-Nath and Bragg diffraction; small-angle and large-angle Bragg diffraction. Accousto-optic devices: Modulators, deflectors, scanners, interconnections, and acoustooptictunable filters. | **10** |
| Unit V | **Magneto-optics**: Principles, Faraday effect, Gyrotropic permittivity, Kerr | **6** |

| | | |
|---|---|---|
| | rotation and Kerr ellipticity, Applications. | |

**References Textbooks:**
1. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press,1989. References
2. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006.
3. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
4. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000.
5. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
6. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988.
7. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.

## **AP-503 –** Introduction to Lasers

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of laser technology |
| **CO-2 :** | Analyze the working principle of lasers |
| **CO-3 :** | Examine the laser radiation beams |
| **CO-4 :** | Illustrate and construct the practical laser systems |
| **CO-5 :** | Summarize different types of laser systems and its working principals |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Light-matter interaction:** Interaction of radiation with atomic systems, Einstein's coefficients, spontaneous emission, stimulated emission, Linewidth of the laser | 10 |
| Unit II: | **Lasers Oscillation**: Theory of laser oscillation; Threshold condition, Rate equation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output power, Pumping techniques. | 10 |
| Unit III | **Laser Resonators and Gaussian Beams**: The Ray Matrix, Resonator Stability, Paraxial Wave Equation, Gaussian Beams, ABCD Law for Gaussian Beams, Gaussian Beam Modes, Hermite–Gaussian and Laguerre–Gaussian Beams, Resonators for He–Ne Lasers, Diffraction, Diffraction Theory of Resonators, Beam Quality. | 10 |
| Unit IV | **Laser Systems 1:** Solid-state lasers, Gas lasers, | 8 |
| Unit V | **Laser Systems 2:** Fiber laser and amplifiers | 8 |
| | | |

Reference Book:
1. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
2. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
3. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988
4. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
5. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).

## **AP-504 –** Semiconductor Photonic Devices

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand the basics of Optical Physics |
| **CO-2 :** | Interpret all the optical properties and processes in semiconductors and dielectrics |
| **CO-3 :** | Examine the working mechanism of different kinds of LEDs and LASERs |
| **CO-4 :** | Illustrate the implementation of Modulation and Switching Devices |
| **CO-5 :** | Explain different types of photodiodes and photodetectors |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Review of Optical Physics:** Energy Bands of Direct and Indirect Semiconductors, Semiconductor Optoelectronic materials, Density of States, Fermi-level, PN Junction, Homo and Hetero Junction, Quantum Wells. Electron-hole pairs | **9** |
| Unit II: | **Light Emitting Diodes:** The electroluminescence Process, LED materials, Device configuration and Efficiency, LED structures, LED performance characteristics, Frequency response and Modulation bandwidth. LEDs for display and Lighting. | **9** |
| Unit III | **Semiconductor Lasers:** Junction Laser Operating Principles, Threshold Current, Heterojunction Laser, Distributed Feedback Lasers and Distributed Bragg Reflector, Ring Lasers: Single and Double, Master Oscillator Power Amplifier. VCSELS and Laser Diode Arrays. | **9** |
| Unit IV | **Modulation and Switching Devices:** Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator. | **9** |
| Unit V | **Photodetectors:** Types of photodetectors, Photoconductors, Junction photodiode, PIN photodiode and APD, Quantum Well IR Detectors, Detectors for long wavelength operation, Wavelength selective detection, Coherent detection. CCDs (EMCCD, ICCD) and Photonic Integrated Circuits. **Photo multiplier tubes (PMT),** Superconducting Nano-wire based detector, | **9** |
| | | |

**References Textbooks:**


1. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).
2. G. Ghione, Semiconductor Devices for High-Speed Optoelectronics, Cambridge University Press (2009)
3. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communication, Oxford University Press (2007), 6$^{th}$ Ed., Ch.15-17.
4. G. Keiser, Optical Fiber Communications, McGraw-Hill Inc., 3$^{rd}$ Ed. (2000), Ch.4, 6.
5. J. Singh, Semiconductor Optoelectronics: Physics and Technology, McGraw-Hill Inc. (1995).

6. J. M. Senior, Optical Fiber Communication: Principles and Practice, Prentice Hall of India, 2nd Ed. (1994), Ch.6-8.
7. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17, and 18.
8. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021).

## **AP-505 –** Photonics Laboratory I

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | To understand basic electronics |
| **CO-2 :** | To interprete characteristics of the devices |
| **CO-3 :** | Examine the working of basic electronic components |
| **CO-4 :** | Illustrate working of optical components |
| **CO-5 :** | Explain difference in diode and Laser characteristics |

**Syllabus:**

| **Syllabus Details** | **Hrs** |
|---|---|
| Photonics<br>1. Michelson Interferometer: Setting up Michelson interferometer using a highly monochromatic laser source, evaluation of laser wavelength by fringe counting.<br>2. Determination of the Electrical and Optical Characteristics of LED and Laser diode.<br>3. Designing of Optical Window, Concave and Convex Lens<br>4. Detection of polarisation states using polarisation components like polarizers, waveplates etc.<br>5. Analysis of various light source spectra using OSA.<br>6. Determination of the refractive index profile of a multimode and single mode fiber by the transmitted near field scanning technique and measurement of NA.<br>7. Macro and Microbending loss in optical fibers and its application<br>8. Measurement of Photodiode characteristics<br>9. Study of Fraunhofer diffraction pattern of a rectangular and circular aperture.<br>10. Optisystem Training Modules | 48 |

## **AP-506 –** Electronic Circuits and Devices

**Syllabus:**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I: | Basics of semiconductor and Introduction to Diodes:<br><br>The energy band theory of crystals, Intrinsic and Extrinsic semiconductors. P-N Junction diode as a Rectifier, Photo-Diode, Filters using Diode, Clipping & clamping circuits, LED, Zener diode | 8 |
| Unit II | Transistors and Oscillators<br><br>Basics of Transistor, Transistor characteristics and applications, basics of oscillators and multivibrators (IC555 as timer). | 10 |
| Unit III | Field Effect Transistor | 10 |

| | | |
|---|---|---|
| | Structure and working of: JFET, I-V characteristics and parameters (Pinch off voltage, trans conductance, drain resistance, amplification factor); MOSFET (construction and application only) Applications: FET as Voltage Variable resistance (VVR), switch, memory cell, DRAM | |
| UNIT IV: | OPAMPS & Multivibrators<br><br>Idea op-amplifier characteristics, Block diagram, Basic Inverting & non inverting amplifier, Basics of oscillator, Basics of Timer IC 555 as astable multivibrator. | 10 |
| UNIT V: | Sequential circuits and Counters<br><br>RS, Clocked RS, JK, Master Slave JK, D Flip flop, Counter-synchronous, asynchronous, up-down counter, modulo-N counter, Decade counter (IC 7490); shift register (IC 7495), ring counter | 8 |

**Reference Books:**


1. Millman's Integrated Electronics - Analog and Digital Circuit and Systems | 2nd Edition by Jacob Millman, Christos Halkias, Chetan Parikh
2. Electronic Principles | 7th Edition by Albert Malvino , David J. Bates


## **AP-507 –** Solid State Physics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand the basic concepts of Solid State Physics |
| **CO-2 :** | Interpret the physical meaning of formulation in Condensed Mateer |
| **CO-3 :** | Examine different Structure related properties |
| **CO-4 :** | Study the Electronic and magnetic properties of solids |
| **CO-5 :** | Develop skills to solve physics problems |

**Syllabus:**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I: | **Crystal Structure and Diffraction:**<br>Real lattices, packing fraction, reciprocal lattices, Brillouin zones. Diffraction by crystals - Ewald sphere construction, Bragg condition in k-space. Geometric structure factor and atomic form factor. Point defects, line defects and dislocations. | 8 |
| Unit II: | **Lattice Dynamics:**<br>Vibrations of crystals with mono-atomic and diatomic basis. Brillouin zones. Optical modes and acoustic modes. Quantization of elastic waves. Phonon momentum. Neutron scattering by phonons. Phonon heat capacity. Phonon density of states. Einstein and Debye theories , thermal | 10 |

| | | |
|---|---|---|
| | conductivity. | |
| Unit III | **Electronic Band Structure in Crystals**: Drude theory of metals. Quantum free electron model of metals (Sommerfeld model). Nearly free electron theory. Brillouin zones. Electron effective mass. Density of states and band gap. Kronig-Penney model. Bloch theorem. Crystal momentum. Qualitative distinction between semiconductors and metals. Fermi surface of metals. Hall effect. | 10 |
| Unit IV | **Dielectric and Magnetic Properties of Solids:** Macroscopic electric field and local electric field in solids. Polarizability and dielectric constant. Claussius-Mossotti relation. Dielectric-Ferroelectric phase transition. Landau theory. Piezoelectricity. | 10 |
| Unit V | **Magnetism** – Diamagnetism, Langevin equation. Pauli paramagnetism in metals. Paramagnetism –Curie law. Ferromagnetism. Quantum mechanical nature of ferromagnetic interaction. Anti-ferromagnetic and ferromagnetic order. | 8 |

**Reference Books:**

1. Introduction to Solid State Physics, Charles Kittel (John Wiley and Sons.).
2. Solid State Physics, A. J. Dekkar (Prentice Hall).
3. Solid State Physics, N. W. Ashcroft and N. D. Mermin (CBS Publishing Asia Ltd.).

## **AP-508 –** Computational Photonics

**Course Objectives:**

| | |
|---|---|
| **CO-1 :** | Understand the simulation methos of photonics devices and fiber Optics |
| **CO-2 :** | Study on mode solution method of photonics devices |
| **CO-3 :** | Study on beam propagation method for Photonics devices |
| **CO-4 :** | Study on FDTD method for photonics band gap |
| **CO-5 :** | Understanding the recent advance in photonics Devices |

**Syllabus:**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I: | Unit-1<br>**Mode Solver Method:** Theory of fully vectorial mode solvers in 2D and 3D structures, low-index polymer waveguides, high-index silicon (SOI) and GaAs/AlGaAs waveguides, buried, etched (rib, ridge), and diffused geometries commonly used in opto-electronics slot waveguides, slanted-wall and graded structures, plasmonic and microwave waveguides, | 9 |
| Unit II: | Unit-2<br>**Beam Propagation Method:** Theory and working of beam propagation method, Tutorials on MMI couplers, optical gratings, co-directional couplers or polarization converters. | 9 |
| Unit III | Unit-3<br>**FDTD Method:** Theory and working of FDTD method, Tutorials on photonics band gap simulation: 2D and 3D of different crystal lattices. | 9 |

| | | |
|---|---|---|
| Unit IV | Unit-4<br>**Fiber Optics Modeling:** Simulation and modeling of single mode and multimode optical fiber using mode solver, FBG and Chirped FBG synthesis, photonic crystal fiber simulation | 9 |
| Unit V | **Nanodesign:** Mask designing for nanofabrication of different device geometry | 9 |
| Unit VI | **Introduction to Finite Element Method** | 3 |

Reference Books:


1. S. Sujecki, Photonics Modelling and Design, CRC Press, 2015.
2. K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000.
3. A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method. Norwood, MA: Artech House, 1995.


## **AP-509 –** Nanophotonics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarization to the concept of Metamaterials |
| **CO-2** | Illustration of Optical Properties in Metamaterials |
| **CO-3** | Examine Surface Plasmon Resonance |
| **CO-4** | Analyze Photonic Bandgap Crystals in different dimensions |
| **CO-5** | Understanding the Importance of Silicon Photonics and Its Applications |

**Syllabus:**

| **Units Divisions** | **Syllabus Details** | **Hours** |
|---|---|---|
| Unit I | Basics of Nanophotonics: Photons and electrons, Quantum confinement effects, 2D, 1D, 0D structures, their growth and properties | **9** |
| Unit II: | **Metamaterials:** Definition of Metamaterials (MTMs) and Left-Handed (LH) MTMs, **Fundamentals of LH MTMs** Left-Handedness from Maxwell's Equations | **9** |
| Unit III: | **Metamaterial in Optics:** Optical Properties of Metal-Dielectric Composites, Optical Magnetism, Negative-refractive Index, Perfect lens and Cloaking objects. | **9** |
| Unit IV | **Surface Plasmon Resonance:** Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation od surface plsmons, surface Plasmon properties, SPR spectroscopy | **9** |
| Unit V | **Photonic band gap crystals:** Photonics Band-Gap: Introduction to Photonics crystal, Photonic Band Structures, One dimensional, Photonic crystal: Origin of Photonics Band Gap, Size of the band gap, Evanescent Modes in Photonics Band gaps, Two-dimensional Photonic crystal: Two-dimensional Bloch States, Square Lattices (Dielectric Columns and Veins), Three-dimensional Photonic crystal: Three-dimensional lattices, | **12** |

**References Textbooks:**


1. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, Christophe Caloz,Tatsuo Itoh, John Wiley and Sons,2006
2. Optical Metamaterials, Fundamentals and Applications, Wenshan Cai Vladimir Shalaev, Springer, 2010.
3. John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade,Photonic Crystal: Molding Light Flow of Light, Princeton University Press, 2008.
4. Graham T. Reed and Andrew P. Knights, Silicon Photonics: An Introduction, JohnWiley and Sons Ltd, 2004
5. Metamaterials: Physics and Engineering Explorations, Nader Engheta Richard W. Ziolkowski, Wiley and Sons,2006
6. Negative-Refraction Metamaterials Fundamental Principles and Applications, G. I. Eleftheriades K. G. Balmain,Wiley and Sons,2005


## **AP-510 –** Electronics and Photonics Laboratory II

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand basic logic circuits |
| **CO-2 :** | Analyze the working of A/D and D/A convertors |
| **CO-3 :** | Illustrate the working Holography |
| **CO-4 :** | Examine the losses in fiber optical communication |
| **CO-5 :** | Interprete the working of fiber lasers |

**Syllabus:**

| **Syllabus Details** | **Hrs** |
|---|---|
| Electronics:<br>1. To study the I-V Characteristics of Diodes (Simple and Zener Diode)<br>2. To study the I-V Characteristics of Transistors in CB, CE, CC modes (NPN and PNP Transistors)<br>3. To study the I-V Characteristics of MOSFETs<br>4. To study the Half, Full, and Bridge rectifier<br>5. To study the Voltage and Current regulation with a fixed load<br>6. To study the Clipping and clamping Circuit<br>7. To study the Characteristics of 741 OPAMPs<br>8. To analyze the inverting and non-inverting amplifier<br>9. To Design Active filters | 20 hrs |
| Photonics:<br>1. Beam Width, Divergence, and $M^2$ measurement of He-Ne/Diode Laser with and without collimation lens.<br>2. Fiber optic link design<br>3. Measurement of attenuation and dispersion in optical fibers<br>4. Fiber to Fiber splicing and splicing loss measurement.<br>5. Setting up of Mach-Zender interferometer | 28 hrs |

| | |
|---|---|
| 6. Design of driver circuit for LED and Laser diode<br>7. Characterization of Erbium Doped Fiber Amplifier<br>8. Holography<br>9. Design of signal conditioning circuits for Photodetectors | |

## EE-624 – DIGITAL SYSTEM DESIGN USING FPGAs

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Familiarized with the design of Combinational and Synchronous and Asynchronous Sequential Circuits. Gave an Overview of PLDs and PALs |
| **CO-2 :** | Covered basic introduction of VHDL and the basic language elements. Various Combinational and Sequential circuits were designed using VHDL |
| **CO-3 :** | In-depth analysis of Faults and testability in digital systems including modelling and detection |
| **CO-4 :** | Interfacing various sensors and reading/writing to/from various file formats. Implementing various modulation schemes |
| **CO-5 :** | Design of a RISC CPU, data and control path components. Introduction to various floating/fractional/fixed-point arithmetic operations. Implementing Data encryption/Decryption system, Error correction, communication modules, BERT |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Digital system design techniques:**<br>Combinational Circuit Design - Synchronous Sequential Circuit Design - Mealy and Moore model - State machine design - Analysis of Synchronous sequential circuit - State equivalence - State Assignment and Reduction - Analysis of Asynchronous Sequential Circuit - flow table reduction – races - state assignment - Design of Asynchronous Sequential Circuit - Designing with PLDs – Overview of PLDs – ROMs - EPROMs – PLA – PAL - Gate Arrays – CPLDs and FPGAs, Designing with ROMs - Programmable Logic Arrays - Programmable Array logic. | 12 |
| Unit II: | **IIVHDL basics and computation module designs:** Introduction to VHDL - Behavioral modeling - Data flow modeling - Structural modeling - Basic language elements<br>– Entity – Architecture - Configurations – Arrays declaration - Subprograms & operator overloading - Packages & libraries – Advanced Features - Model simulation - Realization of combinational and sequential circuits using VHDL – Registers – Flip flops - counters – Shift registers – Multiplexers - sequential machine – Multiplier – Divider, ALU, MAC, CORDIC, Introduction to Synthesis. | 6 |
| Unit III | **Fault modeling, detection and test pattern generation algorithms:**<br>Introduction to testing – Faults in Digital Circuits – Modeling of faults – Logical Fault Models – Fault detection – Fault Location – Fault dominance – Logic simulation – Test generation for combinational | 6 |

| | | |
|---|---|---|
| | logic circuits – Testable combinational logic circuit design - Introduction to Design for Testability - BIST. | |
| Unit IV | **Digital system design with real-time I/O interface:** Sensors interface - uni-polar & bi-polar A/D converter - D/A converter interface - display devices interface - RS232, USB, Ethernet, VGA interface - RF data link - high voltage switch control - realy/AC/DC motor & buzzer control - PWM signal generation - PS/2 key-board & matrix keypad interface – digital camera interface, arbitrary data/signal generation – sensor data acquisition and writing/reading to/from .xlsx and .doc file - implementation of modulation schemes | 12 |
| Unit V | **Contemporary designs and solutions:** Design of data path components, Control path components - Design of a simple RISC CPU - Debugging using Embedded Logic Analyzers - Audio codec (AC97) interface – Test-bench design - ChipScope Pro Analyzer - introduction to floating/fractional/fixed-point arithmetic operations - Xilinx Sys-Gen tools - MATLAB/VHDL interface with Sys-Gen tools -BERT interface – implementation of DPCM, data encryption/decryption system, EC techniques, communication modules design, DA based computations. | 10 |

**LIST OF EXPERIMENTS:**

| SL No | NAME OF EXPERIMENTS |
|---|---|
| 01. | The Basic FPGA Design Flow<br>To understand use of Xilinx ISE<br>To understand Xilinx Synthesis Technology or XST.<br>Familiarization of Xilinx Vivado Design Tools. |
| 02. | Familiarization of FPGA Boards<br>Xilinx FPGA Boards (Virtex 6,Kintex7)<br>Implementation of Full adder, ALU , Memory and FIFO on FPGA |
| 03. | Fault Detection Logic Implementation on FPGA<br>1. Stuck at Fault 2.Memory BIST |
| 04. | Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analyzers. |

**REFERENCE TEXT BOOKS:**


1. Jesse H. Jenkins, "Designing with FPGAs and CPLDs", Prentice Hall, NJ,1994
2. Fundamentals of Logic Design – Charles H. Roth, 5th ed., Cengage Learning.
3. Kevin Skahill, "VHDL for Programmable Logic", Addison -Wesley, 1996
4. Z. Navabi, "VHDL Analysis and Modeling of Digital Systems", McGRAW-Hill, 1998
5. Digital Circuits and Logic Design – Samuel C. Lee , PHI
6. Smith, "Application Specific Integrated Circuits", Addison-Wesley, 1997
7. P.K. Lala, “Digital Circuit Testing and Testability”, Academic Press, 2002


**AP-623 – Introduction to Fiber Optics**

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understand the basics concepts of Fiber Optic Communication |
| **CO-2** | Understand all the sub-components of Fiber Optics |
| **CO-3** | Examine the working mechanism of Fiber Optics |
| **CO-4** | Illustrate the practical implementation of Fiber Optic Communication |
| **CO-5** | Summarize different applications of Fiber Optic Communication |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Optical Fibers:** Light Propagation in Optical Fibers, Optical fiber Modes and Configurations, Mode Theory for Circular waveguides, SM and GI Fibers, Fiber Materials, PhC fibers, Fiber fabrication.<br>**Optical Fibers Characteristics:** Fiber Attenuation, Absorption losses, scattering losses, Radiation losses, Bending losses, Measurement of losses, Dispersion in fibers, Effect of dispersion in the communication link, Dispersion reduction, and compensation techniques. | **10** |
| Unit II: | **Power Launching and Coupling:** Source to Fiber launching and Launching Schemes for Coupling Improvements. Fiber to Fiber joints, Laser coupling to SM fiber, Fiber splicing, Optical Fiber Connector.<br>**Optical Receivers:** Basic Concepts, Common Photodetectors, Receiver Design, Receiver Noise, Coherent Detection, Receiver Sensitivity, Sensitivity Degradation, Receiver bandwidth, and Performance | **9** |
| Unit III | **Fiber Amplifier:** Optical Amplification in rare-earth-doped fibers, Types of Fiber Amplifiers, EDFA, Amplifier Noise, Optical SNR, System Application, Raman Amplifiers, Wideband Optical Amplifier | **9** |
| Unit IV | **Optical Fiber Sensors:** Introduction, Classification and Types of Optical Fiber Sensors, Sensor Modulation techniques, Fiber Bragg Grating Sensors: Principle and Applications. | **9** |
| Unit V | **Overview of Optical Fiber Communication:** Lightwave communications, Optical Spectrum Bands, and Visible Units, Network Information rate and WDM concepts. Key Elements of fiber optics system, Standards for Optical fiber communications. | **9** |

**References Textbooks:**


1. A.K. Ghatak & K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press 1998
2. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008
3. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998
4. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998
5. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988


**AP-511 –** Non-linear Optics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of nonlinear process |
| **CO-2 :** | Analyse the optical response of NLO devices |

| | |
|---|---|
| **CO-3 :** | Examine the working principle of different NLO devices |
| **CO-4 :** | Illustrate the application of NLO for ultrashort pulse generation |
| **CO-5 :** | Understand the quantum optics |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Nonlinear optics basics**: Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients | **8** |
| Unit II: | **Second order nonlinear effects**: Second harmonic generation, Phase matching condition, Various phase matching techniques, Characterization of second order nonlinear optical materials, Periodically poled materials and their applications in nonlinear optical devices. | **10** |
| Unit III | Sum and difference frequency generation, Optical parametric amplification (OPA) and oscillation (OPO), Analysis of OPA and OPO; practical device configurations and applications. Spantaneous Parametric Down Conversion (SPDC) | **8** |
| Unit IV | **Third order non linear effects**: Third harmonic generation, Four wave mixing and Self-phase-modulation Optical Kerr effect, Self-focusing, Optical Solitons; Optical phase conjugation and Optical bistability. Stimulated Raman Scattering and Stimulated Brilluoin Scattering. | **10** |
| Unit V | **Ultrafast Optics**: Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Nonlinear Schrödinger equation, Supercontinuum generation. | **8** |
| | **Applications of Nonlinear optics, Raman Amplifiers, Nonlinear fiber optics and devices** | **4** |

## AP-512 – Laboratory -III

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Characterization of Fiber Optics Devices |
| **CO-2 :** | Analyse the optical multiplexing techniques and its device performance |
| **CO-3 :** | Examine the working principle of different electro-optic and magneto-optic effects |
| **CO-4 :** | Illustrate the different beam characterization methods |
| **CO-5 :** | Understand the design of different spectroscopic systems |

**Syllabus:**

| Syllabus Details | Hrs |
|---|---|
| Characterization of Fiber Bragg grating<br>Power budget analysis using Optical Time Domain Reflectometer (OTDR)<br>Study of Time Division Multiplexing of digital signals<br>Study of a Wavelength Division Multiplexing(WDM) in optical fiber link<br>Study of Add/drop multiplexer<br>Study of Bit error rate and Eye pattern analysis<br>Setting up a Free space Laser Communication experiment link<br>Measurement of third order nonlinear optical coefficient using Z-scan | 48 hrs |

| | |
|---|---|
| Study of Faraday effect<br>Design of a fiber optic sensor<br>Line coding and decoding, voice coding<br>Measurement of insertion loss of an isolator, coupler and multiplexer<br>Beat length measurement in birefringent fibers.<br>Laser Raman Spectroscopy Experiments<br>Holography<br>**Note: Any 12 experiments are mandatory** | |

## PGC-601 – Research Methodology and IPR

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understanding the fundamentals of research and its methodology |
| **CO-2 :** | Choose the appropriate research design and develop appropriate 3 hypotheses for a research project |
| **CO-3 :** | Knowledge of manuscript preparation, patents and Intellectual property |
| **CO-4 :** | Technology transfer and application of IPR in various domains |

**Syllabus:**

| Units Divisions | Syllabus Details |
|---|---|
| Unit I: | Meaning of research problem, Sources of the research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of the research problem.Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations |
| Unit II: | Effective literature studies approach, analysis Plagiarism, Research ethics, |
| Unit III | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee |
| Unit IV | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process ofPatenting and Development: technological research, innovation, patenting, development.International Scenario: International cooperation on Intellectual Property. Procedure forgrants of patents, Patenting under PCT. |
| Unit V | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.<br>Patent information and databases. Geographical Indications |
| Unit VI | New Developments in IPR: Administration of Patent System. New developmentsin IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case<br>Studies, IPR and IITs. |

**References Textbooks:**

1. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for science & engineering students’”
2. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
3. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for beginners”
4. Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd,2007.
5. Mayall, “Industrial Design”, McGraw Hill, 1992.
6. Niebel, “Product Design”, McGraw Hill, 1974.
7. Asimov, “Introduction to Design”, Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”, 2016.
9. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008

**List of Electives**

**Elective Course Content for Semster -II**

## AP-631 – Laser Applications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarize to a variety of applications on lasers |
| **CO-2** | Interpret how laser-based metrological techniques work |
| **CO-3** | Understand laser spectroscopy applications |
| **CO-4** | Investigate various methods of how a laser can be used for defence applications |
| **CO-5** | Summarize different applications of lasers |

**Syllabus:**

| Units | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Laser Metrology: Laser** for measurement of distance, length, velocity, acceleration; rotation sensing; RLG and FOG. | **6** |
| Unit II | **Laser Spectroscopy:** IR absorption Spectroscopy, Laser Raman spectroscopy, Laser induced breakdown spectroscopy (LIBS), laser-induced fluorescence (LIF), Tunable diode laser spectroscopy (TDLS), Terahertz spectroscopy, Photoacoustic spectroscopy, Instrumentation in laser spectroscopy, Isotope Separation & Enrichment. Bio-Medical Application of Lasers | **12** |
| Unit III | **Holography:** Holographic interferometry and applications; Holography for non – destructive testing – Holographic components | **6** |
| Unit IV | **Industrial Application of Laser:** Laser cutting, Laser welding, Laser drilling, Laser marking, Photolithography, Laser-based unmanned ground vehicles | **9** |
| Unit V | **Defence Applications:** Low power laser applications including Laser Range finders-LRF (DPSSL, Eye Safe & High PRF) & Laser Target Designators; Dazzlers, Laser Warning receivers, Infrared counter measures, Laser Guidance; Laser-based navigation; Laser-based imaging; Laser-based remote sensing: Laser radar, laser radar seekers, LIDAR basic concept and applications | **12** |

## AP-642 – Terahertz Devices and Applications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of terahertz technology |
| **CO-2** | Analyze the working principle of different types of terahertz signal sources |
| **CO-3** | Examine the working mechanism of different types of terahertz detectors |
| **CO-4** | Illustrate the practical implementation of fabrication of components and circuits for terahertz systems |
| **CO-5** | Summarize different applications of terahertz technologyfor imaging, sensing and communications |

**Syllabus:**

| Units | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Basics of Terahertz Technology:** Electromagnetic radiation and propagation fundamentals, Introduction to terahertz technology, Background, Terahertz gap, Key technological issues for terahertz technology, Advantages and limitations of terahertz waves, Material properties at mm and sub-mm frequencies | **9** |
| Unit II | **Terahertz Sources:** Terahertz sources based on electronics: Diodes, transistors, resonant tunnelling diodes, vacuum electronics; Terahertz sources based on photonics: Non-linear crystals, quantum cascade lasers, plasma-based source; Terahertz sources based on optoelectronics: Photomixer, photoconductive antenna and its types; Noises at terahertz frequencies in different sources | **9** |
| Unit III | **Terahertz Detectors:** Terahertz detectors based on electronics: HOT electron bolometer, Heterodyne SIS receivers: Theory and Design, Superconducting tuning circuitries, HEB heterodyne receivers: Theory and Design, Terahertz MMICs: Theory and Design, Terahertz detectors based on photonics | **9** |
| Unit IV | **Terahertz Components:** Terahertz components: Metamaterials and plastic fibers, HEMT cryogenic amplifiers: Theory and Design, Antennas, Filters, Waveguides, Beam Splitter, Beam Combiner, Polarizer, Mirrors, Isolator, Circulator, Cameras, Fabrication Technologies, Metamaterial THz devices, Spintronic THz components. | **9** |
| Unit V | **Terahertz Applications:** Terahertz applications: Time domain Colinear and Non-colinear terahertz spectroscopy, Optical-pump-THz-probe Spectroscopy, Terahertz Imaging, Terahertz sensing and analysis, Terahertz wireless communication, Terahertz remote-sensing, 3D terahertz tomography system, Industrial applications, Space Communication, Cutting-edge terahertz technologies | **9** |

**References Textbooks:**


1. Rostami, H. Rasooli, H. Baghban, Terahertz Technology: Fundamentals and Applications, Germany, Springer, 2011.

2. R. E. Miles, P. Harrison, D. Lippens, Terahertz Sources and Systems “, Dordrecht: Kluwer, Springer, 2000.
3. K. Sakai, Terahertz Optoelectronics, Springer, 2004.
4. H.-J. Song, T. Nagatsuma, Handbook of Terahertz Technologies, Devices and applications, Pan Stanford Publishing Pte. Ltd., 2015.
5. D. Saeedkia, Handbook of Terahertz Technology for Imaging, Sensing and Communications, Woodhead Publishing, 2013.


## AP-643 – Free Space Optical Communications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of Free Space Optical Communication |
| **CO-2** | Understand all the sub-components |
| **CO-3** | Examine the working mechanism of FSOC |
| **CO-4** | Illustrate the practical implementation of FSOC |
| **CO-5** | Summarize different applications of FSOC such as VLC/UWOC |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Introduction FSOC/OWC,** Basic Link configuration of FSOC, various application areas of FSOC, Indoor Channel modelling, various link configurations, Artificial light interference effects in indoor channel. | **9** |
| Unit II: | **Channel Modelling -Outdoor channel,** Atmospheric channel loss related issues, Atmospheric turbulence effects, Measurement of $C_n^2$, Various atmospheric turbulence models, Effects of atmospheric turbulence on laser beam propagation, Realization of atmospheric effects on OWC test beds | **9** |
| Unit III | **Modulation Techniques:** Importance of modulation in FSO, various modulation formats, selection criteria for modulation, basic modulation schemes OOK,PPM, PIM, DH-PIM, BPSK etc. and error propagation<br>**FSO link Performance under atmospheric turbulence:** performance of FSO link in various modulation formats, comparison across the modulation formats, the turbulence-induced penalty in FSO link, Link budget analysis, Power budget analysis | **11** |
| Unit IV | **Mitigation techniques:** introduction, aperture averaging, various diversity techniques, spatial diversity, time diversity coding techniques, adaptive optics and other techniques. | **9** |
| Unit V | **Laser beam Tracking, pointing & acquisition:** Acquisition and Tracking systems, System description, Acquisition methodology, tracking and pointing control system, RF cross-link system design, link equation Intoduction to Free Space Quantum Optical Communication | **10** |

**References Textbooks:**

1. Arun K. Majumdar, Free-Space Laser Communications Principles and Advances. Springer Publications
2. Hemani Kaushal, Free Space Optical Communication. Springer Publication
3. J. Franz and V.K. Jai, Optical Communication Systems. Narosa Publications
4. Morris Katzman, Laser Satellite Communications. Prentice Hall Inc 1991
5. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K. Jha

**<u>Elective Course Content for Semster -III</u>**

### AP-603 – Technology and Packaging of MEMS systems

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Students to be able to understand concepts involved in MEMS |
| **CO-2 :** | Students to understand the technologies involved in MEMS fabrication and packaging, their advantages and limitations |
| **CO-3 :** | Students to be able to understand working principles in micro sensors and actuators |
| **CO-4 :** | Students to become capable of conceptualizing the design of a microsystem |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Evolution of Microsystems:** Concept & History of Micro systems & MEMS, Benefits of Micro Systems, Comparison between Microsystems & microelectronics, Multidisciplinary nature of microsystems development. | **2** |
| Unit II: | **Scaling Laws in Miniaturization:** Introduction to scaling, geometric scaling, scaling in rigid body dynamics, scaling in electrostatic forces, scaling in electromagnetic Electricity, scaling in fluid mechanics, Scaling in Heat Transfer. | **4** |
| Unit III | **Engineering, Science & Materials for Microsystems**: Atomic structure, Crystal Structures, Bonding in materials, Ionization, Doping in Semiconductors, Diffusion Process, Plasma Physics, Electrochemistry, Silicon as a substrate material for MEMS, Compounds of silicon, Si Piezo resistors, other Piezo electric materials, GaAs, Polymer, Materials used in packaging | **8** |
| Unit IV | **Fabrication of Microsystems**: Photolithography, Ion Implantation, Diffusion, Oxidation, chemical & physical vapor deposition, Epitaxial growth of films, Chemical etching, Plasma etching. | **8** |
| Unit V | **Micromachining processes:** Bulk Micromachining**,** Surface Micromachining, The LIGA Process. | **4** |
| Unit VI | **Working principles of microsystems:** Microsensors: Acoustics wave sensors, Biomedical & Bio sensors, Chemical Sensors, Optical Sensors, Pressure Sensors, Thermal Sensors.<br>MEMS with Microactuators: Microgripper, Micromotors, Micro valves, Micro pumps, Micro accelerometer<br>Microfluidics | **8** |
| Unit VII | **Microsystem packaging:** Levels in microsystem packaging, Interfaces in | **4** |

| | | |
|---|---|---|
| | Microsystem packaging, Essential packaging technologies, 3-d Packaging, assembly of Microsystems. Multi User MEMS Program (MUMPs) | |

| **Lab Assignments** | | **Hrs** |
|---|---|---|
| Lab 1 | To study the etching process in silicon | 4 |
| Lab 2 | Thin film deposition and analysis | 4 |
| Lab 3 | 3D Printing | 4 |

**References Textbooks:**


1] Tai-Ran Hsu, ‘MEMS & Microsystem, Design and Manufacture’,McGraw Hill, 2012

2] Physics of Semiconductor Devices by S.M. Sze,Wiley Publications(2006)

3] Mark J Jackson, Micro and Nano-manufacturing , Springer; First Edition, (2006)ISBN

4] Zheng Cui,Micro-nanofabrication: Technologies and Applications, Springer First Edition (2006),ISBN-10:3540289224

5] R. Kassing, P. Petkov,W.Kulish, C. Popov., Functional Properties of Nanostructured Materials. Springer (ISBN: 978-1-4020-4595-0 (Print) 978-1-4020-4594-3(Online)


## AP-513 – Introduction to programming

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Learn a language, Python, for expressing computations |
| **CO-2 :** | Develop an informal understanding of computational complexity |
| **CO-3 :** | Examine the process of moving from an ambiguous problem statement to a computational formulation of a method for solving the problem |
| **CO-4 :** | Illustrate the useful set of algorithmic and problem reduction techniques |
| **CO-5 :** | Use computational tools (including simple statistical, visualization, and machine learning tools) to model and understand data |

**Syllabus:**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I: | Introduction to Python & Simple Numerical Programs<br>Installing Python and Python IDEs, Basic elements of Python, Variables and assignment, branching programs, strings and input, loops, Simple codes, approximate solutions, Floats, Newton–Raphson | 12 |
| Unit II: | Functions, scoping, and abstraction<br>Functions, Scoping, Using functions to modularize code, Functions as objects, | 6 |
| Unit III | Structured types and mutability<br>Ranges and iterables,Strings, Tuples, Ranges, and Lists, SETS, Dictionaries | 6 |
| Unit IV | Recursion, global variables, modules and files, classes<br>Fibonacci Numbers, Palindromes, Global Variables, modules, files, testing and debugging, Abstract data types and classes, some important complexity classes | 12 |

| | | |
|---|---|---|
| Unit V | Object-oriented programming, algorithms, data structures, Plotting<br>Search algorithms, sorting algorithms, Matplotlib | 10 |

**References Textbooks:**

1. Introduction to Computation and Programming Using Python, by John V Guttag, MIT Press

**Any MOOC course from NPTEL equivivalent to at least 3 credits or higher**

# M.Sc. INFORMATION TECHNOLOGY

1. **Name of Course** : MSc (IT)
2. **Duration** : 98 Weeks
3. **Eligibility** : Officers nominated by IHQ MoD (N). (Minimum educational qualification – Graduate).
4. **Semester** : 04

5. **Semester I (20 weeks and 24 Credits)**.

| **Course Code** | **Subject** | **L-P/T (Hours per subject)** | **Marks** | **Credits** | **Remarks** |
|---|---|---|---|---|---|
| MSIT501 | **Software Engineering** –SDLC techniques, System Design & Modelling and SSAD | 3-1/0 | 100 | 04 | 91% - 100% **O**<br>81% - 90% **A+**<br>71% - 80% **A**<br>61% - 70% **B+**<br>55% - 60% **B**<br><br>(A minimum of 50% in each subject and an overall 55% is to be achieved for award of Msc IT) |
| MSIT502 | **Basic Database Management** – RDMS, SQL, Database Replication and Disaster Recovery | 3-1/0 | 100 | 04 | |
| MSIT503 | **Software Programming Part-I** - OOPS Concepts & Application Development with insight of C, C++ concepts | 3-1/0 | 100 | 04 | |
| MSIT504 | **Networking** – OSI, Topologies and Network configuration | 3-1/0 | 100 | 04 | |
| MSIT505 | **Operating System** - Windows Server Administration with Microsoft Office Share Point Server and Microsoft Exchange Server | 3-1/0 | 100 | 04 | |
| MSIT506 | **Cyber Security** - Security Lifecycle and management of IT assets, Risk Management Framework Systems, Cyber Security Guidelines | 3-1/0 | 100 | 04 | |
| **Total** | | | **600** | **24** | |

6. **Semester II (20 weeks and 24 Credits)**.

| Course Code | Subject | L-P/T (Hours per subject) | Marks | Credits | Remarks |
|---|---|---|---|---|---|
| MSIT507 | **Software Programming Part-II** - ASP.Net Programming | 3-1/0 | 100 | 04 | 91% - 100% **O**<br>81% - 90% **A+**<br>71% - 80% **A**<br>61% - 70% **B+**<br>55% - 60% **B**<br><br>(A minimum of 50% in each subject and an overall 55% is to be achieved for award of Msc IT) |
| MSIT508 | **Advance Networking** – VLAN, Wireless and Mobility, Network Security | 3-1/0 | 100 | 04 | |
| MSIT509 | **Linux/Unix/Aix & Administration** – Administration, Software Tools, Utilities, Troubleshooting Problems | 3-1/0 | 100 | 04 | |
| MSIT510 | **Application Orientation** - FIS, ILMS, ICMS, GMS | 3-1/0 | 100 | 04 | |
| MSIT511 | **ERP** – Basic terminology**,** SAP (Basic, ABAP & Security modules) | 3-1/0 | 100 | 04 | |
| MSIT512 | **Project Implementation**<br>Software development final phase based on the training imparted in the previous semesters. Evaluation of the project will be done based on timely completion, testing, completion of VA documents, and user acceptance by INS Hamla. VA documents include: -<br>User manual<br>System Specification Manual<br>Installation Manual<br>System Admin Manual<br>Maintenance Manual<br>Cyber Security Policy<br>Risk Assessment & Risk Management<br>Incident Response Plan | - | 100 | 04 | |
| **Total** | | | **600** | **24** | |

7. **<u>Semester III - 20 weeks and 20 Credits</u>**.

| **Course Code** | **Subject** | **L-P/T (Hours per subject)** | **Marks** | **Credits** |
|---|---|---|---|---|
| MSIT5 13 | **PowerBuilder** – Introduction to PowerBuilder application & component, PowerScript language, PowerScript functions, Object-oriented programming with PowerBuilder techniques, Multitier applications with PoweBuilder, Database connection using PowerBuilder | 3-1/0 | 100 | 04 |
| MSIT5 14 | **Sybase** - Introduction to Sybase, Creating database systems, Security management, Database Backup and Recovery System. Maintenance, Installation of Sybase Server. | 3-1/0 | 100 | 04 |
| MSIT5 15 | **Project Management** | 3-1/0 | 100 | 04 |
| MSIT5 16 | **NPTEL** – Suitable IT related Course worth 04 credits available at the time of course. | - | 100 | 04 |
| MSIT5 17 | **<u>OJT Phase</u>**.<br><br>Implementation of existing software at various Ships & establishments, testing of the software for environment acceptance and modification as per user requirements. In addition, the officer will be evaluated by his Commanding Officer/ OiC of the unit based on the utilisation of various naval software and implementation of Naval IT Policies in his/her respective unit. | - | 100 | 04 |
| **Total** | | | **500** | 20 |

8. **<u>Semester IV - 20 weeks and 17 Credits</u>**.

| **Course Code** | **Subject** | **Marks** | **Credits** |
|---|---|---|---|
| MSIT5 18 | **<u>Dissertation Phase</u>** | 425 | 17 |

**<u>Course Summary</u>**

| **Semester** | **Weeks** | **Marks** | **Credits** |
|---|---|---|---|
| I | 20 | 600 | 24 |
| Semester break | 06 | - | |
| II | 20 | 600 | 24 |
| Semester break | 06 | - | |

| | | | |
|---|---|---|---|
| III | 20 | 500 | 20 |
| Semester break | 06 | - | |
| IV | 20 | 425 | 17 |
| **Grand Total** | **40** | **2125** | **85** |

**Objectives of the Course**

The ITMC syllabus encompasses topics ranging from Basic Programming in C/C++, Software Development, Database management, SQL, ASP.Net, Advance Networking, SAP modules, Linux, various Cyber Security Policies and orientation to applications used in the Indian Navy. The course curriculum has been formulated and structured based on learning outcome for the Officers trained for carrying out IT duties in various ships and shore establishments of the Indian Navy as follows:-

| Ser | Learning Outcome |
|---|---|
| (a) | To be able to carry out duties of System Administrator/ IT Manager |
| (b) | To be able to coordinate and oversee adherence to Naval IT Policy in installations and upkeep of IT infrastructure |
| (c) | To be able to coordinate the implementation of IT software projects at ships, establishments, fleet and command levels |
| (d) | To coordinate procurement, maintenance and repair of hardware, software and network components etc. |
| (e) | To coordinate configuration management and update |
| (f) | To be able to develop software specific to Navy's requirements |
| (g) | To be able to implement Naval IT Security Policy |
| (h) | To be able to draw up the system requirement specification of a small/ medium Local Area Network |
| (j) | To be able to assist in the development of multimedia Packages |

**DETAILED SYLLABUS SOFTWARE ENGINEERING – MSIT501**

**UNIT – I: Introduction to Software Engineering.** The evolving role of software, changing nature of software, software myths.

**A Generic view of process.** Software engineering- a layered technology, a process framework, the capability maturity model integration (CMMI), process patterns, process assessment, personal and team process models.

**Process models.** The waterfall model, incremental process models, evolutionary process models, the unified process.

**UNIT – II: Software Requirements.** Functional and non-functional requirements, user requirements, system requirements, interface specification, the software requirements document.

**Requirements engineering process.** Feasibility studies, requirements elicitation and analysis, requirements validation, requirements
management.

**System models.** Context models, behavioural models, data models, object models, structured methods.

**UNIT – III: Design Engineering.** Design process and design quality, design concepts, the design model.

**Creating an architectural design.** software architecture, data design, architectural styles and patterns, architectural design, conceptual model of UML, basic structural modelling, class diagrams, sequence diagrams, collaboration diagrams, use case diagrams, component diagrams.

**UNIT – IV: Testing Strategies.** A strategic approach to software testing, test strategies for conventional software, black-box and white-box testing, validation testing, system testing, the art of debugging.

**Product metrics.** Software quality, metrics for analysis model, metrics for design model, metrics for source code, metrics for testing, metrics for maintenance.

**UNIT – V: Metrics for Process and Products.** Software measurement, metrics for software quality.

**Risk management:** Reactive Vs proactive risk strategies, software risks, risk identification, risk projection, risk refinement, RMMM, RMMM plan.

**REFERENCE BOOKS:**

1. Software Engineering, an Engineering approach- James F. Peters, Witold Pedrycz, John Wiley.
2. Software Engineering principles and practice- Waman S Jawadekar, The Mc Graw Hill Companies.
3. Fundamentals of object-oriented design using UML Meiler page-Jones: Pearson Education.

**DETAILED SYLLABUS BASIC DATABASE MANAGEMENT – MSIT502**

**Unit – I: Introduction to Databases and Transactions**. What is database system, purpose of database system, view of data, relational databases, database architecture, transaction management.

**Unit - II: Data Models**. The importance of data models, Basic building blocks, Business rules, The evolution of data models, Degrees of data abstraction.

**Unit – III: Database Design, ER-Diagram and Unified Modelling Language**. Database design and ER Model overview, ER-Model, Constraints, ER-Diagrams, ERD Issues, weak entity sets, Codd's rules, Relational Schemas, Introduction to UML.

**Relational database model**. Logical view of data, keys, integrity rules.

**Relational Database design**. features of good relational database design, atomic domain and Normalization (1NF, 2NF, 3NF, BCNF).

**Unit – IV: Relational Algebra and Calculus**. Relational algebra introduction, Selection and projection, set operations, renaming, Joins, Division, syntax, semantics. Operators, grouping and ungrouping, relational comparison.

**Calculus.** Tuple relational calculus, Domain relational Calculus, calculus vs algebra, computational capabilities.

**Unit – V: Constraints, Views and SQL**. What is constraints, types of constrains, Integrity constraints.

**Views.** Introduction to views, data independence, security, updates on views, comparison between tables and views.

**SQL.** data definition, aggregate function, Null Values, nested sub queries, Joined relations. Triggers.

**Unit – VI: Transaction management and Concurrency control**. Transaction management, ACID properties, serializability and concurrency control, Lock based concurrency control (2PL, Deadlocks),Time stamping methods, optimistic methods, database recovery management.

**PRACTICALS:**
1) Design a Database and create required tables. For e.g. Bank, College Database.
2) Apply the constraints like Primary Key , Foreign key, NOT NULL to the tables.
3) Write a SQL statement for implementing ALTER, UPDATE and DELETE.
4) Write the queries to implement the joins.
5) Write the query for implementing the following functions: MAX(), MIN(),AVG(),COUNT().
6) Write the query to implement the concept of Integrity constrains.
7) Write the query to create the views.
8) Perform the queries for triggers.
9) Perform the following operation for demonstrating the insertion, updation and deletion using the referential integrity constraints.
10) Write the query for creating the users and their role.

**REFERENCE BOOKS:**
1. A Silberschatz, H Korth, S Sudarshan, "Database System and Concepts", fifth Edition McGraw-Hill ,
2. Rob, Coronel, "Database Systems", Seventh Edition, Cengage Learning.

**DETAILED SYLLABUS SOFTWARE PROGRAMMING PART - I – MSIT503**

**Unit – I: Introduction**. What is object oriented programming? Why do we need object-oriented? Programming characteristics of object-oriented languages. C and C++.

**Unit – II: C++ Programming basics**. Output using Cout. Directives. Input with Cin. Type bool. The Setw manipulator. Type conversions.

**Unit – III: Functions**. Returning values from functions. Reference arguments. Overloaded function. Inline function. Default arguments. Returning by reference.

**Unit – IV: Object and Classes**. Making sense of core object concepts (Encapsulation, Abstraction, Polymorphism, Classes, Messages Association, Interfaces) Implementation of class in C++, C++ Objects as physical object, C++ object as data types constructor. Object as function arguments. The default copy constructor, returning object from function. Structures and classes. Classes objects and memory static class data. Const and classes.

**Unit – V: Arrays and string arrays fundamentals**. Arrays as class Member Data, Arrays of object, string, The standard C++ String class.

**Unit – VI: Operator overloading**. Overloading unary operations, Overloading binary operators, data conversion, pitfalls of operators overloading and conversion keywords. Explicit and Mutable.

**Unit – VII: Inheritance**. Concept of inheritance. Derived class and based class. Derived class constructors, member function, inheritance in the English distance class, class hierarchies, inheritance and graphics shapes, public and private inheritance, aggregation: Classes within classes, inheritance and program development.

**Unit – VIII: Pointer.** Addresses and pointers. The address of operator and pointer and arrays. Pointer and Faction pointer and C-types string. Memory management: New and Delete, pointers to objects, debugging pointers.

**Unit – IX: Virtual Function.** Virtual Function, friend function, Static function, Assignment and copy initialization, this pointer, dynamic type information.

**Unit – X: Streams and Files**. Streams classes, Stream Errors, Disk File I/O with streams, file pointers, error handling in file I/O with member function, overloading the extraction and insertion operators, memory as a stream object, command line arguments, and printer output.

**Unit – XI: Templates and Exceptions**. Function templates, Class templates Exceptions.

**Unit – XII: The Standard Template Library**. Introduction algorithms, sequence containers, iterators, specialized iterators, associative containers, strong user-defined object, function objects.

**PRACTICALS:**
Programming exercises and project using C++ programming languages, to study various features of the languages. Stress to be laid on writing well-structured modular and readable programs accompanied by good documentation.

1) Function Blocks
   a) Handling default reference arguments
   b) Handling inline and overloaded function
2) Objects and Classes. Creating UDT using classes and objects.
3) Arrays and String as objects. Insertion, Deletion, reversal sorting of elements

**REFERENCE BOOKS:**

1.Object Oriented Programming in C++ by Robert Lafore Techmedia Publication.
2. The complete reference C – by Herbert shieldt Tata McGraw Hill Publication.
3. Object Oriented Programming in C++ Saurav Sahay Oxford University Press.
4. Object Oriented Programming in C++ R Rajaram New Age International Publishers 2nd.
5. OOPS C++ Big C++ Cay Horstmann Wiley Publication.

## DETAILED SYLLABUS NETWORKING – MSIT504

**Unit – I: INTRODUCTION**. Network applications, network hardware, network software, reference models: OSI, TCP/IP, Internet, Connection oriented network -X.25, frame relay.

**THE PHYSICAL LAYER**. Theoretical basis for communication, guided transmission media, wireless transmission, the public switched telephone networks, mobile telephone system.

**Unit – II: THE DATA LINK LAYER**. Design issues, error detection and correction, elementary data link protocols, sliding window protocols, example data link protocols - HDLC, the data link layer in the internet.

**THE MEDIUM ACCESS SUBLAYER**. Channel allocations problem, multiple access protocols, Ethernet, Data Link Layer switching, Wireless LAN, Broadband Wireless, Bluetooth.

**Unit – III: THE NETWORK LAYER**. Network layer design issues, routing algorithms, Congestion control algorithms, Internetworking, the network layer in the internet (IPv4 and IPv6), Quality of Service.

**Unit – IV: THE TRANSPORT LAYER**. Transport service, elements of transport protocol, Simple Transport Protocol, Internet transport layer protocols: UDP and TCP.

**UNIT – V: THE APPLICATION LAYER**. Domain name system, electronic mail, World Wide Web: architectural overview, dynamic web document and http.

**APPLICATION LAYER PROTOCOLS.** Simple Network Management Protocol, File Transfer Protocol, Simple Mail Transfer Protocol, Telnet.

**REFERENCE BOOKS:**

1. Behrouz A. Forouzan (2006), Data communication and Networking, 4th Edition, Mc Graw-Hill, India.
2. Kurose, Ross (2010), Computer Networking: A top down approach, Pearson Education, India.

## DETAILED SYLLABUS OPERATING SYSTEM – MSIT505

**Unit – I: Windows Server. Active Directory Domain Service (ADDS) Deployment, working with OUs, Users and Groups in Active Directory, Understanding DNS in Windows Server 2022, Understanding DHCP and IPAM in Windows Server 2022, Understanding the concepts of multi domains and sites in Windows Server 2022 AD.**

**Unit – II: Administering your environment using Group Policy Objects (GPOs), Managing File Shares on Windows Server 2022, Working with disks, volumes, file systems and storage space, Supporting Remote Access within a Windows Server 2022 network, Working with Hyper-V in Windows Server 2022.**

**Unit – III: SharePoint Fundamentals-** Understand IIS Web Server and hosting websites in IIS. Understand the role of SharePoint in developing Corporate Portal. Creating Sites and Subsites. Understanding and the use out of the box lists and libraries to build the SharePoint site. Creating Custom Lists and Libraries. Working with Content Types and Site Columns. Use out of the box Web Parts. Use out of the box workflow management.

**Unit – IV: SharePoint Designer and Branding Training.** Develop familiarity with SharePoint Designer 2016, Creating External Lists using BCS, Branding SharePoint site, working with Master Pages and Themes, Creating forms for lists and libraries using InfoPath.

**Unit – V: SharePoint Administration.** Installing and configuring all the required software's products to work with Microsoft SharePoint 2016. Creation of SharePoint Web Applications, Site Collections, managing permissions for Active directory users in database based on Claims authentication. Provisioning Service Applications and binding with Web Applications. Managing large amount of data and documents using Content management features like document sets, document IDs and content organizer. Configuring and manage user profile service and activate various socializing features of SharePoint. Implementing Search Features in the site. Plan and execute Backup and Restore.

**Unit – VI**: Basics of Email System, Active Directory for Exchange Server, Domain Name System, Introduction to Exchange Server, Deploy Basic Exchange Server, Mail Transport Service, Client Access Service, Outlook on the Web, Mobile ActiveSync, Edge Transport Server, Hybrid Exchange - Introduction to Hybrid Exchange, Hybrid Exchange - Hybrid Identity, Hybrid Exchange Configuration Wizard

**Unit – VII:** Create and Test Resources in a Hybrid Exchange Setup, Migration and Mail flow management, Decommission your Exchange Server in a Hybrid Setup, Introduction to Exchange Server Migration, Collect Information and Understand Existing Server, Install New Exchange Server 2019 with AD and Exchange 2016 Setup, Coexistence - together Exchange 2016 and 2019, Migration - Move mailbox users from Exchange 2016 to Exchange 2019, Decommission - Exchange Server 2016, Database Availability Group, Backup Exchange Server using Windows Backup

**REFERENCE BOOKS:**

1. Windows Server 2022 Administration Fundamentals A beginner's guide to managing and administering Windows Server environments (English, Paperback, Dauti Bekim)
2. Microsoft SharePoint 2016 Step by Step. by Olga Londer (Author), Penelope Coventry (Author)
3. Microsoft Exchange Server 2016 Administration Guide: (English, Paperback, Van Biljon Edward)

**DETAILED SYLLABUS CYBER SECURITY – MSIT506**

**Unit – I: Fundamentals of Cyber Security**. What is Cyber Security? Introduction to Cyber Security.

**Unit – II: Network Security**. Introduction to Network Security. Theory of Proxy Server. Malwares and Trojans. Denial of Service. Basics of Cryptography. Wireless Security and Attacks.

**Unit – III: Database Security**. Introduction to Web Server. SQL Security and Attacks. Email Analysis and Sending Fake Email. Incident Response.

**Unit – IV: Cyber Crime**. Introduction to Cyber Crime. Reasons for Cyber Crime. Classification of Conventional and Cyber Crime. Distinction between Conventional and Cyber Crime. Cyber Criminal Mode and Manner of Committing Cyber Crime. Computer Crime Prevention Measures.

**Unit – V: Cyber Laws**. Introduction to IT Act 2000. Offences Under IT Act 2000. Penalties Under IT Act 2000. Punishments under IT Act 2000. Establishment of Authorities under IT Act and their functions, powers, etc. Investigation of Cyber Crimes. Agencies for Investigation in India, their Powers and their Constitution as per Indian Laws. Procedures followed by First Responders. Evidence Collection and Seizure Procedures of Digital mediums.

**Unit – VI: Cyber Security Audit and Compliance**. Review of an organisation's IT infrastructure. Policies and procedures have been implemented and are working effectively. Identify vulnerability and ways to resolve it. New policies to be implemented to improve system efficiency and security.

**REFERENCE BOOKS:**

1. Cyber security for Beginners by Raef Meeuwisse
2. Certified Information (Security Expert, Main Book, Innobuss Knowledge Solutions (P) Ltd.
3. Information Technology Act 2000.

## DETAILED SYLLABUS SOFTWARE PROGRAMMING PART-II MSIT507

**Unit – I: Introduction to Web Applications**. Html Basic Tags, Javascript, CSS, Introduction to Server Side and Client Side Scripting, Web Page Designing using HTML and JavaScript, Overview of Asp.Net 4.0, Overview of Request Life Cycle.

**Unit – II: Introduction to Server Controls**. Consume Standard Controls, List Controls, Post Back issue handling, dynamically adding Controls to webform, Navigation Controls, File upload control, Multiview control, Wizard control, AdRotator, Webparts.

**Unit – III: Customizing Web Applications**. Themes and Skins, Master Pages and Content Pages, Using Style Sheets.

**Unit – IV: Developing and using Webforms Controls**. Creating Web Forms Application, Handling Images, ASP.NET Handler to generate images dynamically, navigating between Pages, Using Site Map Path, Using Tree View, Using Menu, Managing Server Controls, Server Control Events.

**Unit – V: Implement Server Controls**. Create and consume User Control, Create and consume Custom control, Create and consume composite control.

**Unit – VI: State Management**. Managing Session and Application, passing complex data using session variable, View State, Profile, Query Strings, Managing Cookies.

**Unit – VII: Designing and Implementing Databases with SQL Server**. Introduction to RDBMS and Database Normalization, Creating Tables and Relationships and constraints, SQL Fundamentals, Stored Procedures.

**Unit – VII: Managing Database with ADO.Net Entity Framework**. Entity Data Model, Link to Entities, Work with Model and not data, Data manipulation with Entity Framework, Data-bound controls, Model First with Entity Framework, Entity Data Source.

**Unit – IX: Developing MVC Models and Controllers**. Exploring ways to create MVC Models, Implementing MVC Controllers, Creating Action Methods, Implementing MVC Views.

**Unit – X: Introduction to WCF**. Service Oriented Architecture, Building WCF Service, Building WCF Client Application.
**Unit – XI: Authentication and Authorization**. Configuring ASP.Net Membership and Roles, Anonymous Authentication and Impersonation Windows Authentication, Forms Authentication.

**Unit – XII: Language Integrated Query**. Introduction to Link, implicitly typed local variable, Anonymous types, Link to Objects LINQ to XML.

**Unit – XIII: AJAX**. Introduction to AJAX, Basic Asp.Net Ajax Controls- AJAX extension controls, scipt Manager, Update Panel, Timer, AJAX control tool kit, Accordion, Tab Container, AJAX Control toolkit extenders, Always Visible Extender, Calendar Extender, Bulleted List Extender, Confirm Button Extender, TextBox Water Mark Extender, Mask Edit Extender, Drag Panel Extender, Filter Text Box Extender, Password Strength.

**Unit – XIV: Introduction to jQuery**. Introduction to Silver light, Introduction to Silverlight, Introduction to XAML, Using Silverlight Controls, Using Silverlight Navigation Application, Programming Silverlight applications, Creating Silverlight WCF Services.

**Unit – XV: Introduction to Mono and cross platform .NET development**. Configuring and Deploying Web Applications, Publishing Web Applications, Create Web Setup Project, Using Copy Web Tool.

**REFERENCE BOOKS**

1. "Professional ASP.NET MVC 5 (WROX)" by Jon Galloway and Brad Wilson
2. "ASP.NET: The Complete Reference" by Matthew Macdonald
3. "ASP.NET 4.5 in Simple Steps" by Kogent Learning Solutions Inc
4. "ASP.NET 4.5, Covers C# and VB Codes, Black Book" by Kogent Learning Solutions Inc

**DETAILED SYLLABUS ADVANCE NETWORKING - MSIT508**

**Unit - I: Network Architecture and Design.** Introduction to network architecture design, including network topologies, addressing, and connectivity requirements for LANs and WANs.

**Overview of Network Architecture.** Introduction to the various components and types of networks that make up a network architecture.

**Types of Networks and their Applications**. Detailed look into the various types of networks such as LAN, WAN, MAN and their applications in real-world scenarios.

**Network Topology and Design Principles**. Understanding the physical and logical topologies of networks, and the various design principles involved in building a network.

**Unit - II: Network Protocols and Technologies.** Overview of various network protocols and technologies, including routing, switching, and TCP/IP protocols.

**Transport Layer Protocols (TCP, UDP).** Understanding the function of the transport layer protocols TCP and UDP and their differences.

**Routing Protocols (OSPF, BGP, EIGRP).** Detailed study of the routing protocols such as OSPF, BGP, and EIGRP used for efficient data transfer across the network.

**Network Address Translation (NAT).** Understanding the concept of NAT and its various types such as Static NAT, Dynamic NAT, and Port Address Translation (PAT).

**Quality of Service (QoS).** Study of the QoS concept and various techniques to prioritize network traffic for improved network performance.

**Unit - III: Virtual Local Area Networks (VLAN).** Understanding the concept of VLANs and their configuration on switches and routers to segment network traffic.

**VLAN Basics and Terminology**. Understanding the basics of VLANs, the terminologies, and the types of VLANs.

**VLAN Configuration and Management.** Configuring and managing VLANs on switches and routers.

**VLAN Security.** Securing VLANs by using various techniques such as access control lists (ACLs) and port security.

**Unit – IV: Wireless and Mobility.** Introduction to wireless networking technologies and mobile devices and their configuration on the network.

**Wireless LAN Standards and Technologies.** Introduction to various wireless LAN standards and technologies such as Wi-Fi, 802.11a/b/g/n/ac.
**Wireless LAN Design and Deployment.** Understanding the design and deployment of wireless networks and various technologies used for this purpose.

**Mobile IP and Mobile Device Management.** Detailed look into the Mobile IP protocol and Mobile Device Management (MDM) techniques for efficient management of mobile devices.

**Unit – V: Network Security.** Overview of various network security measures and mechanisms, including access control, authentication, encryption, and firewall configurations.

**Network Threats and Vulnerabilities.** Understanding various network threats and vulnerabilities such as Denial of Service (DoS) attacks, malware, and social engineering.

**Access Control and Authentication.** Study of various authentication mechanisms such as biometrics, 2-factor authentication, and access control mechanisms such as RBAC.

**Firewall and Intrusion Detection Systems (IDS).** Understanding the functioning of firewalls and IDS, their differences and how they work together to provide network security.

**Unit – VI: Network Management and Monitoring.** Understanding the methods and protocols used for efficient network management and monitoring, including network performance monitoring, troubleshooting, and configuration backup and restore.

**Network Management Protocols (SNMP, NetFlow).** Introduction to various network management protocols such as SNMP and NetFlow used for efficient network management and monitoring.

**Network Performance Monitoring.** Techniques used for monitoring network performance such as bandwidth utilization, packet loss, and latency.

**Network Troubleshooting.** Understanding various network troubleshooting techniques and tools used for identifying and fixing network issues.

**PRACTICALS:**

Chapter 1: Network Architecture and Design

1) Design a Local Area Network (LAN) for a small office, considering factors such as network topology, addressing, and connectivity requirements.
2. Configuring OSPF routing protocol: Students can configure and troubleshoot the Open Shortest Path First (OSPF) routing protocol on routers in a simulated network environment.
3) Configure VLANs on switches and routers, assign ports to specific VLANs, and test connectivity between devices in different VLANs.
4) Set up a wireless network using a wireless access point and configure it with the necessary security measures, such as Wi-Fi Protected Access (WPA) or Wi-Fi Protected Access II (WPA2).
5) Use Mobile Device Management (MDM) tools to manage and monitor mobile devices connected to the network.
6) Configure a firewall on a network device, such as a router or a dedicated firewall appliance, to control access and protect the network from threats.

7) Use monitoring tools, such as Simple Network Management Protocol (SNMP) and NetFlow, to monitor network performance and troubleshoot issues.

**REFERENCE BOOKS:**

1. A Top-Down Approach by James F. Kurose and Keith W. Ross
2. Designing Cisco Network Service Architectures by Sean Wilkins
3. The Protocols by W. Richard Stevens
4. CCNP Routing and Switching SWITCH by David Hucaby

**<u>DETAILED SYLLABUS LINUX/UNIX/AIX & ADMINISTRATION - MSIT509</u>**

**Unit - I**. Introduction to UNIX/Linux Kernel System Structure, User Perspective, Assumptions about Hardware, Architecture of UNIX Operating System, Concepts of Linux Programming-Files and the File system, Processes, Users and Groups, Permissions, Signals, Inter-process Communication.

**Unit - II**. Introduction to RED Hat LINUX Hardware Requirements, Red Hat LINUX Installation, Advantages of LINUX, Other LINUX distributions, Concept of Linux loader.

**Unit - III**. Working with Linux LINUX file system, Shells, Text editors, Changing User Information, File Permissions, Virtual Consoles UNIT III: The X Window System Basic X window system, Configuring X window systems, Starting X, Selecting & using X window.

**Unit - IV**. Managing Services, Software & System Resources LINUX Boot Process, System services and run levels, controlling services at boot with administrative tools, Starting and stopping services manually, Using RPM for software management, Using RPM on the command line, Extracting a single file from & RPM file, Graphical Package Management, System monitoring tools.

**Unit - V**. Printing with Linux Configuring & managing print services, Local printer installation, Network printer installation, LINUX printing commands, Using the Common UNIX Printing System (CUPS), Console print control.

**Unit - VI**. Network Connectivity Networking with TCP/IP, Hardware devices for networking, Using RED HAT Linux network, configuration tools, Using DHCP [Dynamic Host Configuration Protocol], Using the network file system, Wireless networking, Introduction to DNS, Essential DNS concepts, configuring namespaces with DNS, Installing Samba, Configuring Samba, Running the Samba Server.

**<u>REFERENCE BOOKS</u>**

1. Red Hat Linux Unleashed, Edition illustrated reprint, “Bill Ball, David Pitts”, Sams, 2001, ISBN 0672319853, 9780672319853.
2. Red Hat Fedora 2 Unleashed, Edition illustrated, “Bill Ball, David Pitts”, Sams, 2005, ISBN 067232721X, 9780672327216.
3. Linux System Programming, O‟Reilly, by Robert Love.
4. Windows Internals, Microsoft Press, by Mark E. Russinovich and David A. Soloman.
5. The Design of the UNIX Operating System, PHI, byMaurice J. Bach.
6. Advanced Programming in the UNIX Environment, Addison-Wesley, by Richard Steve

## DETAILED SYLLABUS APPLICATION ORIENTATION - MSIT510

**Unit - I**. Financial Information System. Introduction to Data/server Architecture and working procedures.

**Unit - II**. Integrated Logistics Management System. Introduction to Data/server Architecture and working procedures.

**Unit - III**. Integrated Clothing Management System. Introduction to Data/server Architecture and working procedures.

**Unit - IV**. Genform Management System. Introduction to Data/server Architecture and working procedures.

**REFERENCE BOOKS**

1. Service Manuals

## DETAILED SYLLABUS ERP - MSIT511

**Unit – I**. **Introduction to ERP.** ERP Definition, Characteristics of ERP, Products of ERP, Benefits of using ERP.

**Unit - II**. **Introduction to SAP.** SAP History, SAP Product line, New Products of SAP, Relation of New SAP Products with the core product, Industry specific Products, Type of SAP Projects, Type of SAP Roles, Architecture of SAP, System Landscape, Types of data used in the SAP system.

**Unit - III**. **Initial Screens.** How to login to the SAP system, SAP Client / GUI, SAP Session - What it is, how to open a new Session, Create new Sessions, Navigation between Sessions, Transactions and Activities, Shortcuts or Transaction Codes, SAP Easy Access screen, SAP IMG screen, Difference between Easy Access and IMG screens.

**Unit - IV**. **Enterprise Structure.** What is Enterprise Structure, the different types of Enterprise Structure, Company structure in real time, Company structure for each process, MM Structure against other process structure, Enterprise Structure terms in real time against those used in the SAP system, Definitions of the elements of enterprise structure, Creation of Enterprise Structure elements in the SAP system.

- (a) Group
- (b) Company
- (c) Plant
- (d) Store
- (e) Purchasing Department
- (f) Valuation Area
- (g) Controlling Area

Assignment of the Enterprise Structure elements in the SAP system

- (a) Assign Company to Group
- (b) Assign Plant to Company

(c) Assign Store to Plant
(d) Assign Purchasing Departments
(e) Assign Controlling Area

**References:**


1. Davenport, T. H. (1998). Putting the enterprise into the enterprise system. Harvard Business Review, 76(4), 121-131.

2. Jacobs, F. R., & Whybark, D. C. (2000). Why ERP? A primer on SAP implementation. Production and Inventory Management Journal, 41(2), 52-58.

3. Klaus, H., Rosemann, M., & Gable, G. G. (2000). What is ERP? Information Systems Frontiers, 2(2), 141-162.


**DETAILED SYLLABUS PROJECT IMPLEMENTATION - MSIT512**

**PRACTICAL**

1. Software development final phase based on the training imparted in the previous semesters. Evaluation of the project will be done based on timely completion, testing, completion of VA documents. VA documents include: -

(a) User manual
(b) System Specification Manual
(c) Installation Manual
(d) System Admin Manual
(e) Maintenance Manual
(f) Cyber Security Policy
(g) Risk Assessment & Risk Management

2. Incident Response Plan

**DETAILED SYLLABUS POWERBUILDER– MSIT513**

**Unit – I: Introduction to PowerBuilder Application and Component.** Overview of PowerBuilder, PowerBuilder development environment, Creating and managing projects in PowerBuilder, creating application and component using PowerBuilder, Understanding the PowerBuilder Application Window, PowerBuilder Interface Elements (Toolbars, Menus, Status Bars), PowerBuilder Workspace, Layout, and Navigation.

**Unit – II: PowerScript Language.** Overview of PowerScript Language, Syntax and Variables in PowerScript,, Data types in PowerScript, Control Structures in PowerScript (Looping, Conditional Statements), Functions and Procedures in PowerScript, Arrays in PowerScript, Working with Objects in PowerScript, Event-driven programming in PowerScript.

**Unit – III: PowerScript Functions.** Understanding the PowerScript Function Library, Built-in PowerScript Functions, Creating Custom Functions in PowerScript, Understanding Function Prototypes in PowerScript, Function Overloading in PowerScript, Passing Parameters to Functions in PowerScript.

**Unit – IV: Object-Oriented Programming with PowerBuilder Techniques.** Understanding the principles of Object-Oriented Programming, creating classes and objects in PowerBuilder, Encapsulation, Inheritance, and Polymorphism in PowerBuilder, Understanding and implementing the PowerBuilder class hierarchy, Designing and implementing reusable code in PowerBuilder, Creating and using PowerBuilder object libraries.

**Unit – V: Multitier Applications with PowerBuilder.** Overview of Multitier Application Architecture, Creating Multitier Applications in PowerBuilder, Understanding the PowerBuilder Distributed Application Services, Creating and using PowerBuilder Web Services, Implementing Data Access in PowerBuilder Multitier Applications, Security Considerations for PowerBuilder Multitier Applications, Database Connection using PowerBuilder.

**Unit – VI: Database Connection using PowerBuilder.** Connecting to a Database using PowerBuilder, Understanding the PowerBuilder Database Interface, Creating DataWindows in PowerBuilder, Retrieving and updating data in PowerBuilder applications, Advanced DataWindow Techniques in PowerBuilder, Stored Procedure Support in PowerBuilder.

**PRACTICALS:**

1. Creating a new project: Start by launching PowerBuilder and creating a new project. Give it a name and select the project type, such as an application or a library.

2. Creating a new window: Add a new window to your project by selecting File > New > Window. You can then add controls to the window, such as buttons, labels, and text boxes.

3. Adding data: PowerBuilder is designed to work with databases, so you can add data to your application using a DataWindow. You can create a new DataWindow by selecting File > New > DataWindow.

4. Binding data to a control: To display data in a control on a window, you need to bind the control to the DataWindow. You can do this by selecting the control and then setting its DataWindow object property.
Creating a menu: You can add a menu to your application by selecting File > New > Menu. You can then add menu items and assign actions to them.

5. Writing code: PowerBuilder uses a programming language called PowerScript. You can write code to add functionality to your application, such as handling events or interacting with the database.

6. Debugging: If your code isn't working correctly, you can use the debugger to step through it and identify any errors. You can launch the debugger by selecting Debug > Start Debugging.

7. Deploying the application: Once you're happy with your application, you can deploy it to users. You can do this by creating an executable file or by creating an installer.

8. Creating a custom class: PowerBuilder allows you to create your own custom classes. You can do this by selecting File > New > User Object and then writing the code for the class.

9. Using version control: If you're working with a team, you can use version control to manage changes to the code. PowerBuilder supports several version control systems, including Git and SVN. You can use the Source Control menu to manage your files

**REFERENCE BOOKS:**

1. PowerBuilder 8: The Complete Reference by James Edelman
2. PowerBuilder 11: A Definitive Guide by Yakov Werde
3. PowerBuilder 11: Advanced Topics by Yakov Werde

**DETAILED SYLLABUS SYBASE – MSIT514**

**Unit – I: Introduction to Sybase.** What is Sybase and its history, Understanding the Sybase architecture, the benefits of using Sybase over other database systems, Sybase products and their features.

**Unit – II: Creating Database Systems.** Creating databases and tables, understanding database objects such as views, stored procedures, and triggers; Data types and their usage, Data normalization.

**Unit – III: Security Management.** Securing data using authentication and authorization, managing user access and permissions, managing encryption of sensitive data, Auditing and monitoring database activity.

**Unit – IV: Database Backup and Recovery System.** Understanding backup and recovery, implementing backup and recovery strategies, using database dump and load utilities, Configuring recovery procedures.

**Unit – V: Maintenance.** Monitoring and optimizing performance, Identifying and resolving performance issues, managing disk space and fragmentation, Using Sybase system tables.

**Unit – VI: Installation of Sybase Server.** Understanding the installation process, Configuring the server settings, setting up client connections, Post-installation tasks and troubleshooting.

**PRACTICALS:**

1. Connect to a Sybase server using Sybase Central or Sybase ASE's command-line interface.
2. Create a new database using Sybase Central or the SQL command CREATE DATABASE.
3. Create a new table in the database using the SQL command CREATE TABLE. Define columns and their data types.
4. Insert new data into the table using the SQL command INSERT INTO.
5. Query the table data using the SQL command SELECT.
6. Modify table data using the SQL command UPDATE.
7. Delete table data using the SQL command DELETE.
8. Create a new stored procedure using the SQL command CREATE PROCEDURE.
9. Execute a stored procedure using the SQL command EXEC.
10. Perform a database backup and recovery using Sybase Central or the backup database and load database SQL commands.
11. Perform the following operation for demonstrating the insertion, updation and deletion using the referential integrity constraints.
12. Write the query for creating the users and their role.

**REFERENCE BOOKS:**

1. Sybase: SQL Server Administrator's Guide by Jeff Garbus and Ashwini Lath
2. Sybase ASE 15.0 Performance and Tuning by Jeff Garbus and Andy Novick

## DETAILED SYLLABUS PROJECT MANAGEMENT - MSIT515

**PRACTICAL**.

1. Creating of Project Documentation
2. Understanding client objectives
3. Planning & Forecasting activities
4. Preparing Approach to all activities and project governance
5. Preparing line of Authority

**REFERENCE BOOKS**

Project Management by Lock, Dennis

## DETAILED SYLLABUS NPTEL - MSIT516

**ONLINE CLASSES & EXAM - NPTEL** - Suitable IT related Course worth 04 credits available at the time of course.

Details of syllabus will be as per course selected from NPTEL website.

## DETAILED SYLLABUS OJT - MSIT517

Implementation of existing software at various Ships & establishments, testing of the software for environment acceptance and modification as per user requirements. In addition, the officer will be evaluated by his Commanding Officer/ OiC of the unit based on the utilisation of various naval software and implementation of Naval IT Policies in his/her respective unit.

## DETAILED SYLLABUS DISSERTATION PHASE - MSIT518

A dissertation on a suitable IT related topic shall be submitted by the course participants.

# M. Sc. DATA SCIENCE

**Program Overview**

The **Master of Science in Data Science** (M.Sc.-DS) program at DIAT is designed to address the current market needs for highly skilled data science and data analytics professionals. The program is designed to help graduates gain skills and experience in designing, implementing, and transforming data sets into actionable knowledge. It provides students with the skills and knowledge needed to develop competencies in managing data science and analytics projects and working with data analytics tools and technologies. The program is aimed at helping to educate a new generation of information professionals capable of taking the leadership role by connecting the dots and using data to support strategic initiatives within the organization.

The Master of Science (M.Sc.) programme in Data Science is designed to meet such demands and train the next generation of data scientists. This is a two-year postgraduate interdisciplinary course spread over four semesters.

Through this course, students will have the opportunity to gain hands-on experience with a variety of analytical tools available for the purpose of structuring large data sets to unearth hidden information and allow the organizations to build and sustain a long-term competitive advantage. The capstone of the programme is a dissertation during second year in which students apply the acquired theoretical knowledge in data science to solve real-world business problems.

**Need of Data Science:** There are many applications, such as climate change, social media, healthcare, e-commerce, weather forecast, etc., that are generating massive amounts of data with volume, velocity, variety, veracity and value at an unprecedented scale. This has led to a critical demand of skilled professionals, Data Scientists, who can mine and interpret the data. Making sense of this massive data is a very difficult challenge for scientific, technological and industrial disciplines. Data science is concerned with the acquisition, storage, retrieval, processing and finally the conversion of data into knowledge where the quantum of data is very large.

Experiments, observations, and numerical simulations in many areas of science and business are currently generating terabytes ($2^{40}$ bytes) of data, and in some cases are on the verge of generating petabytes ($2^{50}$ bytes) and beyond. Today we are witnessing an exponential growth in the volume of data being produced and stored. This can be explained by the evolution of the technology that results in the proliferation of data with different formats from the most diverse domains (e.g. health care, banking, government or logistics) and sources (e.g. sensors, social networks or mobile devices). Facebook, for example, has an average of 4.75 billion pieces of content shared among friends every day. Every business is generating enormous quantities of data that are too big to be processed and analyzed by the traditional Relational Database Management Systems (RDBMSs) and Data Warehouses (DWs) technologies, and thus are struggling to meet the performance and scalability requirements of the market. To alleviate these limitations, companies like Facebook, Google, Yahoo and Amazon etc. are making advancement by creating solutions and recruiting technologies to deal with these “Big Data” scenarios. Adopting Big Data-based technologies not only mitigates the problems presented above, but also opens new perspectives that allow extracting value from Big Data. Big Data-based technologies are being applied with success in multiple scenarios like in: (1) e-commerce and marketing, the crowds do on the web allow identifying trends that improve campaigns, evaluate personal profiles of a user, so that the content shown is the one he will most likely enjoy; (2) government and public health, allowing the detection and tracking of disease outbreaks via social media or detect frauds; (3) transportation, industry and surveillance, with real-time improved estimated times of arrival and smart use of resources. Hence, understanding the science behind data is the need of the hour. There are three disciplines that forms the core of Data Science and are inter-related: Computer Science, Mathematics and Statistics. An important difference between Data Science and Computer Science is that Data Science heavily uses the more continuous aspects of Mathematics together with extensive Statistics. Data Science is the combination of Statistics, Mathematics, Programming, Problem-Solving, capturing data in ingenious ways, the ability to look at things differently, and the activity of cleansing, preparing and aligning the data.

**Organization of M.Sc programme:**

This programme is of four-semester duration. The first and second semester is comprised of five Theory courses and two Lab courses where each course either has a practical component or a lab class. The respective course instructor will give assignments / practical problems based on the course content which will be executed in the Lab. The practice problems can be solved by using Advanced Data structures (C / C++) / MATLAB / MATHEMATICA / Simula8 / Maplesim / SPSS / R / Python / Extend Sim. . .etc., The department has the licensed version of all these softwares and are available to student. The first and second semester contains all courses as compulsory, while the third semester has two core courses and an option to choose three elective courses. The interested students can take any course as an audit course; however, no credits will be counted for attending an audit course. In addition to this, a **mini project is also introduced in this semester which gives an insight to the student that how to do the literature survey, how the theoretical courses are applicable in practical implementation like in real life situations / industry, problem identification, report writing, presentation skills etc. under the guidance of respective supervisor(s).**

The final semester is entirely dedicated to the dissertation work. The course evaluation process is comprised of three assessment tests, an internal evaluation and a final semester examination. Furthermore, after the completion of second semester, the students are encouraged to do a summer internship for about one and half month at their place of choice or any organization to identify their project work. The department faculty and respective supervisor will encourage and support students to build their projects in relevance to DRDO labs / other premier institutes and industry. However, the department will not sponsor such projects; except official arrangements, like issuing NOC certificate etc. The internship/project related arrangements and expenses are to be entirely borne by student at their own responsibility. Every student is required to submit a thesis report and present their project work to the thesis evaluation committee (the thesis evaluation committee will be formed as per the rules and regulations of DIAT PGC guidelines) at the end of the final semester.

**Eligibility Criteria for Admission to join this programme**

| | |
|---|---|
| M. Sc.<br>(Data Science) | **Minimum Educational Qualifications:**<br>The candidate must have a qualified Bachelor’s degree in any branch or discipline |
| | **Essential subjects in Bachelor's Degree along with minimum duration:**<br>Mathematics/Statistics as a subject for at least two years/four semesters<br>Qualified JAM Exam Paper in **Mathematical Statistics (MS) or Mathematics (MA).** |

**Programme objectives and Outcomes.**

| Sl. No. | Programme Educational Objectives (PEO’s) |
|---|---|
| EO1 | To enable learners to develop knowledge and skills in current and emerging areas on various theoretical and practical aspects of data science. |

| | |
|---|---|
| EO2 | Ability to apply knowledge of mathematics, probability and statistics, computer science and solve problems. |
| EO3 | To demonstrate expert / impart knowledge of data science, statistics, tools, techniques and technologies of data science. |
| O4 | To train and develop in depth understanding of the key technologies in data science such as database management, data mining, data visualization techniques like: Hadoop, R, Python, and statistics, complex machine learning algorithms to build predictive models for a wide range of application domains |
| O5 | To develop project-management, critical-thinking, problem-solving, formulate and implement a novel research idea and decision-making skills in the field of data science. |

| Sl. No. | Programme Outcomes (PO) |
|---|---|
| PO1 | An ability to independently carry out research /investigation and development work to solve practical problems |
| PO2 | An ability to write and present a substantial technical report/document |
| PO3 | Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program. |

| Sl. No. | Programme Specific Outcomes (PSO) |
|---|---|
| PSO1 | **Problem Analysis and Design:** Ability to identify analyse and design solutions for data Science problems using fundamental principles of mathematics, Statistics, computing sciences, and relevant domain disciplines. |
| PSO2 | **Modern software tool usage:** Acquire the skills in handling data analytics programming tools towards problem solving and solution analysis for domain specific problems. |
| PSO3 | **Applications in Multidisciplinary domains:** Understand the role of statistical approaches and apply the same to solve the real-life problems in the fields of data science. Apply the research-based knowledge to analyse and solve advanced problems in data science. |

**Semester I:**

| Sl. No. | Course Code | Course Name | Contact hours / week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | C |
| 8. | AMMSCD501 | Computational Linear Algebra | 3 | 1 | 0 | 4 |
| 9. | AMMSCD502 | Probability & Statistical Methods with R | 3 | 0 | 0 | 3 |
| 10. | AMMSCD503 | Data Science with Python | 3 | 0 | 0 | 3 |
| 11. | CSMSCD506 | Advanced Database Management Systems | 3 | 1 | 0 | 4 |
| 12. | CSMSCD507 | Computer Organization and Architecture | 3 | 1 | 0 | 4 |
| 13. | AMMSCD504 | Data Science with Python Lab | 0 | 0 | 4 | 2 |
| 14. | AMMSCD505 | Probability & Statistical Methods with R Lab | 0 | 0 | 4 | 2 |
| | | TOTAL | 15 | 03 | 08 | 22 |

**Semester II:**

| Sl. No. | Course Code | Course Name | Contact hours /week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | C |
| 1. | AMMSCD521 | Optimization Techniques | 3 | 1 | 0 | 4 |
| 2. | AMMSCD522 | Time Series Analysis & Forecasting Methods | 3 | 1 | 0 | 4 |
| 3. | AMMSCD523 | Machine Learning and Deep Learning | 3 | 0 | 0 | 3 |
| 4. | AMMSCD524 | Data Structures & Algorithms | 3 | 0 | 0 | 3 |
| 5. | CSMSCD530 | Big Data Analysis and Algorithms | 3 | 1 | 0 | 4 |
| 6. | AMMSCD525 | Data Structures & Algorithms with Python / C Lab | 0 | 0 | 4 | 2 |
| 7. | AMMSCD526 | Machine Learning and Deep Learning Lab | 0 | 0 | 4 | 2 |
| | | TOTAL | 15 | 03 | 08 | 22 |

**Semester III:**

| Sl. No. | Course Code | Course Name | Contact hours / week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | C |
| 1. | AMMSCD531 | Regression Analysis and Predictive Modelling | 3 | 1 | 0 | 4 |
| 2. | CSMSCD540 | Artificial Intelligence | 3 | 1 | 0 | 4 |
| 3. | | Elective - 1 | 3 | 1 | 0 | 4 |
| 4. | | Elective - 2 | 3 | 1 | 0 | 4 |
| 5. | | Elective - 3 | 3 | 1 | 0 | 4 |
| 6. | | M. Sc. Dissertation (Mini Project) | 08** | | | 04 |
| | | TOTAL | 15 | 05 | 08** | 24 |

**Semester IV:**

| Sl. No. | Course Code | Course Name | Contact hours / week | | Credits |
|---|---|---|---|---|---|
| | | | L | T / P | |
| | AMMSCD 570 | M. Sc. Dissertation Final | 28** | | 14 |
| | | TOTAL | 28 | | 14 |

****Contact Hours / week: -**

- ✓ **Lecture – L (Theory) / Tutorial (T) means - one contact hour for one credit**
- ✓ **Practical (P) (Lab session) / means two contact hours for one credit.**

**List of Electives are given below:** Few of the elective courses are listed below. However, the students are allowed to choose Elective Courses (necessary permission / approval of the department is required to suggest the relevance of the course / programme) of various departments of their respective programmes, which will be updated time to time and it will be made available in the DIAT-PG Course of Study book.

| Sl. No. | Course Code | Course |
|---|---|---|
| 1. | AMMSCD532 | Multivariate Data Analysis |
| 2. | AMMSCD533 | Digital Image Processing |
| 3. | AMMSCD534 | Reinforcement Learning |
| 4. | AMMSCD535 | Data Mining Techniques |
| 5. | AMMSCD536 | Mathematical Cryptography |
| 6. | CSMSCD541 | Natural Language Processing |
| 7. | CSMSCD542 | Pattern Recognition |
| 8. | CSMSCD543 | Cloud Computing |
| 9. | CSMSCD544 | Computer Vision |
| 10. | CSMSCD545 | Computer Forensics |
| 11. | CSMSCD546 | IoT Analytics |
| 12. | CSMSCD547 | Distributed Databases |
| 13. | TMMSCD550 | Business Economics and Financial Analysis |
| 14. | MOOC / NPTEL (4 credit Level to be opted) | |

**Guidelines for Submission of M.Sc. (Data Science) Mini Project**

All the candidates of M. Sc. (Data Science) mini project are required to submit a project report based on the work done by him/her during the project period.

The department will allot the supervisors / guides to each student as per DIAT norms however preference will be given by considering the students choice to work under the supervisor and areas of research. The Project topics should be based on syllabus or beyond suitable for defence/industry applications. The evaluation for 100 Marks (4 Credits) is carried out at the end of the pre-final semester or after completion of theory exam papers (Sem III).

**The mini project is evaluated for 100 Marks as per the below mentioned criteria**.

| | Evaluation criteria | Marks |
|---|---|---|
| **Part 1 Continuous Evaluation** | Three reports, one per month, are to be submitted to the respective supervisor; and each report carries 10 Marks. The report should contain topics as relevant to the below mentioned points.<br>**Specify the broad topic of your mini project based on the relevant field which you studied in this curriculum or industry related or literature survey etc.**<br>**Study minimum 12 to 15 quality research papers based on the selected topic.**<br>**Prepare the SWOT analysis of selected research papers / reports.**<br>**Identify the research problem which may helpful to final dissertation in the final semester.**<br>**Propose your novelty / improvement in terms of algorithm/new feature.**<br>**Design the architecture for the proposed problem.**<br>**Design a set of experiments to be carried out for the proposed** | **30 Marks (Supervisor will submit the marks)** |

| | | |
|---|---|---|
| | **problem.**<br>**Perform the experimental analysis (in Python language or any other programming languages).**<br>**Write a short research paper based on your contribution.** | |
| **Part 2** | **Submit mini project report followed by Demo/ Presentation / Viva**. It will be conducted based on the report submitted by the student. The Viva Voce Committee (as per DIAT-PGC guidelines) will evaluate the presentation.<br><br>**Summary of the Mini Project Report (As per DIAT-PGC Rules & Regulations)**<br>All students must submit a Summary of the Mini Project Report separately with the project report.<br>Summary, preferably, should not be more than 3-4 pages. The content should be as brief as which will explain the objective and implementation of the project that the candidate is going to take up. The write up must adhere to the guidelines and should include the following<br>Name / Title of the Project<br>Statement about the Problem<br>Why are the particular topic chosen?<br>Objective and Scope of the Project<br>Methodology (including a summary of the project)<br>Hardware & Software to be used<br>Testing Technologies used<br>What contribution would the project make?<br>**TOPIC OF THE PROJECT**- This should be explicitly mentioned at the beginning of the Synopsis. Since the topic itself gives a peep into the project to be taken up, candidate is advised to be prudent on naming the project. This being the overall impression on the future work, the topic should corroborate the work.<br>**OBJECTIVE AND SCOPE:** This should give a clear picture of the project. Objective should be clearly specified. What the project ends up to and in what way this is going to help the end user has to be mentioned.<br>**PROCESS DESCRIPTION:** The process of the whole software system proposed, to be developed, should be mentioned in brief. This may be supported by DFDs / Flowcharts to explain the flow of the information.<br>**RESOURCES AND LIMITATIONS:** The requirement of the resources for designing and developing the proposed system must be given. The resources might be in form of the hardware/software or the data from the industry. The limitation of the proposed system in respect of a larger and comprehensive system must be given.<br>**CONCLUSION:** The write-up must end with the concluding remarks- briefly describing innovation in the approach for implementing the | **70 Marks (Viva Voce Committee)** |

| | | |
|---|---|---|
| | Project, main achievements and also any other important feature that makes the system stand out from the rest. | |
| **Total 100 Marks along with grade will be submitted to the CoE by the constituted committee.** | | |

## FIRST SEMESTER

| | | | | |
|---|---|---|---|---|
| Course Code | **AMMSCD501** | | | |
| Name of the Course | **Computational Linear Algebra** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**

The course focuses on iterative techniques for solving large sparse linear systems of equations which typically stem from the discretization of partial differential equations. In addition, computation of eigenvalues, least square problems and error analysis will be discussed.

**Course Outcomes:**

Develop the skill set to

explain and fluently apply fundamental linear algebraic concepts such as matrix norms, Eigen- and singular values and vectors;

estimate stability of the solutions to linear algebraic equations and eigenvalue problems; recognize matrices of important special classes, such as Normal, Unitary, Hermitian, Positive-definite and select efficient computational algorithms based on this classification;

implement the above algorithms on a computer, verify your code, and understand the behavior of your code through the underlying theory.

understand the effects of finite precision on numerical computing, including stability, conditioning, and error types.

evaluate the complexity (computational cost) of the covered numerical algorithms.

**Course Contents**

| | | |
|---|---|---|
| **Unit - 1** | **Matrices and Its Properties** | **06 Hours** |
| Matrices and Gaussian Elimination, Matrix Notation, Matrix Multiplication, Triangular Factors, Row Exchanges, Inverses and Transposes, Special Matrices and Applications, IEEE Floating Point Arithmetic, Analysis of Round-off Errors | | |
| **Unit - 2** | **Vector Spaces** | **08 Hours** |
| Vector Spaces, Subspaces, Solving Ax = 0, and Ax = b, Linear Independence, Basis and Dimension, Four Fundamental Subspaces, Graphs and Networks, Linear Transformations | | |
| **Unit - 3** | **Orthogonal and Projections** | **08 Hours** |
| Orthogonality - Orthogonal Vectors and Subspaces, Cosines and Projections onto Lines, Least Squares, Orthogonal Bases and Gram - Schmidt, Fast Fourier Transform | | |
| **Unit - 4** | **Eigenvalue Problems** | **08 Hours** |
| Overview of eigenvalue problems – Diagonalization of a Matrix, Difference Equations and Powers, Differential Equations, Complex Matrices, Similarity Transformations, Positive Definite Matrices - Tests for Positive Definiteness, Spectral Decomposition, | | |
| **Unit - 5** | **Matrix Decomposition** | **08 Hours** |

| | | |
|---|---|---|
| Eigenvalues and Singular Values - Schur's Decomposition, Reduction of Matrices to Hessenberg and Tridiagonal Forms; Power, Inverse Power and Rayleigh Quotient Iterations; QR Algorithm, Implementation of Implicit QR Algorithm; Sensitivity Analysis of Eigenvalues; Reduction of Matrices to Bi-diagonal Forms, QR Algorithm for SVD, Singular Value Decomposition (SVD) | | |
| **Unit - 6** | **Various Methods for Linear Systems** | **16 Hours** |
| Computation with Matrices - Matrix Norms, Condition Numbers, Stability, Sensitivity Analysis and Ill-Conditioning; Linear systems – Direct Methods: Back Substitution, LU factorization, Gaussian Eliminations, Cholesky Factorization, QR Factorization, Stability and Sensitivity Analysis; Iterative Methods: Jacobi, Gauss-Seidel and Successive Overrelaxation Methods; Krylov Methods: Linear least-squares - Gram- Schmidt Orthonormal Process, Rotators And Reflectors, Moore- Penrose Inverse, Rank Deficient Least-Squares Problems, Sensitivity Analysis, Arnoldi and GMRES, CG (conjugate gradients). | | |
| **Texts / References Books** | | |
| **Text Books:** | | |
| Linear Algebra and Its Applications - by Gilbert Strang, 4th Edition, Thomson Brooks/Cole.<br>Numerical Linear Algebra - by L. N. Trefethen and David Bau, SIAM, 1997.<br>Matrix Analysis and Applied Linear Algebra - by Carl D. Meyer, SIAM, 2000<br>Fundamentals of Matrix Computation - by D. S. Watkins, 2nd Edn Wiley, 2002. | | |
| **Reference Books:** | | |
| Applied Numerical Linear Algebra - by J.W. Demmel, SIAM, 1997.<br>Matrix Computation - by G. H. Golub and C.F.Van Loan, 3rd Edn., Hindustan book agency, 2007.<br>Numerical Linear Algebra and Applications - by B. N. Datta, 2nd Edn., SIAM, 2010.<br>Numerical Linear Algebra - by Allaire, Grégoire, Kaber, Sidi Mahmoud, Springer (2008) | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| NPTEL Lecture on Advanced Linear Algbera by Prof. Premananda Bera, IIT Roorkee | | |

| | | | | |
|---|---|---|---|---|
| Course Code | **AMMSCD502** | | | |
| Name of the Course | **Probability & Statistical Methods with R** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **0** | **0** | **3** |
| Offered in (Spring / Autumn) | **Autumn** | | | |
| **Course Objectives:**<br>The goal of this course is to inculcate the knowledge on probabilistic concepts and its applications, descriptive statistics, various distribution and its variants, learn the sampling techniques and understand the concept of inferential statistics for decision making. | | | | |
| **Course Outcome:**<br>Students will<br>be able to visualize and summarize the data.<br>know the usage of probability concepts in a given situation.<br>be able to select a suitable distribution and also generate random samples.<br>be skillful in drawing samples by choosing suitable sampling techniques and estimating the parameters<br>be able to formulate hypothesis and perform suitable statistical tests. | | | | |
| **Course Contents** | | | | |

<table>
<tr><th>Unit – 1</th><th>Descriptive Statistics</th><th>10 Hours</th></tr>
<tr><td colspan="3">Raw Data – Graphical Plots and Charts - Frequency Distribution – Histogram and Frequency Polygons – Relative Frequency Distributions – Cumulative Frequency Distributions – Frequency Curves and Their Types - Measures of Central Tendency: Mean, Median, Mode, Trimmed Mean – Measures of Dispersion: Range, Standard Deviation, Quartile Deviation, Mean and Median Absolute Deviation – Moments - Measures of Skewness and Kurtosis – Notion of Linear Correlation and Linear Regression – Simple Problems.</td></tr>
<tr><th>Unit – 2</th><th>Basic Probability, Random Variables and Probability Distributions</th><th>10 Hours</th></tr>
<tr><td colspan="3">Concept of Probability – Axioms of Probability - Conditional Probability – Simple Problems - Independent Events - Bayes’ Rule (without proof) and Simple Applications. Discrete and Continuous Random Variables, Probability Distributions for Discrete and Continuous Random Variables – Distribution Functions for Discrete and Continuous Random Variables – Joint Distributions - Independent Random Variables - Probability Distributions of Functions of Random Variables – Marginal and Conditional Distributions – Mathematical Expectation.</td></tr>
<tr><th>Unit – 3</th><th>Special Probability Distributions</th><th>10 Hours</th></tr>
<tr><td colspan="3">Notions of Binomial, Poisson Distribution and Normal Distributions – Properties – Relationship Between Binomial and Normal Distributions, Poisson and Normal Distributions – Uniform, Exponential, Gamma Distributions, t, Chi-square and F Distributions - Bivariate Normal Distribution – Simulation: Random Number Generation from Exponential, Gamma and Normal Distributions.</td></tr>
<tr><th>Unit – 4</th><th>Sampling Theory and Statistical Estimation Theory</th><th>06 Hours</th></tr>
<tr><td colspan="3">The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Sampling Techniques and Various Sampling distributions, Estimating Sampling Error, Estimation of Parameters, Likelihood Estimation, MLE of a generic probability model, Properties of Estimators: Unbiasedness, Consistency, Efficiency, Sufficiency. Point and Interval Estimates and Their Reliability, Confidence Interval Estimates of Population Parameters Based on Normal, t and Chi-square Distributions.</td></tr>
<tr><th>Unit – 5</th><th>Statistical Decision Theory</th><th>06 Hours</th></tr>
<tr><td colspan="3">Statistical Decisions, Statistical Hypothesis, Tests of Hypothesis and Significance, One-tail and Two-tail Tests. Parametric Tests: Tests Involving Normal, t, Chi-square and F Distributions - Test for Goodness of Fit, Contingency Tables, Tests for Independence of Attributes, One-way and Two-way Analysis of Variance. Non-parametric Tests: Sign Test, Run Test, Wilcoxon Signed Rank Test, Mann-Whitney U test, Kruskal-Wallis Test.</td></tr>
<tr><th>Unit – 6</th><th>Data Visualization to R</th><th>12 Hours</th></tr>
<tr><td colspan="3">Basics of R – Vectors – Operations – Filtering - Matrices and Arrays – Matrix Operations - Lists – List Operations – List Components and values - Data Frames – Creation and Merging - Tables – Structures – Control Structures – Functions – Recursions; Data Visualization with ggplot2 – aesthetic mappings - geometric objects – statistical transformations – coordinate systems - Data transformation with dplyr – Exploratory data analysis– missing values – co variation – patterns and models – ggplot2 calls</td></tr>
<tr><th colspan="3">Texts / References Books</th></tr>
<tr><td colspan="3">Text Books:</td></tr>
<tr><td colspan="3">Applied Statistics and Probability - by Montgomery, D. C., and Runger, G. C., For Engineers, Seventh Edition, John Wiley & Sons, Inc., 2018.<br>Fundamentals of Mathematical statistics - by S.C. Gupta and V.K. Kapoor, Sultan Chand and Sons, New Delhi.<br>Practical Statistics for Data Scientists - Bruce, P., Bruce, A., and Gedeck, P., Second Edition, O’Reilly Media, Inc., 2020.<br>The Art of R Programming: A Tour of Statistical Software Design - by Norman Matloff, NoStarch Press,</td></tr>
</table>

First Edition, 2011.

R for Data Science: Import, Tidy, Transform,Visualize, and Model Data - by Hadley Wickham, Garett Grolemund, O'Reily Publications, First Edition, Feb 2017.

**Reference Books:**

Statistical Methods - by N. G. Das, 1st Edition, McGraw Hill, 2008.

Statistical Methods Concept, Application and Computation - by Y. P. Aggarwal, Sterling Publishers, 1998.

Hands-on Programming with R: Write your own functions and simulations - by Garrett Grolemund, O'Reilly Publisher, 2014.

**Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]**

NPTEL Lecture on Essentials of Data Science with R: Probability and Statistical Inference by Prof. Shalabh, IIT Kanpur

R Programming for Data Science by Roger D. Peng

| | | | | |
|---|---|---|---|---|
| Course Code | **AMMSCD503** | | | |
| Name of the Course | **Data Science with Python** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **0** | **0** | **3** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**

This course aims to provide working knowledge of Python Programming, and basic understanding of the concepts of strings, lists, dictionaries, line properties, different setter methods and practical uses of class methods, overloading and polymorphism. It also aims to get students familiar with different conditional statements, plots and implementation of recursive functions.

**Course Outcome:**

Through this course, students will

gain a solid understanding of key concepts and principles in data science

develop strong programming skills in Python and learn how to leverage Python libraries such as NumPy, Pandas, Matplotlib, and Scikit-learn for data manipulation, analysis, and modeling.

acquire the skills to understand the data and learn techniques to summarize data to gain insights and identify patterns

understand various statistical concepts and techniques needed for data analysis.

develop an understanding of various algorithms for classification, regression, clustering and dimension reduction, and learn about evaluation metrics and techniques for model selection and tuning.

**Course Contents**

| Unit – 1 | Introduction to Python | 10 Hours |
|---|---|---|

Python Basics, Variables, Expressions and Statements: Assignment Statements, Variable Names, Expressions Statements, Order of Operations; Functions: Function Calls, Composition, Adding New Functions, Definitions and Uses, Flow of Execution; Conditionals and Recursion: Floor Division and Modulus, Boolean Expressions, Logical Operators, Conditional Execution; Fruitful Functions: Return Values, Incremental Development, Composition, Boolean Functions: Iteration: Reassignment, Updating Variables, While Statement, Break, Square Roots

| Unit – 2 | Advanced Concepts in Python | 10 Hours |
|---|---|---|

| | | |
|---|---|---|
| Strings: String Length, For Loop Traversal, Searching, Looping and Counting; Lists: Traversing a List, List Operations, Deleting Elements; Dictionaries: Looping and Dictionaries, Reverse Lookup, Dictionaries and Lists, Global Variables; Tuples: Assignment, Return Values, Variable-Length Argument Tuples, Lists and Tuples, Dictionaries and Tuples; Files: Reading and Writing, Format Operator, Filenames and Paths, Catching Exceptions; Classes and Objects: Programmer Defined Types, Attributes, Rectangles, Instances As Return Values. Classes And Methods: Object Oriented Features, Init() Method, Str Method, Operator Overloading, Polymorphism, Inheritance | | |
| **Unit – 3** | **Data Manipulation using Python Libraries** | **10 Hours** |
| Introduction to NumPy: the World of Arrays with Numpy, Computation of NumPy Arrays, Aggregations, Comparisons, Sorting Arrays, Structured Data; Data Manipulation with Pandas: Installing and Using Pandas, Introducing Pandas Objects, Data Indexing and selection, Operating on Data in Pandas, Handling Missing Data, Hierarchal Indexing, Combing Plotting Data using Matplotlib: Plotting using Matplotlib, Customization of Plots: Marker, Colour, Linewidth and Line Style, The Pandas Plot Function (Pandas Visualization), Plotting a Line Chart, Plotting Bar Chart, Plotting Histogram, Plotting Scatter Chart, Plotting Quartiles and Box Plot, Plotting Pie Chart. | | |
| **Unit – 4** | **Fundamental Learning Algorithms** | **10 Hours** |
| Regression and Classification Methods, K-Nearest Neighbors (K-NN), Naïve Bayes Classifier, Support Vector Machines (SVMs), Linear Regression, Logistic Regression, Decision Trees, Random Forests, k-NN clustering, Hierarchical Clustering, Dimension Reduction, Model Evaluation and Validation Techniques. | | |
| **Unit – 5** | **Data Visualization** | **08 Hours** |
| Making Sense of Data through Advanced Visualization: Area plots, Bubble charts, Hexagon bin plots, Trellis plots, 3D plot of a surface; Understanding Data Types in Python; Empowering Data Analysis with Pandas, Data Cleansing, Data Operations; Visualization with Matplotlib: Simple Line Plots, Simple Scatter Plot, Visualizing Errors, Density and Contour Plots, Histograms, Binnings and Density. Customization with Matplotlib: Customizing Plot Legends, Customizing Colorbars, Multiple Subplots, Text and Annotations, Customizing Ticks, Configuration and Stylesheets, Three-Dimensional Plotting, Geographic Data with Basemap and Visualisation with Seaborn | | |
| **Unit – 6** | **Data Ethics and Recent Trends** | **06 Hours** |
| Data Science Ethics, Ethical Considerations in Data Collection And Usage – Doing Good Data Science – Owners of the Data - Valuing Different Aspects of Privacy - Getting Informed Consent - The Five Cs – Diversity – Inclusion – Future Trends – Privacy Issues and Data Protection Regulations – Bias and Fairness in Machine Learning Models – Responsible AI Practices | | |
| **Texts / References Books** | | |
| **Text Books:** | | |
| Mastering Python for Data Science - by Samir Madhavan, PACKT Publishing, 2015.<br>Think Python - by Allen Downey O'Reilly Publications, 2nd Edition, 2016.<br>Python Data Science Handbook Essential Tools for Working with Data – by Jake Vander Plas, O'Reilly Media, 1st edition, 2016.<br>Ethics and Data Science - by D J Patil, Hilary mason, Mike Loukides, O' Reilly, 1st Edition, 2018.<br>An Introduction to Statistical Learning: with Applications in R - by Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, Springer, 1st edition, 2013. | | |
| **Reference Books:** | | |

| |
|---|
| Data Science from Scratch: First Principles with Python - by Joel Grus, O'Reilly, 1st Edition, 2015.<br>Data Analytics using Python - by Bharti Motwani, Wiley, 1st Edition, 2020.<br>Python Data Science Essentials - by Alberto Boschetti and Luca Massaron, Packt publishing, 3rd Edition, 2018.<br>Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython - by Wes McKinney, O'Reilly Media, Inc., 2nd edition, 2017.<br>Programming Python - by Mark Lutz, O'Reilly Publications, 4th Edition, 2011.<br>Python in a nutshell - by Alex Martelli, Anna Ravenscroft, Steve Holden, O'Reilly Publications, 3rd Edition, 2017. |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Python for Data Science by Prof. Ragunathan Rengasamy, IIT Madras<br>NPTEL Lecture on Data Analytics with Python by Prof. A. Ramesh by IIT Roorkee |

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|---|---|---|---|---|
| Course Code | **CSMSCD506** | | | |
| Name of the Course | **Advanced Database Management Systems** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

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|---|
| **Course Objectives:**<br>This course aims to introduce the database design and systems, learn how data is stored, organized and managed efficiently in a database and further provides the knowledge of transaction processing and concurrency control. |
| **Course Outcomes:**<br>Develop the skill set to<br>define database models and database management and explain the applications of database models.<br>experiment with various database languages.<br>distinguish the ACID/BASE properties and data consistency.<br>be able to write SQL queries to manipulate data in a RDBMS<br>appraise and adopt the NoSQL databases for the recent technologies. |
| **Course Contents** |

| | | |
|---|---|---|
| **Unit – 1** | **Databases: Architecture and Management** | **10 Hours** |
| Database System Architecture: Centralized and Client-Server Architectures, Server system Architectures, Database Architecture, Transaction Management, Data Models and Its Evolution, Degrees of Data Abstraction, Parallel Systems, Distributed Systems, Elastic Search, Network Types; Data Management: Information Systems and Data Databases – SQL Databases – Big Data – No SQL Databases – Organizing of Data Management. | | |
| **Unit – 2** | **Data Models** | **10 Hours** |
| Data Modeling: Data Model-Key-Value Data Model- Columnar Data Model, Graph Based Data Model Graph Data Model, From Data Analysis to Database–The Entity-Relationship Model - Implementation in the Relational Model-Implementation in the Graph Model – Enterprise-wide Data Architecture – Formula for Database Design | | |
| **Unit – 3** | **Interactions with Databases** | **10 Hours** |
| Database Languages: Interacting with Databases-Relational Algebra-Relationally Complete Languages-Graph based Languages-Embedded Languages-Handling NULL Values-Integrity Constraints – Data Protection Issues, | | |

| | | |
|---|---|---|
| Database Design and ER Model, Relational Schemas, RDBMS, Atomic Domain and Normalization, Relational Algebra, Selection and Projection, Set Operations, Renaming, Joins, Semantics, Grouping And Ungrouping, Relational Comparison, With SQL, Null Values, Nested Sub Queries, Joined Relations. | | |
| **Unit – 4** | **Properties of a Database** | **06 Hours** |
| Ensuring Data Consistency: Multi-user Operation – Transaction Concept – Consistency in<br>Massive Distributed Data – Comparing ACID and BASE, Serializability and Concurrency Control, Lock Based Concurrency Control, Time Stamping Methods, Optimistic Methods, Database Recovery Management, CAP Theorem | | |
| **Unit – 5** | **NoSQL Databases** | **10 Hours** |
| System Architecture: Processing of Homogeneous and Heterogeneous Data – Storage and Access Structure – Translation and Optimization of Relational Queries – Parallel Processing with Map Reduce – Layered Architecture – Use of Different Storage Structures -NoSQL Databases: Need of NoSQL, Value of Relational Databases, impedance mismatch, Application and Integration Databases, Attack of the clusters, Emergence of NoSQL, Development of Non-relational Technologies – Key-value stores – Column-Family Stores – Document Stores – XML Databases – Graph Databases. NoSQL. NoSQL Data Architecture Patterns: NoSQL Data model: Aggregate Models- Document | | |
| **Unit – 6** | **Data Storage and Distributed Models** | **08 Hours** |
| Distributed Models- Single Server, Sharding, Master-Slave Replication, Peer to Peer Replication. Key-Value Databases: Comparison of Relational and Key Value Store, Features. Document Databases: Comparison of Relational and Document Database, Advantages and Disadvantages, Features. Column Family Stores- Comparison of Relational and Column Family, Advantages and Disadvantages | | |
| **Texts / References Books** | | |
| **Text Books:** | | |
| Database System Concepts - by Abraham Silberschatz, Henry F.korth,S. Sudarshan, McGraw Hill, 6th Ed., 2013 ( Unit : I–IV).<br>Database Management Systems - by R. Ramakrishnan, J. Gehrke, McGraw Hill Education, 3rd Ed., 2014.<br>Fundamental of Database Systems - by Ramez Elmasri, Shamkant B Navathe, 7th Ed., 2016.<br>Database Systems: The Complete Book - by Hector Garcia-Molina, Jeffrey Ullman, Jennifer Widom, Pearson, 2nd Ed., 2008. | | |
| **Reference Books:** | | |
| An Introduction to Database Systems - by C.J. Date, A. Kannan, S. Swamynathan, Pearson Ed. Reprint, 8th Edition, 2016.<br>Database Systems - by Rob Coronel, Course Technology Inc., 7th Ed., 2006.<br>SQL & NoSQL Databases - by Andreas Meier and Michael Kaufmann, Springer, Morgan Kaufmann, 2019.<br>Modern Database Management - by J. Hoffer, R. Venkataraman, H. Topi, Pearson, 12th Ed., 2016. | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| NPTEL Lecture on Introduction to Database Systems by Prof. P.Sreenivasa Kumar, IIT Madras | | |

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|---|---|---|---|---|
| Course Code | **CSMSCD507** | | | |
| Name of the Course | **Computer Organization and Architecture** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**
The purpose of the course is to introduce principles of computer organization and the basic architectural concepts. It begins with basic organization, design, and programming of a simple digital computer and introduces simple register transfer language to specify various computer operations. Topics include computer arithmetic, instruction set design, microprogrammed control unit, pipelining and vector processing, memory organization and I/O systems, and multiprocessors

**Course Outcomes:**
Understand the basics of instructions sets and their impact on processor design.
Demonstrate an understanding of the design of the functional units of a digital computer system.
Evaluate cost performance and design trade-offs in designing and constructing a computer processor including memory.
Design a pipeline for consistent execution of instructions with minimum hazards.
Recognize and manipulate representations of numbers stored in digital computers

**Course Contents**

| | | |
|---|---|---|
| **Unit - 1** | **Digital Computers** | **14 Hours** |
| Introduction, Block diagram of Digital Computer, Definition of Computer Organization, Computer Design and Computer Architecture. Register Transfer Language and Micro operations: Register Transfer language, Register Transfer, Bus and memory transfers, Arithmetic Micro operations, logic micro-operations, shift micro-operations, Arithmetic logic shift unit. Basic Computer Organization and Design: Instruction codes, Computer Registers Computer instructions, Timing and Control, Instruction cycle, Memory Reference Instructions, Input – Output and Interrupt. | | |
| **Unit - 2** | **Microprogrammed Control** | **10 Hours** |
| Control memory, Address sequencing, micro program example, design of control unit. Central Processing Unit: General Register Organization, Instruction Formats, Addressing modes, Data Transfer and Manipulation, Program Control. | | |
| **Unit - 3** | **Data Representation** | **10 Hours** |
| Data types, Complements, Fixed Point Representation, Floating Point Representation. Computer Arithmetic: Addition and subtraction, multiplication Algorithms, Division Algorithms, Floating – point Arithmetic operations. Decimal Arithmetic unit, Decimal Arithmetic operations. | | |
| **Unit - 4** | **Data Representation** | **10 Hours** |
| Data types, Complements, Fixed Point Representation, Floating Point Representation. Computer Arithmetic: Addition and subtraction, multiplication Algorithms, Division Algorithms, Floating – point Arithmetic operations. Decimal Arithmetic unit, Decimal Arithmetic operations. | | |
| **Unit – 5** | **Input-Output Organization** | **10 Hours** |
| Input-Output Interface, Asynchronous data transfer, Modes of Transfer, Priority Interrupt Direct memory Access. Memory Organization: Memory Hierarchy, Main Memory, Auxiliary memory, Associate Memory, Cache Memory. | | |
| **Unit - 6** | **Reduced Instruction Set Computer** | **10 Hours** |
| CISC Characteristics, RISC Characteristics. Pipeline and Vector Processing: Parallel Processing, Pipelining, Arithmetic Pipeline, Instruction Pipeline, RISC Pipeline, Vector Processing, Array Processor. Multi Processors: Characteristics of Multiprocessors, Interconnection Structures, Interprocessor arbitration, Interprocessor communication and synchronization, Cache Coherence. | | |

**Texts / References Books**

**Text Books:**

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|---|
| Computer System Architecture by M. Moris Mano, Pearson Education/ Prentice Hall of India, 3rd Ed., 2010.<br>Computer Organization and Design: The Hardware/Software Interface by David A. Patterson, John L. Hennessy, Morgan Kauffman, 5th Ed., 2013.<br>Computer Systems: A Programmer's Perspective by Randal Bryant, David O'Hallaron, Pearson, 3rd Ed., 2015.<br>Computer Architecture: A Quantitative Approach by John L. Hennessy, David A. Patterson, Morgan Kauffman, 6th Ed., 2017. |
| **Reference Books:** |
| Computer Organization and Architecture: Designing for Performance by William Stallings, Pearson Education, 9th Ed., 2013.<br>Structured Computer Organization by A. S. Tanenbaum, Pearson Education India, 6th Ed., 2016.<br>Computer Organization by Car Hamacher, Zvonks Vranesic, Safea Zaky, McGraw Hill, 5th Ed., 2011. |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Computer Architecture and Organization by Prof. Indranil Sengupta, Prof. Kamalika Datta, IIT Kharagpur<br>NPTEL Lecure on Computer Organization and Architecture (Web) by Prof. Bhaskaran Raman, IIT Kanpur |

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|---|---|---|---|---|
| Course Code | **AMMSCD504** | | | |
| Name of the Course | **Data Science with Python Lab** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **0** | **0** | **4** | **2** |
| Offered in (Spring / Autumn) | **Autumn** | | | |
| **Course Objectives:**<br>The course aims to introduce the basic concepts and usage of variables, expressions and practice the use of functions in Python Programming Language, highlight the practical aspects of data science and develop a broad view of data science implementations in academics and various industries. | | | | |
| **Course Outcomes:**<br>Develop the skill set to<br>have knowledge of how data science is implemented in various industries.<br>work on hands-on exercises and projects that involve solving data-related problems using Python and Data Science techniques.<br>learn how to pre-process and clean raw data to make it suitable for analysis including handling missing data, dealing with outliers, data normalization, and feature scaling.<br>be able to analyze raw data and use different statistical methods on the data.<br>be able to develop programs in Python and implement functions using parameters. | | | | |
| **Course Contents** | | | | |
| **Topics** | | | | |
| Find all numbers which are multiples of 17, but not the multiples of 5, between 2000 and2500?<br>Swap two integer numbers using a temporary variable. Repeat the exercise using the code format: a, b = b, a. Verify your results in both the cases.<br>Given two pairs of Cartesian points such as (x1, y1) and (x2, y2). Find the Euclidean distance between them. Hint: Use math module to find the square root.<br>Print the first 2 and last 3 characters in a given string. Use the string slicing concept. Do not use loops. If the length of the string is less than 5, print a suitable message. | | | | |

Implement bubble sort. Do not use the default sort() method. Hint: So as to familiarize with the concept of sorting, and nested looping structures.

Implement shallow copy and deep copy of a list. You may use the copy module. Hint: While we copy a list, just a reference is copied. Hence if we make any changes to one of the lists, the same will reflect in the other as well. This is called shallow copying. Hence, in some cases we might need to deep copy, where a completely independent copy is created. This can be achieved through the deepcopy() method of the copy module.

Write a temperature converter program, which is menu driven. Each such conversion logic should be defined in separate functions. The program should call the respective function based on the user's requirement. The program should run as long as the user wishes so.

Find the largest of n numbers, using a user defined function largest().

Write a function that capitalizes all vowels in a string. Hint: Do not use the ASCII concept. Use the upper() method.

Write a function leapYear() which receives a four digit year and returns a Boolean value: True if the year is leap, False if the year is not leap.

Read a line containing digits and letters. Write a program to give the count of digits and letters. Hint: Instead of checking ASCII, use the in-built methods like isdigit(), isalpha()etc.

Write a function myReverse() which receives a string as an input and returns the reverse of the string.

Use the list comprehension methodology in python, to generate the squares of all odd numbers in a given list. Hint: List comprehension is one of the powerful techniques in python;

Check if a given string is palindrome or not.Hint: do not use the C philosophy where we compare indices. Instead, copy the string as a new list, reverse the list using reverse(), join the list so that the reversed string is formed, using join(). Compare the new string and the old one.

Write a function to see if a given number is prime or not. Do not use any flag variables. Use a math module to find the square root, and its roof which will be fed in to range(). Hint: Just the return statements are enough. No need for flag variables. The loop has to run up to the roof of the square root of the number.

Write a function to find the factorial of a number using recursion.

Extend the above problem to find the nCr of given values of n and r. Verify the result with the help of the filter tools module, which helps to find the combinations.

Write a program that eliminates duplicates in a list. Do not use the concept of sets. Now, convert the original list into a set. Verify the result in both cases.

The user will enter five integers separated by commas. Write a program to read these values, and make a list. Print the list.Hint: They will need to read the input using raw_input(), and then split the one and only line of input using split(). Then each of the values will need to be appended to a list, which will be empty at first.

Generate a dictionary and print the same. The keys of the dictionary should be integers between 1 and 10 (both inclusive). The values should be the cubes of the corresponding keys.

Create a nested dictionary. The roll number of a student maps to a dictionary. This inner dictionary will have name, age, and place as keys. Read details of at least three students. Hint: A sample output should look like the one given below: {11: {'name': 'Sachin', 'age': 18, 'place': 'Kochi'}, 12:{'name':'Ammu', 'age': 19, 'place': 'Kannur'}, 13: {'name':'jishad', 'age':20, 'place':'Calicut'}}

Enter a word. Create a dictionary with the letters of this word as keys, and the corresponding ASCII values as values. Hint: Students may use the ord() function. Further, this is a simple problem, if list comprehension is used.

Write a python program to find the tuples which all the elements are divided by a 'k' element from a list of tuples

Write a Python program to print all pair combinations of elements from 2 tuples. Hint: Students may use list comprehension.

. Write a Python program to concatenate consecutive elements in tuple. Hint: use map() and tuple methods for concatenation .

. Write a pandas program to select a name and score columns in rows 1,3,5,6 from the data frame consists of column values as index, name, score, attempts and qualify

. Write a pandas program to implement line and box plots on the data frame student having the values as roll, name, exam1, exam2 and exam3.

. Implement Multiple plots.

. Implement Scatter plots with histogram.

. Implement Bubble charts.

**Texts / References Books**

**Text Books:**

Mastering Python for Data Science by Samir Madhavan, PACKT Publishing, 2015.

Think Python by Allen Downey, O'Reilly Publications, 2nd Ed., 2016.

**Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]**

NPTEL Lecture on Data Analytics with Python by Prof. A. Ramesh, IIT Roorkee

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|---|---|---|---|---|
| Course Code | **AMMSCD505** | | | |
| Name of the Course | **Probability and Statistical Methods with R Lab** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **0** | **0** | **4** | **2** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**

This course aims to build the fundamentals of probability and statistics, make students understand the importance of probability distributions and set the mathematical foundations for data science learning.

**Course Outcome:**

Develop the skill set to

Identify and execute basic syntax and programs in R.

Perform the Matrix operations using R built in functions

Apply non numeric values in vectors.

Create the list and data frames

Exploit the graph using ggplot2.

**Course Contents**

**Topics**

**Overview of R:**

History and Overview of R- Basic Features of R-Design of the R System- Installation of R- Console and Editor Panes- Comments- Installing and Loading R Packages- Help Files and Function Documentation- Saving Work and Exiting R- Conventions- R for Basic Math- Arithmetic- Logarithms and Exponentials- E-Notation- Assigning Objects- Vectors- Creating a Vector- Sequences, Repetition, Sorting, and Lengths- Subsetting and Element Extraction- Vector-Oriented Behaviour

**Practical Component:**

Develop the R program for Basic Mathematical computation –Square, Square root, exponentialetc.

Create an object X that stores the value then overwrite the object in by itself divided by Y.Print the result to the

console.
Create and store a sequence of values from x to y that progresses in steps of 0.3
Overwrite the existing object using the same sequence with the order reversed.
Confirm that the length of the vector created is 20.
Extract the first and last elements of already created vector from, storing them as a new object

**Matrices And Arrays:**
Defining a Matrix – Defining a Matrix- Filling Direction- Row and Column Bindings- Matrix Dimensions-Subsetting- Row, Column, and Diagonal Extractions- Omitting and Overwriting- Matrix Operations and Algebra- Matrix Transpose- Identity Matrix- Matrix Addition and Subtraction- Matrix Multiplication- Matrix Inversion-Multidimensional Arrays- Subsets, Extractions, and Replacements

**Practical Component:**
Create and store a three-dimensional array with six layers of a 4 X 2 matrix, filled with a decreasing sequence of values between 4.8 and 0.1 of the appropriate length
Extract and store as a new object the fourth- and first-row elements, in that order, of the second column only of all layers of (1).
Use a fourfold repetition of the second row of the matrix formed in (2) to fill a new array of dimensions 2 X 2 X 2 X 3.
Create a new array comprised of the results of deleting the sixth layer of (1).
Overwrite the second and fourth row elements of the second column of layers 1, 3, and 5 of (4) with-99.

**Non-Numeric Values:** Logical Values- Relational Operators- Characters- Creating a String- Concatenation-Escape Sequences- Substrings and Matching- Factors- Identifying Categories- Defining and Ordering Levels-Combining andCutting

**Practical Component:**
Confirm the specific locations of elements equal to 0 in the 10 X 10 identity matrix I10
Store this vector of 10 values: foo <- c(7,5,6,1,2,10,8,3,8,2).Then, do the following:
Extract the elements greater than or equal to 5, storing the result as bar.
Display the vector containing those elements from foo that remain after omitting all elements that are greater than or equal to 5.
Store the string "Two 6-packs for $12.99". Then do the following:
Use a check for equality to confirm that the substring beginning with character 5 andending with character 10 is "6-pack".
Make it a better deal by changing the price to $10.99.
Create a factor with levels of confidence as follows: Low for percentages [0,30]; Moderate for percentages (30,70]; and High for percentages (70,100].

**Lists And Data Frames:** Lists of Objects-Component Access-Naming-Nesting-Data Frames-Adding Data Columns and Combining Data Frames-Logical Record Subsets-Some Special Values-Infinity-NaN-NA-NULL-Attributes-Object-Class-Is-Dot Object-Checking Functions-As-Dot Coercion Functions-

**Practical Component:**
Create a list that contains, in this order, a sequence of 20 evenly spaced numbers between -4 and 4; a 3 X 3 matrix of the logical vector c(F, T,T,T,F,T,T,F,F) filled column-wise; a character vector with the two strings "don" and "quixote"; and a factor vector containing the observations c("LOW","MED","LOW","MED","MED","HIGH"). Then, Extract row elements 2 and 1 of columns 2 and 3, in that order, of the logical matrix.
Create and store this data frame as dframe with the fiiels of person, sex, funny in your R workspace.Append the

two new records.
Write a single line of code that will extract from mydataframe just the names and ages of any records where the individual is female and has a level of funniness equal to Med OR High.
Use your knowledge of handling character strings in R to extract all records from mydataframe that correspond to people whose names start with S.

**Basic Plotting:** Using plot with Coordinate Vectors-Graphical Parameters-Automatic Plot Types-Title and Axis Labels- Color-Line and Point Appearances-Plotting Region Limits-Adding Points, Lines, and Text to an Existing Plot-ggplot2 Package-Quick Plot with qplot-Setting Appearance Constants with Geoms-- READING AND WRITING FILES- R-Ready Data Sets- Contributed Data Sets- Reading in External Data Files- Writing Out Data Files and Plots- Ad Hoc Object Read/Write Operations

**Practical Component:**
Create a database with the fields of weight, height and sex then create a plot of weight on the x-axis and height on the y-axis. Use different point characters or colors to distinguish between males and females and provide a matching legend. Label the axes and give the plot a title.
Create a plot using ggplot2 for the same database consists of weight on the x-axis and height onthe y-axis. Use different point characters or colors to distinguish between males and females and provide a matching legend. Label the axes and give the plot a title.
Write R code that will plot education on the x-axis and income on the y-axis, with both x- and y-axis limits fixed to be [0;100]. Provide appropriate axis labels. For jobs with a prestige valueof less than or equal to 80, use a black * as the point character. For jobs with prestige greater than 80, use a blue @.

**Texts / References Books**

**Text Books:**
The Book of R - A First Programming and Statistics - by Tilman M.Davies, Thomson Brooks/Cole. Library of Congress Cataloging-in-Publication Data, 4th Ed., 2016.
R for Data Science by Hadley Wickham, Garrett Grolemund, O'Reilly Publication, 2017.
An Introduction to Statistical Learning: with Applications in R by Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, Springer, 1st Ed., 2017.
Introductory Statistics with R by Peter Dalgaard, Springer, 2nd Ed., 2008.

**Reference Books:**
R Programming for Beginners by Steven Keller, CreateSpace Independent Publishing Platform 2016.
Learning R Programming by Kun Ren, Packt Publishing, 2016.
R Programming for Data Science by Roger D. Peng, Lulu.com, 2012.
Probability and Statistics with R by Maria Dolores Ugarte, Ana F. Militino, Alan T. Arnholt, Chapman and Hall, 1st Ed., 2008.

**Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]**
https://web.itu.edu.tr/~tokerem/The_Book_of_R.pdf
https://online-learning.harvard.edu/subject/r

## SECOND SEMESTER

| | | | | |
|---|---|---|---|---|
| Course Code | **AMMSCD521** | | | |
| Name of the Course | **Optimization Techniques** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |

| Offered in (Spring / Autumn) | **Spring** |
|---|---|

**Course Objectives:**

To study the model formulation and discussion of documented real-world applications. Study of mathematical programming algorithms. Apply the mathematical results and numerical techniques of optimization theory to concrete Engineering problems

**Course Outcome:**

Develop the skill set to

become a mathematical translation of the verbal formulation of an optimization problem;

discovery, study and solve optimization problems;

Investigate, study, develop, organize and promote innovative solutions for various applications

be able to formulate optimization problems with constraints and without constraints

have an understanding of transportation and assignment problems and various optimization techniques

**Course Contents**

| **Unit - 1** | **Constrained and Unconstrained Optimization** | **08 Hours** |
|---|---|---|
| Constrained optimization (Penalty methods, Lagrange multipliers, Karush-Kuhn-Tucker conditions). Unconstrained optimization using calculus (Taylors’s theorem, convex functions, coercive functions), Unconstrained optimization via iterative methods (Newton’s method, gradient/conjugate gradient methods, quasi-newton methods) | | |
| **Unit - 2** | **Linear Programming** | **16 Hours** |
| Introduction to Linear Programming Problem (LPP), Graphical Method, Simplex Method, Dual Simplex Method, Two Phase Method, Degeneracy, Alternative Optima, Graphical Sensitivity Analysis, Sub-Optimization; LP-Duality and Sensitivity Analysis: Definition of Dual, Primal-Dual Relationships, Dual Simplex Sensitivity or Post Optimal Analysis, Revised Simplex Method, Bounded-Variable Algorithm, Duality, Parametric programming | | |
| **Unit - 3** | **Integer Programming** | **06 Hours** |
| Formulation and Applications-Cutting Plane Algorithm-Branch and Bound Method. | | |
| **Unit - 4** | **Deterministic Inventory models** | **06 Hours** |
| EOQ models, EOQ with price breaks, Multi-Item EOQ with storage limitation. | | |
| **Unit - 5** | **Queuing Systems** | **06 Hours** |
| Pure birth and Pure death models, generalized Poisson queuing model, single server models. | | |
| **Unit - 6** | **Numerical methods for optimization** | **12 Hours** |
| Minimization and maximization of convex functions- Local & Global optimum- Convergence-Speed of convergence. Nelder Mead’s Simplex search method. | | |

**Texts / References Books**

**Text Books:**

Operations Research- An Introduction by Hamdy A.Taha, Pearson, 10th Ed., 2019.

Numerical Optimization by J. Nocedal, S. Wright, Springer, 2nd Ed., 2006.

Numerical Methods and Optimization by Hari Arora, S.K. Kataria& Sons, 2013.

An Introduction to Optimization, 4th Edition, by Edwin K. P. Chong, Stanislaw H. Zak, John Wiley & Sons, 2008

Practical Optimization: Algorithms and Engineering Applications by Andreas Antoniou, Wu-Sheng Lu, Springer, 2007.

**Reference Books:**

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|---|
| Optimization Techniques, by L. R. Foulds, Springer, UTM, 1981.<br>Introduction to Linear Optimization by D. Bertsimas and J. N. Tsitsiklis, Athena Scientific, 1997.<br>Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer, 2016.<br>Engineering Optimization: Theory and Practice by S.S. Rao, Wiley, 5th Ed., 2019.<br>Introduction to Optimization by E.M.L. Beale, E. M. Beale, Wiley, 1998.<br>Nonlinear Programming by D. P. Bertsekas, Athena Scientific, 3rd Ed., 2016.<br>An Introduction to Optimization by Edwin K. P. Chong, Stanislaw H. Zak, Wiley, 4th Ed., 2013. |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Numerical Optimization by Dr. Shirish K. Shevade, IISc Bangalore<br>NPTEL Lecture on Constrained and Unconstrained Optimization by Dr. Debjani Chakraborty, Prof. A. Goswami, IIT Kharagpur |

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|---|---|---|---|---|
| Course Code | **AMMSCD522** | | | |
| Name of the Course | **Time Series Analysis & Forecasting Methods** | | | |
| Core / Elective | Core | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Spring** | | | |

**Course Objectives:**

This course focuses on Time series analysis and growth models, to understand exponential smoothing methods, study forecasting with ARIMA models and estimate ARIMA model parameters. It also centers on the spectral analysis of weakly stationary process.

**Course Outcome:**

Develop the skill set to

To learn about Exponential, Gompertz and Logistic curves and their fitting.

To understand trend adjusted exponential smoothing methods.

To study MA, AR, ARMA and ARIMA models.

To understand Box-Jenkins models and estimate auto covariance and auto correlation functions.

To study Periodogram and Correlogram analyses.

**Course Contents**

| **Unit 1** | **Introduction to Time Series Analysis** | **14 Hours** |
|---|---|---|
| Review of Time Series Analysis. Growth models: Modified Exponential Curve, Gompertz curve, Logistic curve and their Fitting; Measurement of cyclical component: Harmonic analysis, auto regression series: Markoff and Yule’s series, Periodogram and correlogram analysis, measurement of irregular component: variate difference method. Difference Equations, Lag Operators, pth-Order Difference Equations. White Noise, Expectations, Stationarity, and Ergodicity. Models of Nonstationary Time Series: Why Linear Time Trends and Unit Roots? Random Walk Models, Brownian Motion, Geometric Brownian Motion. Canonical Correlation Time Series Models of Heteroscedasticity: ARCH and GARCH model, Granger Causality Test ADF, KPSS Test for Stationary | | |
| **Unit 2** | **Exponential smoothing methods** | **10 Hours** |
| Trend adjusted exponential smoothing, double and triple exponential smoothing, Holt and Winters smoothing, chow’s adaptive control methods, brown’s one parameter adaptive method: | | |
| **Unit 3** | **Detailed study of the stationary processes** | **10 Hours** |
| Linear Models, Autoregressive Processes, Moving Average (MA), Auto Regressive (AR), ARMA and AR Integrated MA(ARIMA)models - forecasting with ARIMA models. | | |

| Unit 4 | Box-Jenkins models | 10 Hours |
|---|---|---|
| Discussion (without proof) of estimation of mean, auto covariance and auto-correlation functions under large sample theory. Choice of AR and MA periods. Estimation of ARIMA model parameters. | | |
| **Unit 5** | **Spectral Analysis** | **05 Hours** |
| Spectral analysis of weakly stationary process. Periodogram and correlogram analyses. Computations based on Fourier transform. | | |
| **Unit 6** | **Forecasting** | **05 Hours** |
| Principles of Forecasting, Forecasts with Gaussian Processes, Wold's Decomposition and the Box-Jenkins Modelling Philosophy, Parameter Estimation, Maximum Likelihood Estimation. Vector Auto regressions; Bivariate Granger Causality Tests. Understanding Kalman Filter | | |
| **Text / References Books** | | |
| **Text Books:** | | |
| Time Series Analysis by James D. Hamilton, Princeton University Press, 2012.<br>Time Series Analysis and Its Applications: With R Examples by Robert H. Shumway, David S. Stoffer, Springer Texts in Statistics, 2017.<br>Understanding the Kalman Filter by Richard J. Meinhold, Nozer D. Singpurwalla, The American Statistician Vol. 37, No. 2, pp. 123-127, (May, 1983).<br>The Statistical Analysis of Time Series by Anderson, T.W., Wiley, 1971.<br>Forecasting and Time Series Analysis by Montgomery, D.C. and Johnson, L.A., McGraw Hill, 1977. | | |
| **Reference Books:** | | |
| Introduction to Statistical Time Series by Fuller, W.A., John Wiley, 2nd Ed., 1995.<br>Forecasting Econometric Time Series by N.Y. Granger, C.W.J. and Newbold, Academic Press, 3rd Ed., 1984.<br>Spectral Analysis and Time Series by Priestley, M.B., Griffin, London, 1981.<br>Time Series Analysis by Kendall, S.M. and Ord, J.K., 3rd Ed., Edward, 1981.<br>The Advanced Theory of Statistics by Kendall, M.G. and Stuart, A.,Vol.3, Charles Griffin, London, 1966.<br>The Spectral Analysis of Time Series by Koopmans, L.H., Academic Press, 1974. | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| Coursera Course on Practical Time Series Analysis<br>NPTEL Lecture on Applied Time-Series Analysis by Dr. Arun K.Tangirala, IIT Madras | | |

| Course Code | **AMMSCD523** | | | |
|---|---|---|---|---|
| Name of the Course | **Machine Learning & Deep Learning** | | | |
| Core / Elective | Core | | | |
| Credits | L | T | P | C |
| | **3** | **0** | **1** | **4** |
| Offered in (Spring / Autumn) | **Spring** | | | |
| **Course Objectives:**<br>This course explains machine learning techniques such as decision tree learning, Bayesian learning. It also aims to understand computational learning theory and study the pattern comparison techniques. | | | | |

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|---|---|---|
| **Course Outcome:**<br>Develop the skill set to<br>understand the concepts of computational intelligence and various machine learning algorithms.<br>apply machine learning techniques to address the real time problems in different areas of science.<br>proficiently perform exploratory data analysis, data visualization, machine learning and big data solutions to a practical problem.<br>understand the broad view of machine learning and deep learning implementations in academics as well as various industries.<br>understand the Neural Networks and its usage in machine learning applications. | | |
| **Course Contents** | | |
| **Unit - 1** | **Introduction** | **10 Hours** |
| Well-posed learning problems, designing a learning system, Perspectives and issues in machine learning Concept learning and the general to specific ordering – introduction, a concept learning task, concept learning as search, find-S: finding a maximally specific hypothesis, version spaces and the candidate elimination algorithm, remarks on version spaces and candidate elimination, inductive bias; Regression: Linear, Non-linear Regression, PCA, SVMs; Decision Tree Learning – Introduction, decision tree representation, appropriate problems for decision tree learning, the basic decision tree learning algorithm, hypothesis space search in decision tree learning, inductive bias in decision tree learning, issues in decision tree learning. | | |
| **Unit - 2** | **Deep Learning** | **12 Hours** |
| Artificial Neural Networks-1– Introduction, neural network representation, appropriate problems for neural network learning, perceptions, multilayer networks and the back-propagation algorithm. Artificial Neural Networks-2- Remarks on the Back-Propagation algorithm, An illustrative example: face recognition, advanced topics in artificial neural networks. Evaluation Hypotheses – Motivation, estimation hypothesis accuracy, basics of sampling theory, a general approach for deriving confidence intervals, difference in error of two hypotheses, comparing learning algorithms. | | |
| **Unit - 3** | **Bayesian learning** | **10 Hours** |
| Introduction, Bayes theorem, Bayes theorem and concept learning, Maximum Likelihood and least squared error hypotheses, maximum likelihood hypotheses for predicting probabilities, minimum description length principle, Bayes optimal classifier, Gibs algorithm, Naïve Bayes classifier, an example: learning to classify text, Bayesian belief networks, the EM algorithm. Computational learning theory – Introduction, probably learning an approximately correct hypothesis, sample complexity for finite hypothesis space, sample complexity for infinite hypothesis spaces, the mistake bound model of learning. Instance-Based Learning- Introduction, k-nearest neighbour algorithm, locally weighted regression, radial basis functions, case-based reasoning, remarks on lazy and eager learning. | | |
| **Unit - 4** | **Genetic Algorithms and Reinforcement Learning** | **12 Hours** |
| Genetic Algorithms – Motivation, Genetic algorithms, an illustrative example, hypothesis space search, genetic programming, models of evolution and learning, parallelizing genetic algorithms.<br>Learning Sets of Rules – Introduction, sequential covering algorithms, learning rule sets: summary,<br>learning First-Order rules, learning sets of First-Order rules: FOIL, Induction as inverted deduction, inverting resolution.<br>Reinforcement Learning – Introduction, the learning task, Q–learning, non-deterministic, rewards and actions, temporal difference learning, generalizing from examples, relationship to dynamic programming. | | |
| **Unit - 5** | **Analytical Learning** | **10 Hours** |

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| Analytical Learning-1- Introduction, learning with perfect domain theories: PROLOG-EBG, remarks on explanation-based learning, explanation-based learning of search control knowledge. Analytical Learning-2- Using prior knowledge to alter the search objective, using prior knowledge to augment search operators. Combining Inductive and Analytical Learning-Motivation, inductive-analytical approaches to learning, using prior knowledge to initialize the hypothesis |
| **Texts / References Books** |
| **Text Books** |
| Machine Learning by Tom M. Mitchell, McGraw Hill Education, $1^{st}$ Ed., 2017.<br>Machine Learning: A Probabilistic Perspective by Kevin P. Murphy, MIT Press, 2012.<br>Machine Learning: An Algorithmic Perspective by Stephen Marsland, CRC Press, 2009.<br>Deep Learning by Aaron Courville, Ian Goodfellow, Yoshua Bengio, MIT Press, 2016. |
| **References Books** |
| Introduction to Machine Learning with Python: A Guide for Data Scientists by Andreas C. Muller, O'Reilly, 2016.<br>Python Machine Learning by Sebastian Raschka, Packt Publishing, 2015.<br>The Elements of Statistical Learning: Data Mining, Inference, and Prediction by Hastie, Tibshirani, Friedman, $2^{nd}$ Ed., Springer, 2017.<br>Introduction to Machine Learning by Ethem Alpaydin, $2^{nd}$ Revised edition, MIT Press, 2010.<br>Python Machine Learning Case Studies by Danish Haroon, Apress, 2017. |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Introduction to Machine Learning by Prof. S. Sarkar, IIT Kharagpur |

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|---|---|---|---|---|
| Course Code | **AMMSCD524** | | | |
| Name of the Course | **Data Structures and Algorithms** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **0** | **0** | **3** |
| Offered in (Spring / Autumn) | **Spring** | | | |

**Course Objectives:**

The course aims to explore basic data structures such as stacks and queues and introduce a variety of data structures such as hash tables, search trees, tries, heaps, graphs and powerful algorithms such as sorting and pattern matching.

**Course Outcomes:**

Develop the skill set to

compute and analyze the algorithms for efficiency using Asymptotic Notations.

develop knowledge of basic data structures such as arrays, linked lists, binary trees, heaps, and hash tables for storage and retrieval of ordered orunordered data.

solve problems by applying suitable data structures with the algorithms for the creation, insertion, deletion, searching, and sorting of each data structure.

define graphs and illustrate graph traversals

design and develop projects requiring the implementation of the data structures.

**Course Contents**

| | | |
|---|---|---|
| **Unit - 1** | **Linear Data Structures** | **10 Hours** |

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|---|---|---|
| Introduction to Data Structures – Fundamental Elements – Asymptotic Notations: Big-Oh, Omega and Theta – Best, Worst and Average case Analysis: Definition and an example -Arrays and its representations – Stacks and Queues – Linked lists - Singly Linked List - Doubly linked list - Linked list-based implementation of Stacks and Queues – Evaluation of Expressions. | | |
| **Unit - 2** | **Non-Linear Data Structures** | **14 Hours** |
| **Trees:** Introduction to Trees – Basic concepts - Binary Trees – Binary tree representations (Array and list) and Traversals Techniques (Preorder, Inorder, Postorder) – Succinct Data Structures: Overview – Level order representation of Binary Trees – Rank and Select – Subtrees. **Graphs**: Definitions, Terminologies, Matrix and Adjacency List Representation of Graphs, Elementary Graph operations, Traversal methods: Breadth First Search and Depth First Search. Data Structures for Graphs, Graph traversals-DFS and BFS, Applications of Graphs-Minimum cost spanning tree using Kruskal's algorithm, Dijkstra's algorithm for Single Source Shortest Path Problem | | |
| **Unit - 3** | **Search Tree Structures and Priority Queues** | **10 Hours** |
| Binary Search Trees – AVL Trees – Splay Trees - Fusion Data Structures: Sketching- Approximating the sketch - Parallel comparison – Desk etching – Application of Fusion Tree Structures - Priority Queues – Heaps implementations – Binary Heap. | | |
| **Unit - 4** | **Sorting And searching** | **10 Hours** |
| **Sorting Algorithms:** Basic concepts - Bubble Sort - Insertion Sort - Selection Sort - Quick Sort – Shell sort-Heap Sort - Merge Sort - External Sorting. **Searching:** Linear Search, Binary Search. | | |
| **Unit - 5** | **Indexing And Disjoint Sets** | **10 Hours** |
| **Indexing:** Hashing - Hash Functions – Separate Chaining – Open Addressing: Linear Probing- Quadratic Probing- Double Hashing- Rehashing – Extendible Hashing. **Disjoint Sets:** Basic data structure - Smart Union Algorithms - Path Compression. | | |
| **Texts / References Books** | | |
| **Text Books:** | | |
| Fundamentals of Data Structures in C by Ellis Horowitz, S. Sahni, and Susan Anderson Freed, Universities Press, 2nd Ed., 2015.<br>Data Structures using C by A. S. Tanenbaum, Y. Langsam, and M.J. Augenstein, PHI/Pearson Education, 2008.<br>Introduction to Algorithms by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein, MIT Press, 3rd Ed., 2009.<br>Algorithms Unlocked by Thomas H. Cormen, MIT Press, 2013. | | |
| **Reference Books:** | | |
| Data Structures using C by Y. Langsam, M. J. Augenstein and A. M. Tanenbaum, , Pearson Education Asia, 2004.<br>Data Structures: A Pseudocode Approach with C by R. F. Gilberg and B.A. Forouzan, Course Technology Inc., 2nd Ed., 2004.<br>The Algorithm Design Manual by Steven S. Skiena, Springer, 2nd Ed., 2008.<br>Algorithms: Part I by Sedgewick Robert, Wayne Kevin, Addison-Wesley Professional, 4th Ed., 2011.<br>***An Introduction to the Analysis of Algorithms by*** Robert Sedgewick and Philippe Flajolet, Addison-Wesley Professional, 2nd Ed., 2013. | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| https://courses.csail.mit.edu/6.851/spring12/scribe/lec12.pdf (Fusion Data Structures)<br>https://nptel.ac.in/courses/106102064/<br>https://www.udemy.com/algorithm/ | | |

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|---|---|---|---|---|---|
| Course Code | **CSMSCD530** | | | | |
| Name of the Course | **Big Data Analysis & Algorithms** | | | | |
| Core / Elective | **Core** | | | | |
| Credits | L | T | P | C | |
| | **3** | **1** | **0** | **4** | |
| Offered in (Spring / Autumn) | **Spring** | | | | |

**Course Objectives:**

The purpose of the course is to introduce principles of computer organization and the basic architectural concepts. It begins with basic organization, design, and programming of a simple digital computer and introduces simple register transfer language to specify various computer operations. Topics include computer arithmetic, instruction set design, microprogrammed control unit, pipelining and vector processing, memory organization and I/O systems, and multiprocessors

**Course Outcomes:**

Through this course, the student will be able to

understand the basics of instructions sets and their impact on processor design.

demonstrate an understanding of the design of the functional units of a digital computer system.

evaluate cost performance and design trade-offs in designing and constructing a computer processor including memory.

design a pipeline for consistent execution of instructions with minimum hazards.

recognize and manipulate representations of numbers stored in digital computers

**Course Contents**

| **Unit - 1** | **Introduction to Big Data Analysis** | **08 Hours** |
|---|---|---|

Evolution of data, data streams, structured & unstructured data, database models, graph data, normalizations, Introduction to Big Data Platform – Challenges of Conventional Systems - Intelligent data analysis – Nature of Data - Analytic Processes and Tools - Analysis vs Reporting

| **Unit - 2** | **Big Data Analytics Platforms** | **10 Hours** |
|---|---|---|

Architectures, Frameworks that enable big data analytics Mining data streams: Introduction to Streams Concepts – Stream Data Model and Architecture - Stream Computing - Sampling Data in a Stream – Filtering Streams – Counting Distinct Elements in a Stream – Estimating Moments – Counting Oneness in a Window – Decaying Window - Real time Analytics Platform (RTAP) Applications - Case Studies - Real Time Sentiment Analysis- Stock Market Predictions.

| **Unit - 3** | **Big Data Analytics Storage & Processing** | **10 Hours** |
|---|---|---|

Data Preprocessing, Multi-Dimensional Data Models, Data Warehousing OLTPS, OLAPS, Data Warehouse Architectures, Datacube Computations, Big Data Mining Frequent Patterns, Big Data Associations & Correlations, Classifications & Predictions, Clustering Techniques & Analysis, Mining Data Streams, Graph Mining Mining Spatial & Temporal Objects, Predictive Analysis, Ad Hoc Queries, Web Analytics

| **Unit - 4** | **Algorithms for Massive Data Sets** | **10 Hours** |
|---|---|---|

Algorithms for SISD, SIMD environments, Linked Big Data Analysis – Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications, Large-Scale Machine Learning, Big Data Analytics on Specific Processors, Hardware and Cluster Platforms for Big Data Analytics, Big Data Next Challenges – IoT, Cognition, and Beyond

| **Unit - 5** | **Big Data Analytics Tools** | **10 Hours** |
|---|---|---|

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|---|---|---|
| **HADOOP RELATED TOOLS:** History of Hadoop- the Hadoop Distributed File System – Components of Hadoop Analysing the Data with Hadoop- Scaling Out- Hadoop Streaming- Design of HDFS-Java interfaces to HDFS Basics- Developing a Map Reduce Application-How Map Reduce Works-Anatomy of a Map Reduce Job Run-Failures-Job Scheduling-Shuffle and Sort – Task execution - Map Reduce Types and Formats- Map Reduce Features Hadoop environment | | |
| **Unit - 6** | **Frameworks** | **06 Hours** |
| Applications on Big Data Using Pig and Hive – Data processing operators in Pig – Hive services – HiveQL – Querying Data in Hive - fundamentals of HBase and ZooKeeper - IBM InfoSphere BigInsights and Streams. Predictive Analytics- Simple linear regression- Multiple linear regression- Interpretation 5 of regression coefficients. Visualizations - Visual data analysis techniques- interaction techniques - Systems and applications. | | |
| **Texts / References Books** | | |
| **Text Books:** | | |
| Big Data Fundamentals: Concepts, Drivers & Techniques by Thomas Erl, Wajid Khattak, Paul Buhler, Prentice Hall, 2016.<br>Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006<br>Introduction to Algorithms by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein, MIT Press, 3$^{rd}$ Ed., 2009.<br>Big Data and Analytics by Seema Acharya, Subhashini Chellappan, Wiley, 2$^{nd}$ Ed., 2019. | | |
| **Reference Books:** | | |
| Understanding Big Data: Analytics for Enterprise Class Hadoop and Streaming Data (McGraw-Hill Education, 2011) by Paul Zikopoulos and Chris Eaton<br>Mining of Massive Datasets by Jure Leskovec, Anand Rajaraman, Jeffrey David Ullman, Dreamtech Press, 2$^{nd}$ Ed., 2016.<br>Big Data Analytics: Methods and Applications by Saumyadipta Pyne, B.L.S. Prakasa Rao, S.B. Rao, Springer, 1$^{st}$ Ed., 2016.<br>Big Data, Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Businesses by Michele Chambers, Michael Minelli, Ambiga Dhiraj, Wiley, 2013.<br>Machine Learning for Big Data: Hands-On for Developers and Technical Professionals by Jason Bell, Wiley, 2014. | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| Article on Why Big Data is the New Competitive Advantage<br>NPTEL Lecture on Algorithms for Big Data by Prof. John Augustine, IIT Madras | | |

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|---|---|---|---|---|
| Course Code | **AMMSCD525** | | | |
| Name of the Course | **Data Structures and Algorithms with C / Python lab** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **0** | **0** | **4** | **2** |
| Offered in (Spring / Autumn) | **Spring** | | | |
| **Course Objectives:**<br>To understand the difference between different data types, learn the basic concepts and usage of variables, expressions and practice the use of functions in Python programming language, identify and practice different conditional statements and implement recursive functions, to understand the concepts of strings, lists and dictionaries, practice the use of classes methods, overloading and polymorphism and implement line properties, | | | | |

use different setter methods and practice different kinds of plots.

**Course Outcomes:**

Develop the skill set to

able to develop programs in Python and implement functions using parameters.

understand the concept of expressions and cnstruct programs using while statement.

list the operations that can be performed on strings and identify the differences between lists and dictionaries.

list the concepts of operator overloading and polymorphism and understand various forms of distribution.

able to implement plots, charts and visualize data.

**Course Contents**

**Topic (Sample Problems)**

Write Python / C programs that use both recursive and non-recursive functions for implementing the following searching methods: a) Linear search b) Binary search

Write Python / C program to implement the following using arrays (Lists) and linked lists (a) List ADT

Write Python / C programs to implement the following using an array (List). (a)Stack ADT (b) Queue ADT

Write a Python /C program that reads an infix expression and converts the expression to postfix form. (use stack ADT).

Write a Python / C program to implement circular queue ADT .

Write a Python /C program that uses both a stack and a queue to test whether the given string is a palindrome or not.

Write Python /C programs to implement the following using a singly linked list. (a)Stack ADT (b) Queue ADT

Write Python / C programs to implement the deque (double ended queue) ADT using Doubly linked list.

Write a Python / C program to implement priority queue ADT.

. Write a Python /C program to perform the following operations: (a) Construct a binary search tree of elements. (b) Search for a key element in the above binary search tree. (c) Delete an element from the above binary search tree.

. Write a Python / C program to implement all the functions of a dictionary (ADT) using Hashing.

. Write a Python / C to implement Dijkstra's algorithm for Single source shortest path problem.

. Write Python programs that use recursive and non-recursive functions to traverse the given binary tree in (a) Preorder (b) Inorder (c) Postorder.

. Write Python / C programs for the implementation of bfs and dfs for a given graph.

. Write Python / C programs for implementing the following sorting methods: (a) Bubble sort (b)Insertion sort (c)Quick sort (d) Merge sort (g) Binary tree sort (e) Heap sort

. Write a Python/ C program that implements Kruskal's algorithm to generate minimum cost spanning tree.

. Write a Python /C program that implements KMP algorithm for pattern matching.

. Write a Python / C Program that reads lines of text from a file and makes frequency count of words. It should then display words followed by their frequency count.

**Texts / References Books**

**Text Books:**

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|---|
| Data structures and Algorithms using Python by Rance D. Necaise, Wiley, 2011.<br>Introduction to Programming in Python, Robert Sedgewick, Kevin Wayne and Robert Dondero, Pearson Education India, 1st Ed., 2016.<br>Python Programming: A Modular Approach by Sheetal Taneja and Naveen Kumar, Pearson India, 1st Ed., 2017.<br>Exploring Python by Timothy A. Budd, Tata McGraw-Hill Edition, 2011. |
| **Reference Books:** |
| Think Python by Allen Downey O'Reilly Publications, 2nd Edition, 2016.<br>Python Programming: Using Problem Solving Approach by Reema Thareja, Oxford University Press, 1st Edition, 2017.<br>Introduction to Programming using Python by Y. Daniel Liang Pearson, Pearson Education, 2017.<br>Programming Python - by Mark Lutz, O'Reilly Publications, 4th Edition, 2011.<br>Python in a nutshell - by Alex Martelli, Anna Ravenscroft, Steve Holden, O'Reilly Publications, 3rd Edition, 2017. |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Data Structure And Algorithms by Prof. Naveen Garg, IIT Delhi<br>NPTEL Lecture on Programming, Data Structures and Algorithms using Python by Prof. Madhavan Mukund, IIT Madras |

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|---|---|---|---|---|
| Course Code | **AMMSCD526** | | | |
| Name of the Course | **Machine Learning and Deep Learning Lab** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **0** | **0** | **4** | **2** |
| Offered in (Spring / Autumn) | **Spring** | | | |

**Course Objectives:**

To understand the concept of Sequential Deep Neural Network and its learning process, how to improve Deep Neural Networks: Hyperparameter Tuning, Regularization and Optimization, and to build and train neural network architectures such as Convolutional Neural Networks. It also focuses on implementation of Recurrent Neural Networks, LSTMs, Transformers and other machine learning algorithms.

**Course Outcomes:**

At the end of this course, students will

understand the fundamental concepts of machine learning and deep learning, including supervised learning, unsupervised learning, neural networks, and deep neural networks.

develop a strong foundation in mathematical concepts and statistical methods that underpin machine learning and deep learning algorithms.

evaluate and compare the performance of different machine learning models using appropriate evaluation metrics and validation techniques.

explore advanced topics in machine learning and deep learning, such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), and generative models.

gain practical experience in implementing machine learning and deep learning algorithms through programming assignments and projects.

**Course Contents**

**Topic (Sample Problems)**

Creating a Data Frame in Pandas from csv files.
Importing Data with Pandas – adding columns to the data frame.
Handling Missing Data- drop, fill, aggregate functions.
Indexing Data Frames with Pandas, Indexing Using Labels in Pandas.
Exploratory Data Analysis with Pandas- for both one dimensional and two-dimensional data (series or data frames) - describe, group data, ANOVA, correlation and correlation methods, rank.
Calculating Mean, Trimmed Mean, Weighted Mean, Median,
Plotting using pandas- Exploratory analysis based on the plots.
Data Visualization with different charts in python.
Apply PCA function. Find Eigen Values and EigenVectors.
Working with JSON Data with python.
Use OpenCV to find a face in an image.
A weather prediction model that predicts if there'll be rain or not in a particular daywith decision tree regression concept.
A Python script to create a confusion matrix on a predicted model.
Consider a dataset where we have a value of response y for every features.
Find a line which fits best and predict the response for any new feature values using simple linear regression.
Find the errors using Least Squares technique to fine tune the model.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| X | 1 | 4 | 3 | 6 | 8 | 9 | 2 | 2 |
| Y | 2 | 4 | 3 | 1 | 3 | 6 | 5 | 0 |

Consider a dataset with p features (or independent variables) and one response (ordependent variable). Also the dataset contains n rows/observations.
Find the regression line using multiple linear regression.
Find the residual error of $i^{th}$ observation.
A researcher has collected data on three psychological variables, four academic variables (standardized test scores), and the type of educational program the student is in for 600 high school students. She is interested in how the set of psychological variables is relatedto the academic variables and the type of program the student is in using Multivariate Regression.
Demonstrate to find the values of the parameters of a function that minimizes the cost function using Stochastic Gradient Descent.
A python program to explore your data with matplotlib and PCA, preprocess your data with normalization. Split the data into training and test sets. construct an unsupervised model ( K-means algorithm) to fit the model to the data, predict values, and validate the model that is built.
Multidimensional data analysis in Python- import, Clustering, Exploratory DataAnalysis.
Demonstrate to perform support vector classifier on a non linear dataset using alinear kernel.

Introduction to Tensorflow
install Tensorflow
understand Tensorflow library.
Check if the following libraries are installed
scipy • numpy • matplotlib • pandas • statsmodels • scikit-learn
Compute the function using Tensorflow library. $f(x, y) = x^2 + y^2 + 2x + y$. Find Expected Results, Check Tensorflow was installed correctly, Evaluate a function using Tensorflow, View the Tensor graph.

| | |
|---|---|
| . Implementation of AND gate using Tensorflow<br>. Deep Neural Network: implement a deep neural network using Tensorflow and Keras. •train the DNN with image 2D or 3D dataset.<br>. Deep Neural Network with Regularization. Implement a deep neural network using Tensorflow and Keras.<br>train the DNN with image 2D or 3D dataset.• add regularization<br>. Deep Neural Network with Dropout<br>implement a deep neural network using Tensorflow and Keras.<br>• train the DNN with different dataset.. • add dropout neurons.<br>. Deep Neural Network with Early stopping<br>implement a deep neural network using TensorFlow and Keras.<br>• train the DNN with image 2D or 3D dataset.<br>• implement early stopping<br>. Build convolutional neural network model (CNN) (Basic model) forimage and other 2Dor 3D data<br>. Evaluate the model using five-fold cross-validation and Develop an Improved Model<br>. Develop a model for Text classification with an RNN | |
| **Texts / References Books** | |
| **Text Books:** | |
| 1. Python Machine Learning by Sebastian Raschka and Vahid Mirialili, Packt publishing, 2nd Edition, 2017.<br>2. Introduction to Machine Learning with Python by Andreas C. Müller and Sarah Guido, ORielly,1st Edition, 2016.<br>3. Machine Learning in Python by Michael Bowles, Wiley Publishers, 2018.<br>4. Python Machine Learning Case Studies by Danish Haroon, Apress, 2017 | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | |
| NPTEL Lecture on Deep Learning by Prof. P.K. Biswas, IIT Kharagpur | |

**THIRD SEMESTER**

| | | | | |
|---|---|---|---|---|
| Course Code | **AMMSCD531** | | | |
| Name of the Course | **Regression Analysis and Predictive Modelling** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**

This course aims to develop an understanding of regression analysis and model building, to provide the ability to develop relationship between variables, to introduce the investigating tools for possible diagnostics in regression techniques and to formulate feasible solution using regression model for real-life problems.

**Course Outcomes:**

Develop the skill set to

develop in-depth understanding of the linear and nonlinear regression model.

demonstrate the knowledge of regression modeling and model selection techniques.

examine the relationships between dependent and independent variables.

estimate the parameters and fit a model and validate the model using hypothesis testing and confidence interval approach.

| | | |
|---|---|---|
| understand the generalizations of the linear model to binary and count data. | | |
| **Course Contents** | | |
| **Unit 1** | **Simple Regression Analysis** | **10 Hours** |
| Introduction to Linear and Nonlinear Model, Ordinary Least Square Method, Simple Linear Regression Model, using Simple Regression to Describe a Linear Relationship, Fitting a Linear Trend to Time Series Data, Validating Simple Regression Model using t, F and p-Test, Developing Confidence Interval. Precautions in Interpreting Regression Result | | |
| **Unit 2** | **Multiple Regression Analysis** | **10 Hours** |
| Concept of Multiple Regression Model to Describe a Linear Relationship, Assessing the Fit of the Regression Line, Inferences from Multiple Regression Analysis, Problem of Overfitting of a Model, Comparing Two Regression Model, Prediction with Multiple Regression Equation, Penalized Likelihood Regression | | |
| **Unit 3** | **Fitting Curves and Model Adequacy Checking** | **10 Hours** |
| Introduction, Fitting Curvilinear Relationship, Residual Analysis, PRESS Statistics, Detection and Treatment of Outliers, Lack of Fit of the Regression Model, Test of Lack of Fit, Problem of Autocorrelation and Heteroscedasticity. Estimation of Pure Errors from Near Neighbors. | | |
| **Unit 4** | **Transformation techniques and Multicollinearity** | **12 Hours** |
| Introduction, Variance Stabilizing Transformations, Transformations to Linearize The Model, Box-Cox Methods, Transformations on The Repressor's Variables, Generalized and Weighted Least Squares, Some Practical Applications; Multicollinerity: Sources of Multicollinearity, Effects of Multicollinearity. Multicollinearity Diagnostics: Examination of Correlation Matrix, Variance Inflation Factors (VIF), Eigen System Analysis of $X^1$ X. Methods of Dealing with Multicollinearity: Collecting Additional Data, Model Re-Specification, and Ridge Regression | | |
| **Unit 5** | **Generalized Linear Models** | **06 Hours** |
| Generalized Linear Model: Link Functions and Linear Predictors, Parameter Estimation and Inference in the GLM, Prediction and Estimation with the GLM, Residual Analysis, and Concept of Over Dispersion, Generalised Additive Models. | | |
| **Unit 6** | **Model building and Nonlinear Regression** | **06 Hours** |
| Variable Selection with LASSO and Elastic Net, Model Building, Model Misspecification. Model Validation Techniques: Analysis af Model Coefficients, and Predicted Values, Data Splitting Method. Nonlinear Regression Model, Nonlinear Least Squares, Spline Regression, Transformation to Linear Model, Parameter Estimation in Nonlinear System, Statistical Inference in Nonlinear Regression, Gaussian Process Regression, Gaussian Process Optimization | | |
| **Texts / References Books** | | |
| **Text Books:** | | |
| Introduction to Statistical Learning with applications in R by Gareth James, Daniela Witten , Trevor Hastie, Robert Tibshirani., Springer, 2013.<br>Regression and Other Stories by Andrew Gelman, Jennifer Hill, Aki Vehtari, Cambridge University Press, 2020.<br>Introduction to Linear Regression Analysis by Douglas C. Montgomery, Elizabeth A. Peck, G. Geoffrey Vining, Wiley India Pvt. Ltd., 3$^{rd}$ Ed., 2016.<br>Applied Regression Analysis by Norman R. Draper, Harry Smith, WILEY India Pvt. Ltd. New Delhi, 3$^{rd}$ Ed., | | |

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| 2015.<br>Gaussian Process for Machine Learning by Carl Edward Rasmussen, Christopher K. I. Williams, MIT Press 2005. |
| **References Books** |
| Applied Multivariate Statistical Analysis by Johnson, R A., Wichern, D. W., PHI learning Pvt., Ltd., 6th Ed., 2013.<br>Applied Regression Modelling by Iain Pardoe, John Wiley and Sons, Inc, 2012.<br>Applied Linear Regression Models by Michael H. Kutner, Chris Nachtsheim, John Neter, McGraw, 2004.<br>Regression Analysis by Example by Samprit Chatterjee, Ali S. Hadi, Wiley, 5th Ed., 2013.<br>The Elements of Statistical Learning: Data Mining, Inference, and Prediciton by Trevor Hastie, Robert Tibshirani, Jerome Friedman, Springer, 2nd Ed., 2009. |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Predicitve Analytics: Regression and Classification by Prof. Sourish Das, IIT Madras |

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|---|---|---|---|---|
| Course Code | **CSMSCD540** | | | |
| Name of the Course | **Artificial Intelligence** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**

The course focuses on learning the distinction between optimal reasoning Vs. human like reasoning and understand the concepts of state space representation, exhaustive search, heuristic search together with the time and space complexities. This course also aims to impart different knowledge of representation techniques and get acquainted with various applications of AI, namely game playing, theorem proving and machine learning.

**Course Outcomes:**

After the completion of this course, the student will be able to

formulate an efficient problem space for a problem expressed in natural language.

select a search algorithm for a problem and estimate its time and space complexities.

apply AI techniques to solve problems of game playing, theorem proving, and machine learning.

comprehend the applications of Probabilistic Reasoning and Bayesian Networks and analyze Supervised Learning Vs. Learning Decision Trees

understand the concepts of state space representation, exhaustive search, heuristic search together with the time and space complexities

**Course Contents**

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|---|---|---|
| **Unit – 1** | **Introduction to AI** | **06 Hours** |
| Introduction to AI - Intelligent Agents, Problem-Solving Agents, Searching for Solutions - Breadth-first search, Depth-first search, Hill-climbing search, Simulated annealing search, Local Search in Continuous Spaces. | | |
| **Unit – 2** | **Games & Logic** | **08 Hours** |
| Optimal Decisions in Games, Alpha–Beta Pruning, Defining Constraint Satisfaction Problems, Constraint Propagation, Backtracking Search for CSPs, Knowledge-Based Agents, Logic- Propositional Logic, Propositional Theorem Proving: Inference and proofs, Proof by resolution, Horn clauses and definite clauses. | | |
| **Unit – 3** | **Knowledge Representation** | **10 Hours** |

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|---|---|---|
| Syntax and Semantics of First-Order Logic, Using First Order Logic, Knowledge Engineering in First-Order Logic. Inference in First-Order Logic: Propositional vs. First-Order Inference, Unification, Forward Chaining, Backward Chaining, Resolution. Knowledge Representation: Introduction to Game Playing- using First order logic- Knowledge Engineering in First Order Logic-Proportional vs First Order Logic-Resolution-Structured representation of Knowledge Using Scripts and Frames. Alpha Beta Pruning Ontological Engineering, Categories and Objects, Events. | | |
| **Unit – 4** | **Production System & Planning** | **10 Hours** |
| Introduction to Production system-control strategies-Rete Algorithm-Planning-STRIPS-Planning with state space search-Partial Order Planning, Definition of Classical Planning, Algorithms for Planning with State Space Search, Planning Graphs, other Classical Planning Approaches, Analysis of Planning approaches. Hierarchical Planning- Planning & acting in the real world | | |
| **Unit – 5** | **Expert System** | **10 Hours** |
| Expert System- Architecture and Roles of Expert System-Typical Expert System-MYCIN-XOON-DART-Case Study-Construction of simple reflex agent with sensor and actuator using Arduino | | |
| **Unit – 6** | **Probabilistic Reasoning** | **10 Hours** |
| Acting under Uncertainty, Basic Probability Notation Bayes' Rule and Its Use, Probabilistic Reasoning, Representing Knowledge in an Uncertain Domain, The Semantics of Bayesian Networks, Efficient Representation of Conditional Distributions, Approximate Inference in Bayesian Networks, Relational and First- Order Probability | | |
| **Texts / References Books** | | |
| **Text Books:** | | |
| Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Norvig, Pearson Education/ Prentice Hall of India, 3rd Ed., 2015.<br>Artificial Intelligence by E. Rich and K. Knight, 3rd Ed., McGraw Hill, 2009.<br>Essentials of Artificial Intelligence by M. Ginsberg, Elsevier Science, 2012. | | |
| **Reference Books:** | | |
| Foundations of Artificial Intelligence and Expert Systems by Janakiraman, K. Sarukesi, Macmillan Series in Computer Science, 2005.<br>Expert Systems: Principles and Programming by Joseph C. Giarratano, Gary D. Riley, Course Technology Inc.,4th Edition, 2015.<br>Artificial Intelligence with Python by Prateek Joshi, Packt Publishing, 2017.<br>Introduction to Artificial Intelligence and Expert Systems by W. Patterson, Prentice Hall of India, 2003.<br>Artificial Intelligence: A New Synthesis by Nils J. Nilsson, Harcourt Asia Pvt. Ltd., 2000. | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| NPTEL Lecture on Artificial Intellience by Prof. P. Dasgupta, IIT Kharagpur<br>NPTEL Lecture on An Introduction to Artificial Intelligence by Prof. Mausam, IIT Delhi | | |

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|---|---|---|---|---|
| Course Code | **AMMSCD532** | | | |
| Name of the Course | **Multivariate Data Analysis** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |
| **Course Objectives:** | | | | |

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|---|---|---|
| To understand the fundamental concepts of Multivariate Data Analysis / Multivariate Statistical Analysis, become conversant with various methods and techniques used in summarization and analysis of multivariate data, to prepare for investigation of multivariate data and examine the possible diagnostics in multivariate methods, to formulate real time problem in a form of multivariate model, to Develop feasible solution of real-life problems, using multivariate methods and techniques and to conduct research using multivariate data analysis techniques. | | |
| **Course Outcomes:**<br>At the end of the course students will be able to:<br>develop an in-depth understanding of the Multivariate models, methods and techniques.<br>demonstrate the knowledge and skill of multivariate normal distributions, related probability distributions and their applications.<br>examine the relationships between dependent and independent variables of multivariate models, estimate the parameters and fit a model.<br>investigate the events of clustering and multidimensional scaling presence in sample data.<br>conduct the application of Structural Equation Modeling (SEM) to real-time observations. | | |
| **Course Contents** | | |
| **Unit 1** | **Introduction to Multivariate Data Analysis** | **10 Hours** |
| Multivariate data and their diagrammatic representation. Exploratory multivariate data analysis, sample mean vector, sample dispersion matrix, sample correlation matrix, graphical representation, means, variances, co-variances, correlations of linear transforms, six step approach to multivariate model building. Introduction to multivariate linear regression, logistic regression, principal component analysis, factor analysis, cluster analysis, canonical analysis and canonical variables, structured equation modeling (SEM). | | |
| **Unit 2** | **Multivariate Normal Distribution (MND)** | **10 Hours** |
| Introduction to multivariate normal distribution, probability density function and moment generating function of multivariate normal distribution, singular and nonsingular normal distributions, distribution of linear and quadratic form of normal variables, marginal and conditional distributions. Random sampling from multivariate normal distributions. Goodness of fit of multivariate normal distribution. Wishart matrix-its distribution and properties. | | |
| **Unit 3** | **Multivariate Linear Model and Analysis of Variance and Covariance** | **10 Hours** |
| Maximum likelihood estimation of parameters, tests of linear hypothesis, distribution of partial and multiple correlation coefficients and regression coefficients. Multivariate linear regression, multivariate analysis of variance of one- and two-way classification data (only LR test). Multivariate analysis of covariance. Hoteling $T^2$ and Mahalanobis $D^2$ applications in testing and confidence set construction. | | |
| **Unit 4** | **Multiple Discriminant Analysis and Logistic Regression** | **12 Hours** |
| Multiple Discriminant Analysis: a two-group discriminant analysis, a three-group discriminant analysis, the decision process of discriminant analysis (objective, research design, assumptions, estimation of the model, assessing overall fit of a model, interpretation of the results, validation of the results).<br>Logistic Regression model and analysis: regression with a binary dependent variable, representation of the binary dependent variable, estimating the logistic regression model, assessing the goodness of fit of the estimation model, testing for significance of the coefficients, interpreting the coefficients. | | |
| **Unit 5** | **Principal Components and common Factor Analysis** | **05 Hours** |
| Population and sample principal components, their uses and applications, large sample inferences, graphical representation of principal components, Biplots, the orthogonal factor model, dimension reduction, estimation of factor loading and factor scores, interpretation of factor analysis. | | |
| **Unit 6** | **Cluster Analysis, Scaling and Structural Equation Modelling (SEM)** | **07 Hours** |

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| Concepts of cluster analysis and multidimensional scaling, similarity measures, hierarchical clustering methods, Ward's hierarchical clustering method's, nonhierarchical clustering methods, K-means methods. Clustering based on statistical models, multidimensional scaling and correspondence analysis, perceptual mapping; Concept of structural equation modeling, Confirmatory factor analysis, canonical correlation analysis, conjoint analysis. |
| **Texts / References Books** |
| **Text Books:** |
| Applied Multivariate Statistical Analysis by Hardly W.K. and Simor L., 4th Edition, Springer-Verlag, 2015.<br>Applied Multivariate Statistical Analysis by Richard A. Johnson and Dean W. Wichern, Prentice Hall India, 7th Edition, 2019.<br>An Introduction to Multivariate Statistical Analysis by Anderson T.W., Wiley, 3rd Edition, 2009.<br>Multivariate Analysis by Kshirsagar, A. M., Marcel Dekkar, 2006. |
| **References Books** |
| Applied Multivariate Statistical Analysis by Johnson, R A., Wichern, D. W., PHI learning Pvt., Ltd., 6th Ed., 2013.<br>Multivariate Statistics and Probability by Rao, C. R. and Rao, M. M., Elsevier & Academic Press, 2014.<br>Multivariate Analysis and its Applications by Bhuyan, K. C., New Central book Agency Pvt. Ltd., 2005.<br>Applied Linear Regression by Weisberg S., 4th Edition, Wiley, 2013.<br>Advanced Multivariate Statistical Analysis with Matrices by Kollo T., and Rosen D. Von, Springer, New York, 2005. |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Multivariate Data Analysis by Dr. Sharmishtha Mitra, Dr. Amit Mitra, IIT Kanpur |

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|---|---|---|---|---|
| Course Code | **AMMSCD533** | | | |
| Name of the Course | **Digital Image Processing** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

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| **Course Objectives:**<br>The course aims to provide a solid foundation in understanding how digital images are represented and stored in computer systems including concepts such as pixel values, color models, and spatial and frequency domains. |
| **Course Outcome:**<br>Develop the skill set to<br>enhance digital images by improving their visual quality.<br>understand and apply methods such as histogram equalization, contrast stretching, noise reduction, and sharpening<br>explore various image compression techniques to reduce the storage space and transmission bandwidth required for images.<br>learn about various linear and non-linear filters to modify images, such as blurring, sharpening, and edge detection filters<br>exposed to real-world applications of digital image processing in fields like medical imaging, remote sensing, computer vision, and multimedia |
| **Course Contents** |

| Unit – 1 | Intrduction to Digital Image Processing | 12 Hours |
|---|---|---|
| Digital Image Processing: Introduction - The Origins of Digital Image Processing - Examples of Fields that Use Digital Image Processing - Fundamental Steps in Digital Image Processing - Components of an Image Processing System - Digital Image Fundamentals: Elements of Visual Perception - Light and the Electromagnetic Spectrum. Image Sensing and Acquisition - Image Sampling and Quantization - Some Basic Relationships Between Pixels - An Introduction to the Mathematical Tools Used in Digital Image Processing. | | |
| **Unit – 2** | **Fourier Transforms** | **12 Hours** |
| Filtering in the Frequency Domain: Background - Preliminary Concepts - Sampling and the Fourier Transform of Sampled Functions - The Discrete Fourier Transform of One Variable - Extensions to Functions of Two Variables - Some Properties of the 2-D DFT and IDFT - The Basics of Filtering in the Frequency Domain - Image Smoothing Using Lowpass Frequency Domain Filters - Image Sharpening Using High Pass Filters - Selective Filtering - The Fast Fourier Transform. | | |
| **Unit – 3** | **Image Restoration** | **12 Hours** |
| Image Restoration and Reconstruction: Noise Models - Restoration in the Presence of Noise Only Spatial Filtering - Periodic Noise Reduction Using Frequency Domain Filtering - Linear, Position-Invariant Degradations - Estimating the Degradation Function - Inverse Filtering - Minimum Mean Square Error (Wiener) Filtering - Constrained Least Squares Filtering - Geometric Mean Filter. | | |
| **Unit – 4** | **Image Transformation** | **12Hours** |
| Wavelet and Other Image Transforms: Matrix-based Transforms – Correlation - Basis Functions in the Time-Frequency Plane - Basis Images - Fourier-Related Transforms - Walsh-Hadamard Transforms - Slant Transform - Haar Transform - Wavelet Transforms. | | |
| **Unit – 5** | **Analysis with Color Images** | **06 Hours** |
| Color Image Processing: Color Fundamentals - Color Models - Pseudo color Image Processing - Basics of Full-Color Image Processing - Color Transformations - Color Image Smoothing and Sharpening - Using Color in Image Segmentation - Noise in Color Images -Color Image Compression. | | |
| **Text / Reference Books** | | |
| **Text Books** | | |
| Digital Image Processing by Rafael Gonzalez, Richard E. Woods, PHI/Pearson Education, 4th Ed., 2018.<br>Wavelet Analysis with Applications to Image Processing by L.Prasad, S.S.Iyengar, CRC Press, 2015.<br>Fundamentals of Image Processing by A. K. Jain, PHI, 2nd Ed., 2015.<br>Digital Image Processing: Principles and Applications by Gregory A. Baxes, Wiley, 1994. | | |
| **References Books** | | |
| Digital Image Sequence Processing, Compression, and Analysis by Todd R.Reed, CRC Press, 2015.<br>Digital Image Processing and Analysis: Human and Computer Vision Applications with Cviptools by Scott E. Umbaugh, CRC Press, 2nd Ed., 2011.<br>Digital Image Processing: An Algorithmic Introduction Using Java by Wilhelm Burger, Mark J. Burge, Springer Science & Business Media, 2012.<br>Digital Image Processing: PIKS Scientific Inside by William K. Pratt, Wiley, 4th Ed., 2007. | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| NPTEL Lecture on Digital Image Processing by Dr. G. Harit, IIT Kharagpur | | |

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| Course Code | **AMMSCD534** |
| Name of the Course | **Reinforcement Learning** |
| Core / Elective | **Core** |

| Credits | L | T | P | C |
|---|---|---|---|---|
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**

The aim of the course will be to familiarize the students with the basic concepts as well as with the state-of-the-art research literature in deep reinforcement learning.

**Course Outcome:**

Develop the skill set to

structure a reinforcement learning problem

understand and apply basic RL algorithms for simple sequential decision-making problems in uncertain conditions

evaluate the performance of the solution

interpret state-of-the-art RL research and communicate their results

gain understanding of exploration-exploitation trade-off in reinforcement learning and understand different strategies to balance exploration and exploitation, such as epsilon-greedy, upper confidence bounds (UCB), and Thompson sampling.

**Course Contents**

| Unit | Title | Hours |
|---|---|---|
| **Unit – 1** | **Introduction to Reinforcement Learning** | **12 Hours** |

Introduction-Reinforcement Learning-Reinforcement Learning as MDP-Learnable Functions in Reinforcement Learning-Deep Reinforcement Learning Algorithms-Policy-based Algorithms-Value-based Algorithms-Model-based Algorithms-Combined Methods-On-policy and Off-policy Algorithms- Deep Learning for Reinforcement Learning- Reinforcement Learning and Supervised Learning-Lack of an Oracle-Sparsity of Feedback

| Unit | Title | Hours |
|---|---|---|
| **Unit – 2** | **Bandit Algorithms** | **12 Hours** |

The Reinforcement Learning problem: evaluative feedback, nonassociative learning, Rewards and returns, Markov Decision Processes, Value functions, optimality and approximation. Bandit Problems: Explore-exploit dilemma, Binary Bandits, learning automata, exploration schemes Dynamic programming: value iteration, policy iteration, asynchronous DP, generalized policy iteration

| Unit | Title | Hours |
|---|---|---|
| **Unit – 3** | **Monte-Carlo Methods** | **12 Hours** |

Monte-Carlo methods: policy evaluation, roll outs, on policy and off policy learning, importance sampling Temporal Difference learning: TD prediction, Optimality of TD (0), SARSA, Q-learning, R-learning, Games and after states. Eligibility traces: n-step TD prediction, TD (lambda), forward and backward views, Q(lambda), SARSA (lambda), replacing traces and accumulating traces

| Unit | Title | Hours |
|---|---|---|
| **Unit – 4** | **Gradient Analysis** | **12 Hours** |

Function Approximation: Value prediction, gradient descent methods, linear function approximation, Control algorithms, Fitted Iterative Methods Policy Gradient methods: non-associative learning - REINFORCE algorithm, exact gradient methods, estimating gradients, approximate policy gradient algorithms, actor-critic methods

| Unit | Title | Hours |
|---|---|---|
| **Unit – 5** | **Different Framework under Reinforcement Learning** | **06 Hours** |

Hierarchical RL: MAXQ framework, Options framework, HAM framework, Option discovery algorithms Case studies: Elevator dispatching, Samuel's checker player, TDgammon, Acrobot, Helicopter piloting, Computational Neuroscience

**Text / Reference Books**

**Text Books:**

Reinforcement Learning - An Introduction by R. S. Sutton and A. G. Barto., MIT Press. 1998.

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| Foundations of Deep Reinforcement Learning Theory and Practice in Python by Laura Graesser, Wah Loon Keng, , Addison-Wesley Professional, 2019.<br>Reinforcement Learning and Optimal Control by Dimitri Bertsekas, Athena Scientific, 2019. |
| **References Books:** |
| Algorithms for Reinforcement learning by Csaba Szepesvari.. Morgan & Claypool Publishers.<br>Reinforcement Learning: State-of-the-Art by Marco Wiering and Martijn van Otterlo, Eds.. Sprinkler.<br>Artificial Intelligence: A Modern Approach by Stuart J. Russell and Peter Norvig.. Pearson.<br>Deep Learning by Ian Goodfellow, Yoshua Bengio,and Aaron Courville.. MIT Press. |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Reinforcement Learning by Dr. B. Ravindran, IIT Madras |

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|---|---|---|---|---|
| Course Code | **AMMSCD535** | | | |
| Name of the Course | **Data Mining Techniques** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

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|---|---|---|
| **Course Objectives:**<br>To preprocess and analyze data, to choose relevant models and algorithms for respective applications and to develop research interest towards advances in data mining. To understand the concepts of data mining, issues and applications. To preprocess and analyze data, to select appropriate models and algorithms for respective applications and to develop research interest towards advances in data mining. To learn various data mining techniques like classification, clustering, association rulemining. | | |
| **Course Outcome:**<br>Develop the skill set to<br>understand different types of data to be mined and categorize the scenario for applying different data mining techniques<br>evaluate different models used for classification and Clustering and focus towards research and innovation<br>understand the fundamental concepts of data mining and preprocessing, and further analyze and evaluate the performance of Association Rule Mining algorithms.<br>understand the classification concepts and the working principles of different algorithms<br>apply the clustering techniques to carry out simple data mining tasks and analyze their performance | | |
| **Course Contents** | | |
| **Unit 1** | **Introduction And Data Preprocessing** | **12 Hours** |
| Data Mining – Kinds of data to be mined-Kinds of patterns to be mined-Technologies-Targeted Applications-Major Issues in Data Mining-Data Objects and Attribute Types-Measuring Data similarity and dissimilarity-Data Cleaning-Data Integration-Data Reduction-Data Transformation – Data Discretization. | | |
| **Unit 2** | **Mining Frequent Patterns and Advanced Pattern Mining** | **13 Hours** |
| Basic Concepts – Frequent Itemset Mining Methods – Pattern Evaluation Methods – Pattern Mining in Multilevel, Multidimensional space – Constraint-Based Frequent Pattern Mining – Mining Compressed or Approximate Patterns – Pattern Exploration and Application. | | |
| **Unit 3** | **Classification Techniques:** | **13 Hours** |
| Basic Concepts–Decision Tree Induction– Bayes Classification Methods – Rule-Based Classification– Model Evaluation and Selection-Techniques to Improve Classification Accuracy – Bayesian Belief Networks – | | |

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|---|---|---|
| Classification by Backpropagation – Support Vector Machines. | | |
| **Unit 4** | **Clustering Techniques:** | **04 Hours** |
| Cluster Analysis-Partitioning Methods-Hierarchical Methods-Density-Based Methods | | |
| **Unit 5** | **Outlier Detection and Applications** | **06 Hours** |
| Outliers and Outlier Analysis-Clustering-Based Approach – Classification-Based Approach-Mining Complex Data Types-Data Mining Applications. | | |
| **Unit 6** | **Data Mining Trends and Research Frontiers** | **06 Hours** |
| Mining Complex Data Types - Other Methodologies - Data Mining Applications - Data Miningand Society – Data Mining Trends | | |
| **Text / Reference Books** | | |
| **Text Books:** | | |
| Data Mining Concept and Techniques by Jiawei Han, Micheline Kamber and Jian Pie, Morgan and Kaufmann Publisher, Third Edition, 2012.<br>Data Mining Techniques by Arun K Pujari, Second Edition, Universities Press India Pvt. Ltd. 2010. | | |
| **References Books:** | | |
| Data Mining and Predictive Analytics by Daniel T. Larose and Chantal D. Larose, Wiley Series on Methods and Applications in Data Mining, Wiley Publications, 2nd Ed., 2015.<br>Data Mining: Practical Machine Learning Tools and Techniques by Ian H. Witten, Eibe Frank and Mark A. Hall, Morgan and Kaufmann Publisher, 3rd Ed., 2014. | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| NPTEL Lecture on Data Mining by Prof. Pabitra Mitra, IIT Kharagpur | | |

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|---|---|---|---|---|---|
| Course Code | **AMMSCD536** | | | | |
| Name of the Course | **Mathematical Cryptography** | | | | |
| Core / Elective | **Core** | | | | |
| Credits | L | T | P | C | |
| | **3** | **1** | **0** | **4** | |
| Offered in (Spring / Autumn) | **Autumn** | | | | |
| **Course Objectives:**<br>The course aims to give elementary ideas from number theory which will have applications in cryptology. Identify and apply various properties of and relating to the integers including the Well-Ordering Principle, primes, unique factorization, the division algorithm, understand the concept of a congruence. To impart the knowledge of encryption and decryption techniques and their applications in managing the security of data | | | | | |
| **Course Outcomes:**<br>Ability to identify and investigate vulnerabilities and security threats and the mechanisms to counter them.<br>Solve problems in elementary number theory.<br>Apply elementary number theory to cryptography.<br>Develop a deeper conceptual understanding of the theoretical basis of number theory and identify how number theory is related to and used in cryptography.<br>Ability to analyze security of cryptographic algorithm against various attacks. . | | | | | |
| **Course Contents** | | | | | |
| **Unit 1** | **Introduction to modern Cryptography** | | | | **12 Hours** |

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|---|---|---|
| Preliminaries, Defining Security in Cryptography Monoalphabetic Ciphers: Using Direct Standard Alphabets, The Caesar Cipher, Modular arithmetic, Direct Standard alphabets, Solution of direct standard alphabets by completing the plain component, solving direct standard alphabets by frequency considerations, Alphabets based on decimations of the normal sequence, Solution of decimated standard alphabets, Monoalphabets based on linear transformation. Polyalphabetic Substitution: Polyalphabetic ciphers, Recognition of polyalphabetic ciphers, Determination of number of alphabets, Solution of individual alphabets if standard, Polyalphabetic ciphers with a mixed plain sequence, Matching alphabets, Reduction of a polyalphabetic cipher to a monoalphabetic ciphers with mixed cipher sequences | | |
| **Unit 2** | **Number Theory: Divisibility** | **08 Hours** |
| Representations of Integers, Computer Operations with Integers, Complexity of Integer Operations, Divisibility, Prime Numbers, The Fundamental Theorem of Arithmetic, Sieve of Eratosthenes, The Distribution of Primes, Greatest Common Divisor, Euclidean Algorithm, Mersenne Numbers, Fermat Numbers, Perfect numbers | | |
| **Unit 3** | **Number Theory: Congruence** | **08 Hours** |
| Congruences, Congruence Applications, Linear Congruences, The Chinese Remainder Theorem, Theorems of Fermat and Euler- Fermat, Wilson's Theorem, Pseudo Primes, Carmichael Numbers, The Euler Phi-Function, The Sum and Number of Divisors, Quadratic Residue, Quadratic Reciprocity. Legendre and Jacobi Symbols, Computing Legendre symbols, Primitive Roots, Quadratic Reciprocity Law, | | |
| **Unit 4** | **Inter Factorization and Primality Testing Algorithms** | **06 Hours** |
| Complexity of Number Theoretic Algorithms, Fermat's Factorization, Kraitchik's Improvement, Trial division, Pollard Rho Algorithm, p-1 method, CFRAC method, quadratic sieve method, elliptic curve method. **Primality testing algorithms:** Fermat test, Miller-Rabin test, Solovay-Strassen test, AKS test. | | |
| **Unit 5** | **Computing discrete logarithms over finite fields:** | **06 Hours** |
| Baby-step-giant-step method, Pollard rho method, Pohlig-Hellman method, index calculus methods, linear sieve method, Coppersmith's algorithm. | | |
| **Unit 6** | **Representation of finite fields** | **08 Hours** |
| Groups, Fields, Finite Fields, Arithmetic in Finite Field, Finding Multiplicative Inverses in finite fields, Prime and extension fields, representation of extension fields, polynomial basis, primitive elements, normal basis, optimal normal basis, irreducible polynomials. Binary Fields and their application in Cryptosystems | | |
| **Unit 7** | **Elliptic Curve Cryptography** | **08 Hours** |
| Introduction to Elliptic Curves, the elliptic curve group, elliptic curves over finite fields, Schoof's point counting algorithm, Discrete Log problem for Elliptic curves, Factorization using Elliptic Curve, Advantage of Elliptic Curve Cryptography over other Public Key Cryptosystems. | | |
| **Text / References Books** | | |
| **Text Books:** | | |
| J. Katz and Y. Lindell, Introduction to Modern Cryptography, 2nd Edition, Chapman & Hall/CRC, 2008<br>Abhijit Das, Computational number theory, Chapman and Hall/CRC., 2018<br>N. Koblitz, A Course in Number Theory and Cryptography, Springer 2006.<br>I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to theory of numbers, John Wiley & Sons, Inc 2006.<br>L. C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.<br>J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.<br>. D. Hankerson, A. Menezes and S. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag, 2004.<br>. J. Pipher, J. Hoffstein and J. H. Silverman, An Introduction to Mathematical Cryptography, Springer-Verlag, 2008.<br>. G.A. Jones and J.M. Jones, Elementary Number Theory, Springer-Verlag, 1998. | | |

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| . R.A. Mollin, An Introduction to Cryptography, Chapman & Hall, 2001.<br>. Song Y. Yan: Number Theory for Computing, Springer-Verlag, Second Edition,2002.<br>. T. H. Cormen, C. E. Leiserson, and R. L. Rivest: Introduction to Algorithms, $2^{nd}$ Edition, PHI, 1994.<br>. K. Rosen: Elementary Theory of Numbers, Fifth Edition, Addison Wesley, 2004.<br>. D. M. Bressoud: Factorization and Primality Testing, Springer-Verlag, 1989. |
| **Reference Books:** |
| V. Shoup, A computational introduction to number theory and algebra, Cambridge University Press<br>M. Mignotte, Mathematics for computer algebra, Springer-Verlag.<br>I. Niven, H. S. Zuckerman and H. L. Montgomery, An introduction to the theory of numbers, John Wiley<br>J. von zur Gathen and J. Gerhard, Modern computer algebra, Cambridge University Press.<br>R. Lidl and H. Niederreiter, Introduction to finite fields and their applications, Cambridge University Press.<br>A. J. Menezes, Applications of finite fields, Kluwer Academic Publishers<br>J. H. Silverman and J. Tate, Rational points on elliptic curves, Springer International Edition.<br>D. R. Hankerson, A. J. Menezes and S. A. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag<br>A. Das and C. E. Veni Madhavan, Public-key cryptography: Theory and practice, Pearson Education Asia<br>. H. Cohen, A course in computational algebraic number theory, Springer-Verlag |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Foundations of Cryptography by Prof. Ashish Choudhury, IIIT Bangalore<br>NPTEL Lecture on Cryptography and Network Security, Dr. Debdeep Mukhopadhyay, IIT Kharagpur |

| Course Code | **CSMSCD541** | | | |
|---|---|---|---|---|
| Name of the Course | **Natural Language Processing (NLP)** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**

To understand algorithms for the processing of linguistic information and computational properties of natural languages, conceive basic knowledge on various morphological, syntactic and semantic NLP tasks, familiarize various NLP software libraries and data sets publicly available, to develop systems for various NLP problems with moderate complexity and to learn steps for creating Machine Learning models.

**Course Outcome:**

Develop the skill set to

Describe the concepts of morphology, syntax, semantics, discourse & pragmatics of natural language.

Demonstrate understanding of the relationship between NLP and statistics & machine learning.

Discover various linguistic and statistical features relevant to the basic NLP task, namely, spelling correction, morphological analysis, parts-of-speech tagging and syntactic parsing.

Demonstrate the concept of semantic analysis and word sense disambiguation.

Understand the components of machine translation process and develop the model for NLP applications.

**Course Contents**

| **Unit – 1** | **Introduction** | **14 Hours** |
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Introduction - NLP tasks in syntax, semantics, and pragmatics. Applications such as information extraction, question answering, and machine translation. The problem of ambiguity. The role of machine learning. Brief

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|---|---|---|
| history of the field - N-gram Language Models - The role of language models. Simple N- gram models. Estimating parameters and smoothing. Evaluating language models. | | |
| **Unit – 2** | **Basic NLP Techniques** | **14 Hours** |
| Part Of Speech Tagging and Sequence Labeling - Lexical syntax. Hidden Markov Models (Forward and Viterbi algorithms and EM training) - Basic Neural Networks. Any basic introduction to perceptron and backpropagation | | |
| **Unit – 3** | **Parsing** | **14 Hours** |
| LSTM Recurrent Neural Networks -Syntactic parsing - Grammar formalisms and treebanks. Efficient parsing for context-free grammars (CFGs). Statistical parsing and probabilistic CFGs (PCFGs). Lexicalized PCFGs. Neural shift-reduce dependency parsing. | | |
| **Unit – 4** | **Semantic Analysis** | **05 Hours** |
| Lexical semantics and word-sense disambiguation. Compositional semantics. Semantic Role Labelling and Semantic Parsing. | | |
| **Unit – 5** | **Machine Translation** | **07 Hours** |
| Information Extraction (IE) - Named entity recognition and relation extraction. IE using sequence labelling. - Machine Translation (MT) Basic issues in MT. Statistical translation, word alignment, phrase-based translation, and synchronous grammars. | | |
| **Text / References Books** | | |
| **Text Books:** | | |
| Speech and Language Processing by Jurafsky Dan and Martin James H., 3rd Ed., 2018. | | |
| **References Books:** | | |
| Practical Natural Language Processing by Sowmya Vajjala, Bodhisattwa Majumder, Anuj Gupta, Harshit Surana, 2020.<br>Natural Language Processing with Python by Steven Bird, Ewan Klein, Edward Loper., 2009. | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| NPTEL Lecture on Natural Language Processing by Prof. Pushpak Bhattacharyya, IIT Baombay | | |

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|---|---|---|---|---|
| Course Code | **CSMSCD542** | | | |
| Name of the Course | **Pattern Recognition** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |
| **Course Objectives:**<br>This course introduces fundamental concepts, theories, and algorithms for pattern recognition and machine learning. Topics include: Pattern Representation, Nearest Neighbor Based Classifier, Bayes Classifier, Hidden Markov Models, Decision Trees, Support Vector Machines, Clustering, and an application of hand-written digit recognition | | | | |
| **Course Outcomes:**<br>Develop the skill set to<br>understand the theory, benefits, inadequacies and possible applications of various machine learning and pattern recognition algorithms.<br>extract informative features from data and select the most relevant features for pattern recognition tasks.<br>apply statistical methods for pattern recognition, including probability theory, Bayesian decision theory, | | | | |

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|---|---|---|
| maximum likelihood estimation, and Bayesian estimation to Pattern Recognition tasks.<br>learn techniques for extracting informative features from data and selecting the most relevant features for pattern recognition tasks.<br>identify and employ suitable machine learning techniques in classification, pattern recognition, clustering and decision problems. | | |
| **Course Contents** | | |
| **Unit - 1** | **Introduction** | **12 Hours** |
| What is Pattern Recognition, Data Sets for Pattern Recognition, Different Paradigms for Pattern Recognition. Representation: Data Structures for Pattern Representation, Representation of Clusters, Proximity Measures, Size of Patterns, Abstractions of the Data Set, Feature Extraction, Feature Selection, Evaluation of Classifier, Evaluation of Clustering. | | |
| **Unit - 2** | **Nearest Neighbor Based Classifier** | **12 Hours** |
| Nearest Neighbor Algorithm, Variants of the NN Algorithm use of the Nearest Neighbor Algorithm for Transaction Databases, Efficient Algorithms, Data Reduction, Prototype Selection. Bayes Classifier: Bayes Theorem, Minimum Error Rate Classifier, Estimation of Probabilities, Comparison with the NNC, Naïve Bayes Classifier, Bayesian Belief Network. | | |
| **Unit - 3** | **Hidden Markov Models** | **12 Hours** |
| Markov Models for Classification, Hidden Morkov Models, Classification using HMMs. Decision Trees: Introduction, Decision Tree for Pattern Classification, Construction of Decision Trees, splitting at the Nodes, Overfitting and Pruning, Examples of Decision Tree Induction. | | |
| **Unit - 4** | **Support Vector Machines** | **10 Hours** |
| Introduction, Learning the Linear Discriminant Functions, Neural Networks, SVM for Classification. Combination of Classifiers: Introduction, Methods for Constructing Ensembles of Classifiers, Methods for Combining Classifiers. | | |
| **Unit - 5** | **Clustering** | **08 Hours** |
| Why is Clustering Important, Hierarchical Algorithms, Partitional Clustering, Clustering Large Data Sets. An Application-Hand Written Digit Recognition: Description of the Digit Data, Preprocessing of Data, Classification Algorithms, Selection of Representative Patterns, Results. | | |
| **Text / References Books** | | |
| **Text Books:** | | |
| Pattern Recognition: An Algorithmic Approach by Murthy, M. Narasimha, Devi, V. Susheela, Spinger Pub, 1st Ed., 2011. | | |
| **Reference Books:** | | |
| Machine Learning by Tom M. Mitchell, Mc Graw Hill, 1997.<br>Fundamentals of Speech Recognition, Lawrence Rabiner and Biing- Hwang Juang. Prentice Hall Pub. | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| NPTEL Lecture on Pattern Recognition by Prof. P.S. Sastry, IISc Bangalore | | |

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|---|---|---|---|---|
| Course Code | **CSMSCD543** | | | |
| Name of the Course | **Cloud Computing** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

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|---|---|---|
| **Course Objectives:**<br>To understand cloud computing evolution as a very important computing model, which enables information, software, and shared resources to be provisioned over the network as services inan on-demand manner. It also provides an insight into what is cloud computing and the various services cloudis capable. | | |
| **Course Outcomes:**<br>Develop the skill set to<br>work with various cloud service providers, such as Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP) and understand the services and technologies offered by these providers, including compute, storage, networking, databases, and analytics.<br>deploy and manage applications and services in the cloud such as cloud provisioning, configuration management, monitoring, scaling, and load balancing.<br>understand security and privacy considerations in cloud computing along with security models, authentication and access control mechanisms, data protection techniques, and regulatory compliance in the cloud.<br>design and implement secure cloud architectures, cloud storage technologies and data management techniques.<br>cloud cost management strategies and techniques, resource allocation, cost models, pricing options, and optimizing cloud resource usage, cloud migration and integration. | | |
| **Course Contents** | | |
| **Unit - 1** | **Computing Paradigms** | **10 Hours** |
| High-Performance Computing, Parallel Computing., Distributed Computing., Cluster Computing., Grid Computing, Cloud Computing., Biocomputing, Mobile Computing., Quantum Computing, Optical Computing. Nano computing. | | |
| **Unit - 2** | **Cloud Computing Fundamentals** | **10 Hours** |
| Motivation for Cloud Computing, The Need for Cloud Computing, Defining Cloud Computing, Definition of Cloud computing, Cloud Computing Is a Service, Cloud Computing Is a Platform, Principles of Cloud computing, Five Essential Characteristics...Four Cloud Deployment Models | | |
| **Unit - 3** | **Cloud Computing Architecture and Management** | **10 Hours** |
| Cloud architecture, Layer, Anatomy of the Cloud, Network Connectivity in Cloud Computing, Applications, on the Cloud, Managing the Cloud, Managing the Cloud Infrastructure Managing the Cloud application, Migrating Application to Cloud, Phases of Cloud Migration Approaches for Cloud Migration | | |
| **Unit - 4** | **Cloud Service Models** | **10 Hours** |
| Infrastructure as a Service, Characteristics of IaaS. Suitability of IaaS, Pros and Cons of IaaS, Summary of IaaS Providers, Platform as a Service, Characteristics of PaaS, Suitability of PaaS, Pros and Cons of PaaS, Summary of PaaS Providers, Software as a Service, Characteristics of SaaS, Suitability of SaaS, Pros and Cons of SaaS, Summary of SaaS Providers. Other Cloud Service Models | | |
| **Unit - 5** | **Cloud Service Providers** | **14 Hours** |
| EMC, EMC IT, Captiva Cloud Toolkit, Google, Cloud Platform, Cloud Storage, Google Cloud Connect, Google Cloud Print, Google App Engine, Amazon Web Services, Amazon Elastic Compute Cloud, Amazon Simple Storage Service, Amazon Simple Queue service, Microsoft, Windows Azure, Microsoft Assessment and Planning Toolkit, SharePoint, IBM, Cloud Models, IBM Smart Cloud, SAP Labs, SAP HANA Cloud Platform, Virtualization Services Provided by SAP, Salesforce, Sales Cloud, Service Cloud: Knowledge as a Service, Rackspace, VMware, Manjrasoft, Aneka Platform | | |
| **Text / Reference Books** | | |
| **Text Books:** | | |
| Essentials of cloud Computing by K. Chandrasekhran, CRC press, 2014. | | |

| References Books: |
|---|
| Cloud Computing: Principles and Paradigms by Rajkumar Buyya, James Broberg andAndrzej M. Goscinski, Wiley, 2011.<br>Distributed and Cloud Computing by Kai Hwang, Geoffery C.Fox, Jack J.Dongarra, Elsevier,2012.<br>Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance by TimMather, Subra Kumaraswamy, Shahed Latif, O'Reilly, SPD, 2011. |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Cloud Computing by Prof. Soumya Kanti Ghosh, IIT Kharagpur |

| Course Code | **CSMSCD544** | | | |
|---|---|---|---|---|
| Name of the Course | **Computer Vision** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**

To introduce students the fundamentals of image formation; develop an appreciation for various issues in the design of computer vision and object recognition systems; and to provide the student with programming experience from implementing computer vision and object recognition applications..

**Course Outcomes:**

At the end of the course students will be able to:

Identify basic concepts, terminology, theories, models and methods in the field of computer vision

Describe known principles of human visual system

Describe basic methods of computer vision related to multi-scale representation, edge detection and detection of other primitives, stereo, motion and object recognition

Suggest a design of a computer vision system for a specific problem

**Course Contents**

| Unit | Title | Hours |
|---|---|---|
| **Unit - 1** | **Introduction** | **05 Hours** |
| Motivation, Image Representation and Image Analysis Tasks, Image Representations, a Few Concepts - Image Digitization, Sampling, Quantization, Digital Image Properties, Metric and Topological Properties of Digital Images, Histograms, Entropy, Image Quality, Noise in Images, Color Images, Color Spaces, Cameras: An Overview. | | |
| **Unit - 2** | **Overview of Mathematics** | **07 Hours** |
| Image, its Mathematical and Physical Background Overview / Linearity / The Dirac Distribution and Convolution / Linear Integral Transforms / Images as Linear Systems/ Introduction to Linear Integral Transforms / 1D Fourier Transform / 2D Fourier Transform / Sampling and the Shannon Constraint / Discrete Cosine Transform / Wavelet Transform / Eigen-Analysis / Singular Value Decomposition / Principle Component Analysis / Other Orthogonal Image Transforms / Images as Stochastic Processes / Images as Radiometric Measurements / Image Capture and Geometric Optics / Lens Aberrations and Radial Distortion / Image Capture from a Radiometric Point of View / Surface Reflectance / | | |
| **Unit - 3** | **Segmentation and Data Structures for Image Analysis** | **12 Hours** |
| Watershed Segmentation / Region Growing Post-Processing / Matching / Matching Criteria / Control strategies of Matching / Evaluation Issues in Segmentation / Supervised Evaluation / Unsupervised Evaluation/Mean Shift Segmentation / Active Contour Models - Snakes / Traditional Snakes and Balloons / Extensions / Gradient | | |

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|---|---|---|
| Vector Flow Snakes / Geometric Deformable Models - Level Sets and Geodesic Active Contours / Towards 3D Graph-Based Image Segmentation / Simultaneous Detection of Border Pairs / Sub-optimal Surface Detection / Graph Cut Segmentation / Optimal Single and Multiple Surface Segmentation, Levels of Image Data Representation / Traditional Image Data Structures / Matrices / Chains / Topological Data Structures / Relational Structures / Hierarchical Data Structures / Pyramids / Quadtrees / Other Pyramidal Structures | | |
| **Unit - 4** | **Shape Representation and Description** | **10 Hours** |
| Region Identification / Contour-Based Shape Representation and Description / Chain Codes / Simple Geometric Border Representation / Fourier Transforms of Boundaries / Boundary Description using Segment Sequences / B-Spline Representation / Other Contour-Based Shape Description Approaches / Shape Invariants / Region-Based Shape Representation and Description / Simple Scalar Region Descriptors / Moments / Convex Hull / Graph Representation Based on Region Skeleton / Region Decomposition / Region Neighborhood Graphs / Shape Classes | | |
| **Unit - 5** | **Cluster Analysis and Object Recognition** | **10 Hours** |
| Concepts of cluster analysis and multidimensional scaling, similarity measures, hierarchical clustering methods, Ward's hierarchical clustering method's, nonhierarchical clustering methods, K-means methods. Clustering based on statistical models, multidimensional scaling and correspondence analysis, perceptual mapping.<br>Knowledge Representation / Statistical Pattern Recognition / Classification Principles / Classifier Setting / Classifier Learning / Support Vector Machines / Cluster Analysis / Neural Nets / Feed-Forward Networks / Unsupervised Learning / Hopefield Neural Nets / Syntactic Pattern Recognition / Grammars and Languages / Syntactic Analysis, Syntactic Classifier / Syntactic Classifier Learning, Grammar Inference / Recognition as Graph Matching / Isomorphism of Graphs and Sub-Graphs / Similarity of Graphs / Optimization Techniques in Recognition. | | |
| **Unit - 6** | **Image Understanding** | **10 Hours** |
| Image Understanding Control Strategies / Parallel and Serial Processing Control / Hierarchical Control / Bottom-Up Control / Model-Based Control / Combined Control / Non-Hierarchical Control / RANSAC: Fitting via Random Sample Consensus / Point Distribution Models / Active Appearance Models / Pattern Recognition Methods in Image Understanding / Classification-Based Segmentation / Contextual Image Classification / Boosted Cascade of Classifiers for Rapid Object Detection / Scene Labeling and Constraint Propagation / Discrete Relaxation / Probabilistic Relaxation / Searching Interpretation Trees / Semantic Image Segmentation and Understanding / Semantic Region Growing | | |
| **Text / Reference Books** | | |
| **Text Books:** | | |
| Image Processing, Analysis, and Machine Vision by Milan Sonka, Vaclav Hlavac, Roger Boyle. 3rd Ed, Thomson Brooks/Cole Pub. | | |
| **References Books:** | | |
| Computer Vision: A Modern Approach by David A. Forsyth and Jean Ponce, Prentice Hall of India, 2006.<br>Introductory Techniques for 3-D Computer Vision by Emanuele Trucco, Alessandro Verri, Prentice Hall, 1998.<br>Computer and Robot Vision by Robert M. Haralick and Linda G. Shapiro, Addison Wesley | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| NPTEL Lecture on Computer Vision by Prof. Jayanta Mukhopadhyay, IIT Kharagpur | | |

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|---|---|---|---|---|
| Course Code | **CSMSCD545** | | | |
| Name of the Course | **Computer Forensics** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |

| | 3 | 1 | 0 | 4 |
|---|---|---|---|---|
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**

To understand the principles and concepts of computer forensics and understand the techniques used in computer forensics investigations. As computer forensics is a rapidly evolving field, this course focuses on developing the skills to stay updated with the latest technologies, tools, and trends in the industry. In addition, learn to adapt their knowledge and techniques to new challenges and emerging threats.

**Course Outcomes:**

Develop the skill set to

identify, collect, preserve, and analyze digital evidence effectively.

learn about incident response procedures and techniques, including identifying and mitigating security incidents.

do malware analysis and analyze reverse-engineer malicious software.

apply various forensic investigation techniques used in computer forensics, such as disk imaging, file recovery, data carving, network analysis, and memory analysis.

stay updated with the latest technologies, tools, and trends in the industry.

**Course Contents**

| Unit | Title | Hours |
|---|---|---|
| **Unit - 1** | **Computer Forensics Fundamentals** | **12 Hours** |

Introduction to Computer Forensics, Use of Computer Forensics in Law Enforcement, Computer Forensics Assistance to Human Resources/Employment Proceedings, Computer Forensics Services, Benefits of Professional Forensics MethodoNS2L20logy, Steps Taken by Computer Forensics Specialists, Who Can Use Computer Evidence?. Types : Types of Military Computer Forensic Technology, Types of Law Enforcement Computer Forensic Technology, Types of Business Computer Forensics Technology.

| Unit | Title | Hours |
|---|---|---|
| **Unit - 2** | **Computer Forensics Evidence and Capture: Data Recovery** | **12 Hours** |

Data Recovery Defined, Data Backup and Recovery, The Role of Backup in Data Recovery, The Data-Recovery Solution, Case Histories. Evidence Collection and Data Seizure: Why Collect Evidence?, Collection Options, Obstacles, Types of Evidence, The Rules of Evidence, Volatile Evidence, General Procedure, Collecting and Archiving, Methods of Collection, Artifacts, Collection Steps, Controlling Contamination: The Chain of Custody.

| Unit | Title | Hours |
|---|---|---|
| **Unit - 3** | **Duplication and Preservation of Digital Evidence** | **12 Hours** |

Preserving the Digital Crime Scene, Computer Evidence Processing Steps, Legal Aspects of Collecting And Preserving Computer Forensic Evidence. **Computer Image Verification and Authentication:** Special Needs of Evidential Authentication, Practical Considerations, Practical Implementation.

| Unit | Title | Hours |
|---|---|---|
| **Unit - 4** | **Computer Forensics Analysis: Discovery of Electronic Evidence** | **12 Hours** |

Electronic Document Discovery: A Powerful New Litigation Tool, Identification of Data: Timekeeping, Time Matters, Forensic Identification and Analysis of Technical Surveillance Devices. Reconstructing Past Events: How to Become a Digital Detective, Useable File Formats, Unusable File Formats, Converting Files. Networks: Network Forensics Scenario, A Technical Approach, Destruction of Email, Damaging Computer Evidence, International Principles Against Damaging of Computer Evidence, Tools Needed for Intrusion Response to the Destruction of Data, Incident Reporting and Contact Forms

| Unit | Title | Hours |
|---|---|---|
| **Unit - 5** | **Current Computer Forensics Tools** | **06 Hours** |

Evaluating Computer Forensics Tool Needs, Computer Forensics Software Tools, Computer Forensics Hardware Tools, Validating and Testing Forensics Software.

**Text / Reference Books**

| **Text Books:** |
|---|
| Computer Forensics: Computer Crime Scene Investigation by JOHN R. VACCA,Firewall Media.<br>Guide to Computer Forensics and Investigations by Nelson, Phillips Enfinger, Steuart Cengage Learning<br>Computer Forensics by David Cowen, Mc Graw Hill. Brian Carrier<br>Forensic Discovery by Dan Farmer & Wietse Venema, Addison Wesley, 2005. |
| **References Books:** |
| Computer Forensics and Cyber Crime by Marjie T Britz, Pearson Education.<br>File System Forensic Analysis by Addison Wesley, 2005<br>Digital Evidence and Computer Crime by Eoghan Casey, Academic Press, 3rd Ed., 2011<br>Chris Pogue, Cory Altheide, Todd Haverkos, Unix and Linux Forensic Analysis DVD ToolKit, Syngress Inc., 2008<br>Eoghan Casey, Handbook of Digital Forensics and Investigation, Academic Press, 2009 |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** |
| NPTEL Lecture on Information Security and Forensics by Special Series, IIT Madras |

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|---|---|---|---|---|
| Course Code | **CSMSCD546** | | | |
| Name of the Course | **IoT Analytics** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |

**Course Objectives:**

To understand IoT analytics, challenges, and connectivity protocols, IoT cloud and integration of Big Data techniques and services. It focuses on inculcating knowledge on creating cloud analytics environment, visualizing IoT Data and getting familiar with IoT analytics applications.

**Course Outcome:**

Develop the skill set to

Understand the concepts and techniques of IoT Data Analytics Lifecycle and Machine Learning Application in IoT

Develop cognitive IoT solutions, leveraging artificial intelligence and data science.

Examine concepts of cloud based IoT, big data and IoT in various domains

Propose new strategies for organizations to optimize cost benefits using IoT data.

Explore end-to-end data science industry use cases using the data analytics lifecycle.

Expose the importance of Data Analytics in IoT with respect to multiple applications

**Course Contents**

| **Unit 1** | **Introduction to Internet of Things and Analytics** | **10 hours** |
|---|---|---|
| Introduction to Internet of Things (IoT): Concepts and Definition of IoT – IoT Devices - IoT Networking Connectivity Protocols – IoT Data Messaging Protocols – MQTT, CoAP. IoT Analytics: Data vs big data-Challenges of IoT Analytics Applications - IoT Analytics Lifecycleand Techniques. | | |
| **Unit 2** | **IoT Cloud and Big Data Integration** | **10 hours** |
| IoT Cloud and Big Data Integration: Cloud based IoT platform – Data Analytics for IoT – DataCollection – WAZIUP software Platform – Ikaas Software Platform - Elastic analytics concepts<br>– designing for scale – Cloud security and analytics – AWS overview - AWS key services forIoT analytics. | | |
| **Unit 3** | **Strategies and Techniques in Data Collection** | **10 hours** |

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|---|---|---|
| Strategies and Techniques in Data collection: Designing Data Processing for Analytics – Applying Big Data to Storage – Apache Spark for IoT Data Processing - Solving Industry Specific Problems. | | |
| **Unit 4** | **Geospatial Analytics to IoT Data** | **10 hours** |
| Geospatial Analytics to IoT Data: Basics – Vector and Raster Based Methods – Processing Geospatial Data. Data Science for IoT Analytics – Machine Learning Basic – Forecasting IoT data using ARIMA – Deep learning with IoT data. | | |
| **Unit 5** | **Applications & Case Studies** | **6 hours** |
| Applications & Case Studies: Data Analysis in Smart Building – Internet of Things Analyticsfor Smart Cities – IoT Analytics: From Data Collection to Deployment and Operationalization. | | |
| **Text / Reference Books** | | |
| **Text Books:** | | |
| Analytics for the Internet of things by Andrew Minteer, Packt Publishing, 2017.<br>Building Blocks for IoT Analytics by John Soldatos, River Publishers, 2016. | | |
| **References Books:** | | |
| Internet of Things: Principles and Paradigms by Rajkumar Buyya, Amir Vahid Dastjerdi, , Elsevier, 2016.<br>Essentials of Cloud computing by R. Chandrasekaran, $2^{nd}$ Edition, Chapman and Hall/CRC, 2015.<br>Hands on Artificial intelligence for IoT by Amita Kapoor, $1^{st}$ Edition, Packt Publishing, 2019. | | |
| **Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]** | | |
| NPTEL Lecture on Introduction to Internet of Things by Prof. Sudip Misra, IIT Kharagpur | | |

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|---|---|---|---|---|
| Course Code | **CSMSCD547** | | | |
| Name of the Course | **Distributed Databases** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |
| **Course Objectives:**<br>To Introduce various Distributed Database Applications in real world scenario, learn more about various Distributed Database Techniques and apply efficient Advanced Techniques to solve engineering problems | | | | |
| **Course Outcome:**<br>Develop the skill set to<br>Be able to Compare various Distributed Databases methods<br>Be able to understand and identify the analytical characteristics of Distributed Databases algorithms.<br>Employ algorithm to model engineering problems, when appropriate. | | | | |
| **Course Contents** | | | | |
| **Unit - 1** | | | | **08 Hours** |
| Features of Distributed versus Centralized Databases, Principles of Distributed Databases, Levels of Distribution Transparency, Reference Architecture for Distributed Databases, Types of Data Fragmentation, Integrity Constraints in Distributed Databases, Distributed Database Design | | | | |
| **Unit - 2** | | | | **08 Hours** |
| Translation of Global Queries to Fragment Queries, Equivalence transformations for Queries, Transforming Global Queries into Fragment Queries, Distributed Grouping and Aggregate Function Evaluation, Parametric Queries. Optimization of Access Strategies, A Framework for Query Optimization, Join Queries, General | | | | |

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| Queries | | |
| **Unit - 3** | | **11 Hours** |
| The Management of Distributed Transactions, A Framework for Transaction Management, Supporting Atomicity of Distributed Transactions, Concurrency Control for Distributed Transactions, Architectural Aspects of Distributed Transactions Concurrency Control, Foundation of Distributed Concurrency Control, Distributed Deadlocks, and Concurrency Control based on Timestamps, Optimistic Methods for Distributed Concurrency Control. | | |
| **Unit - 4** | | **11Hours** |
| Reliability, Basic Concepts, Nonblocking Commitment Protocols, Reliability and concurrency Control, Determining a Consistent View of the Network, Detection and Resolution of Inconsistency, Checkpoints and Cold Restart, Distributed Database Administration, Catalog Management in Distributed Databases, Authorization and Protection | | |
| **Unit - 5** | | **16 Hours** |
| Architectural Issues, Alternative Client/Server Architectures, Cache Consistency, Object Management, Object Identifier Management, Pointer Swizzling, Object Migration, Distributed Object Storage, Object Query Processing, Object Query Processor Architectures, Query Processing Issues, Query Execution, Transaction Management, Transaction Management in Object DBMSs, Transactions as Objects Database Integration, Scheme Translation, Scheme Integration, Query Processing Query Processing Layers in Distributed Multi-DBMSs, Query Optimization Issues Transaction Management Transaction and Computation Model, Multidatabase Concurrency Control, Multidatabase Recovery, Object Orientation and Interoperability, Object Management Architecture CORBA and Database interoperability, Distributed Component Object Model, COM/OLE and Database Interoperability, PUSH-Based Technologies | | |
| **Text / Reference Books** | | |
| **Text Books:** | | |
| Distributed Databases Principles & Systems, Stefano Ceri, Giuseppe Pelagatti,TMH.<br>Principles of Distributed Database Systems, M. Tamer Ozsu, Patrick Valduriez , Pearson Education, 2nd Edition. | | |
| **References Books** | | |
| Distributed Database Systems, Chanda Ray, Pearson.<br>Distributed Database Management Systems, S. K. Rahimi and Frank. S. Haug, Wiley. | | |

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|---|---|---|---|---|
| Course Code | **TMMSCD550** | | | |
| Name of the Course | **Business Economics and Financial Analysis** | | | |
| Core / Elective | **Core** | | | |
| Credits | L | T | P | C |
| | **3** | **1** | **0** | **4** |
| Offered in (Spring / Autumn) | **Autumn** | | | |
| **Course Objectives:**<br>To learn the basic Business types, impact of the Economy on Business and Firms specifically. To analyze the Business from the Financial Perspective. | | | | |

**Course Outcome:** Develop the skill set to

The students will understand the various forms of business and the impact of economic variables on the Business. The Demand, Supply, Production, Cost, Market Structure, Pricing aspects are learnt. The students can study the firm's financial position by analysing the Financial Statements of a Company.

| Course Contents | | |
|---|---|---|
| **Unit 1** | **Introduction to Business and Economics** | **12** |
| Business: Structure of Business Firm, Theory of Firm, Types of Business Entities, Limited Liability Companies, Sources of Capital for a Company, Non-Conventional Sources of Finance. Economics: Significance of Economics, Micro and Macro Economic Concepts, Concepts and Importance of National Income, Inflation, Money Supply in inflation, Business Cycle, Features and Phases of Business Cycle. Nature and Scope of Business Economics, Role of Business Economist, Multidisciplinary nature of Business Economics. | | |
| **Unit 2** | **Demand and Supply Analysis** | **12** |
| Elasticity of Demand: Elasticity, Types of Elasticity, Law of Demand, Measurement and Significance of Elasticity of Demand, Factors affecting Elasticity of Demand, Elasticity of Demand in decision making, Demand Forecasting: Characteristics of Good Demand Forecasting, Steps in Demand Forecasting, Methods of Demand Forecasting. Supply Analysis: Determinants of Supply, Supply Function & Law of Supply. | | |
| **Unit 3** | **Production, Cost, Market Structures & Pricing** | **12** |
| Production Analysis: Factors of Production, Production Function, Production Function with one variable input, two variable inputs, Returns to Scale, Different Types of Production Functions. Cost analysis: Types of Costs, Short run and long run Cost Functions. Market Structures: Nature of Competition, Features of Perfect competition, Monopoly, Oligopoly, Monopolistic Competition. Pricing: Types of Pricing, Product Life Cycle based Pricing, Break Even Analysis, Cost Volume Profit Analysis. | | |
| **Unit 4** | **Financial Accounting** | **09** |
| Accounting concepts and Conventions, Accounting Equation, Double-Entry system of Accounting, Rules for maintaining Books of Accounts, Journal, Posting to Ledger, Preparation of Trial Balance, Elements of Financial Statements, Preparation of Final Accounts. | | |
| **Unit 5** | **Financial Analysis through Ratios** | **09** |
| Financial Analysis through Ratios: Concept of Ratio Analysis, Liquidity Ratios, Turnover Ratios, Profitability Ratios, Proprietary Ratios, Solvency, Leverage Ratios (simple problems). Introduction to Fund Flow and Cash Flow Analysis (simple problems). | | |

**Texts / References Books**

**Text Books:**

D.D. Chaturvedi, S.L. Gupta, Business Economics - Theory and Applications, International Book House Pvt. Ltd. 2013.

Dhanesh K Khatri, Financial Accounting, Tata McGraw Hill, 2011.

Geethika Ghosh, Piyali Gosh, Purba Roy Choudhury, Managerial Economics, 2e, Tata McGraw Hill Education Pvt. Ltd. 2012.

**Reference Books:**

Paresh Shah, Financial Accounting for Management 2e, Oxford Press, 2015.

S.N. Maheshwari, Sunil K Maheshwari, Sharad K Maheshwari, Financial Accounting, 5e, Vikas Publications, 2013.

# SCHOOL OF DEFENCE TECHNOLOGY
# M. Sc. DEFENCE TECHNOLOGY

### SEMESTER-I

| Sr No | COURSE CODE | COURSE | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 1 | NA501 | Armament Technology | 3 | 1 | | 4 |
| 2 | NA502 | Guided Missile and Radar Technology | 3 | 1 | | 4 |
| 3 | NA503 | Information Warfare and Cyber Security | 3 | 1 | | 4 |
| 4 | NA504 | Energitic Materials, Lasers and Fiber Optices | 3 | 1 | | 4 |
| 5 | NA505 | Electronic Warfare and Sonar Technology | 3 | | 2 | 4 |
| 6 | NA506 | Information and Communication Technology | 3 | | 2 | 4 |
| | | | | | | **24** |

### SEMESTER-II

| Sr No | COURSE CODE | COURSE | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 1 | NA507 | Statistics, Reliability and Operation Research | 3 | 1 | | 4 |
| 2 | NA508 | Acquisition Process - Revenue and Capital | 3 | 1 | | 4 |
| 3 | NA509 | Artificial Intelligence and Machine Learning | 3 | | 2 | 4 |
| 4 | NA510 | Mechanics of Mechatronics and Robotics | 3 | | 2 | 4 |
| 5 | NA511 | Advances in Marine Propulsion and Materials | 3 | | 2 | 4 |
| 6 | NA512 | Infrastructure Management of Navy | 2 | 1 | 2 | 4 |
| | | | | | | **24** |

### SEMESTER-III

| Sr No | COURSE CODE | COURSE | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 1 | NA513 | Naval Planning Process | 2 | 1 | 2 | 4 |
| 2 | NA514 | Maritime Workshop | 2 | 1 | 2 | 4 |
| 3 | NA515 | Naval Operational Logistics | 2 | 1 | 2 | 4 |
| 4 | NA516 | Sustenance Planning at Sea | 2 | 1 | 2 | 4 |
| 5 | NA517 | Naval Operations | 2 | 1 | 2 | 4 |
| 6 | NA518 | Geopolitical Studies | 2 | 1 | 2 | 4 |
| 7 | NA519 | Naval Procurement Management | 2 | 1 | 2 | 4 |
| | | | | | | **28** |

### SEMESTER-IV

| Sr No | COURSE CODE | COURSE | L | T | P | CREDIT |
|---|---|---|---|---|---|---|
| 1 | NA551 | Mini Project - International Relations | 2 | 2 | 4 | 6 |
| 2 | NA552 | Mini Project - Naval Qualitative Staff Requirements | 2 | 2 | 4 | 6 |
| 3 | NA553 | Dissertation | - | | - | 12 |
| 4 | | ***Elective-I*** | - | | - | 4 |
| | | | | | | **28** |
| | | **Total Credits** | | | | **104** |

**ELECTIVE-I**

| SER | COURSE CODE | COURSE |
|---|---|---|
| 1 | NA554 | Skill Development (Prezi, Power BI, Advance Excel, AI & Data Science) |
| 2 | NA555 | Open Elective from any Department |

**<u>Detailed Syllabus for M. Sc. Defence Technology – DSTSC (Navy)</u>**

**Course Name –** ***Armament Technology***
**Course Code –** ***NA501***

**Unit I : Explosive Technology and Polymers** - Military Explosives, Propellants, Pyrotechnics, Modern Engineering Materials, Rubbers and Elastomers, Fuels and Lubricants, Ammunition.
**Unit II: CBRN (NBC)** - CBRN threat perceptions, radiation exposure status and op exposure Guidance, Procedure for decn drills, detection and quarantine, CBRN Organisation and training set up in all three services incl their scaling, Duties of staff offrs at various levels and action / reports required to be taken / generated post CBRN attack, CBRN warning sys and CBRN message interpretation, Future and present battle field in r/o CBRN warfare, Armed forces preparedness wrt CW & BW.
**Unit III: Armament -** Armament Engineering, Fire control system, Naval Armament, Guided Naval Armaments, Naval Gun Fire Support and requirement of migration to heavy calibre guns on naval ships, Electro-Magnetic Rail Guns, Advanced Hit Efficiency and Destruction (AHEAD) Ammunition, Magneto Hydrodynamic Explosive Munitions
**Unit IV:** Underwater Weapons, Heavy Weight and Light Weight Torpedoes, Super Captivating Torpedoes, Processor Based Mines, Torpedo Defence Systems, Extended Range Anti-Submarine Rocket, Adaptive beam control optics and software algorithms to fine tune energy into focused beam, High Power Microbeam,
**Unit V: Air Armament** - Aircraft Gun ammunitions, Bombs and Fuzes, Classification and requirement of aircraft bombs, Construction, description and functioning of various bombs and fuzes & New Generation fuzes and its requirement, Principles of rocket technology, Construction features of aviation rockets, Rockets of IAF inventory and its capabilities.

**Course Name –** ***Guided Missile and Radar Technology***
**Course Code –** ***NA502***

**Unit I: Introduction to guided missiles** - Missile System, Missile Propulsion Missile Aerodynamics Missile Guidance Missile Control, Smart Munitions with flight path control for loitering capability, Scramjet technology in missile propulsion, Hypersonic Missiles, Multi-Spectral and Multi Lens Missiles Seekers, Size, weight and power (SWaP) – Constrained enhanced electronics for sensors, Guidance and Communications.
**Unit II: Radar Technology -** Basic Principle and Properties of Electro Magnetic Waves, Basic terminology of Radar, Principle of Radar, Radar Range Equation, Operating Principle of Radar Transmitter, Operating Principle of Radar Receiver.
**Unit III:** Types of Radar Antennas and their characteristics, Types of Displays and applications, Operating Principle of Pulsed Radar, Operating Principle of CW Radar, velocity measurement of Target, Operating Principle of FMCW Radar, Range measurement using FMCW radar, Operating Principle of MTI Radar, explanation of Blind speeds and Delay Line Canceler.
**Unit IV:** Operating Principle of Tracking Radar, Types of tracking, Range Gate Tracking, Operating Principle of Phased Array Radar, Types of arrays, Principles of Beam Forming and Beam Steering, Introduction to Link II System. Configuration of Link-II Mod-III**.**

**Course Name –** ***Information Warfare and Cyber Security***
**Course Code –** ***NA503***

**Unit I: Introduction of Information Warfare** - Role of Information in Warfare, EW vs IW, Information Environment, Evolution of IW, Enabling Technologies, OODA Loop (Decision Cycle).
**Unit II:** Basic Engagement Model (Edward Waltz), Spectrum of IW, Relevance of IW, Objectives of IW, Defining features of IW, Principles of IW, Components of IW, Application of IW, IW Vision, Effects of offn IW, Objectives of offn IW, Effects of Def IW, Objectives of Def IW, IW Planning Process & Key
**Unit III:** Issues, Definition, Aim, Principles of Psychology Warfare, Objectives of Psychology Warfare, Psychology Operations Roles, Category of Psychology Operations, Types of Psychology Operations, Benefits, Planning Considerations, Agencies & their Responsibilities, Audiences, Key Communicators, Classification of Audiences, Types of Audiences, Theme types, Theme Selection, Symbol, Symbol Selection. Analysis & Techniques of Counter Psychology Operations.
**Unit IV: Introduction of Cyber Security -** Cyber Security Vulnerabilities and Cyber Security Safeguards, Securing Web Application, Services and Servers, Intrusion Detection and Prevention, Cryptography and Network Security, Cyberspace and the Law, Cyber Forensics, Cyber Security for Naval Officer,
**Unit V:** Organisation of IHQ-DIW/ NCG and Commands CCOSW, Cyber Security Governance, Vulnerability Assessment Methodology, Risk Management Framework, Disaster Recovery, Business Continuity and Crisis Management Plans, Emerging Threats and Defences.

**Course Name –** ***Energetic Materials, Lasers and Fiber Optices***
**Course Code –** ***NA504***

**Unit I: Introduction of Energetic Materials, LASERS -** Concept of Coherence, Absorption, Spontaneous Emission and Stimulated Emission Processes, Population Inversion, Pumping, Gain, Optical Cavities, Main Components of Laser, Principle of LASER Action.
**Unit II:** Introduction to General LASERS and their types. Three & Four level LASERS, CW & Pulsed LASERS, Atomic, Ionic, Molecular, Excimer, Liquid and Solid-State LASERS and Systems, Short Pulse Generation and Measurement,
**Unit III: Laser** - Laser Applications in Medicine and Surgery, Materials Processing, Optical Communication, Metrology and LIDAR and Holography, LASER weapons
**Unit IV: Introduction of Fiber Optices** - Geometrical Optics Description of Step and Graded-Index Fibers, Wave Optics Description, Modes in Step-Index Fibers, Dispersion in Single-Mode Fibers: (Group-Velocity and Polarization-Mode, Dispersion-Induced Limitations, Losses, Nonlinear effect), Applications of Fiber Optics

**Course Name –** ***Electronic Warfare and Sonar Technology***
**Course Code –** ***NA505***

**Unit I: Introduction of Electronic Warfare** - Electromagnetic Environmental Effects (E3), Electromagnetic Noise, EMI Triangle, Emissions, Susceptibility, Coupling Paths, Historical Examples / Incidents related to EMI/EMC, Decibel (dB), dBm, dBi, dBc, Conducted Voltage (dBμV), Conducted Current (dBμA), Radiated Electric Field (dBμV/m), Radiated Magnetic Field (dBpT), Near & Far Fields, Power Density, Standards Bodies in the World (ITU, IEC, CISPR, CENELEC, FCC, IEEE, SAE, GOST, VCCI etc).
**Unit II:** Difference between Commercial & Military EMI/EMC Test Standards, Examples of Commercial Test Standards & Military Test Standards, MIL-STD-461, Applicability of MILI-STD-461 Tests, Typical CE, CS, RE & RS tests (test setup and method) Grounding, Bonding, Shielding, Filtering.
**Unit III:** Operational methods to contain EMI; EMC in design (of equipment and platforms); Operational

Problem Analysis & Solution, HERF, HERP, HERO, Limits of safety in standards, Test Methods, Precautions to be taken.
**Unit IV**: **Sonar Technology -** Oceanography and Underwater Acoustics, Sound Transmission in the Ocean, Propagation Characteristics, Ray, Acoustics & Shadow Zones.

**Course Name –** ***Information and Communication Technology***
**Course Code –** ***NA506***

**Unit I: Introduction of Computer Networking -** Data communication & Computer Networks – Transmission Media, Digital & Analog Transmission, Routing, Network Topologies, Various Network types like LAN, WAN, MAN, Introduction to Networking Components like HUB, Router, Switches, ISO / OSI model, Introduction to Wireless Networks. Internet and Applications like e-mail, FTP, Telnet, WWW etc.
**Unit II**: **Introduction of Basic Communication -** Elements and Brief Description of a Communication System, Modulation, RF frequency bands with Typical Applications. Propagation of Radio waves, Tropo-Scatter, SATCOM. Ground Waves, Sky Wave, Atmospheric Effects on Sky Wave Propagation
**Unit III: Introduction of Satellite Communication -** Satellite Orbits, MIMO in HF and Tropo Scatter Communications, Satellite Navigation Systems.
**Unit IV: Introduction of Computer Networking -** Data communication & Computer Networks – Transmission Media, Digital & Analog Transmission, Routing, Network Topologies, Various Network types like LAN, WAN, MAN, Introduction to Networking Components like HUB, Router, Switches, ISO / OSI model, Introduction to Wireless Networks. Internet and Applications like e-mail, FTP, Telnet, WWW etc.

**Course Name–** ***Statistics, Reliability and Operation Research***
**Course Code –** ***NA507***

**Unit I: Introduction of Reliability** – Engineering Types of Statistics (Descriptive and
Inferential Statistics), Types of Data (Primary/ Secondary, Grouped/ Ungrouped and Qualitative/ Quantitative) and Data Representation (Textual, Graphical and Tabular).
**Unit II:** Measures of Central Tendencies (Mean, Mode & Median) for Grouped and Ungrouped, Measures of Dispersions (Mean Deviation and Standard Deviation), Basic Axioms of Probability, Tree Types of Events: Dependent/ Independent, Mutually Exclusive/Not Mutually Exclusive Events.
**Unit III: Operation and Research -** Overview of OR techniques, Linear Programming (Formulation and Finding initial basic feasible solution, Optimality check of Solutions, Simplex Method, Introduction to Duality, Sensitivity & Degeneracy) and Introduction to Goal Programming.
**Unit IV:** Transportation Models (LCC & VAM), Optimization of Transportation Models and Transshipment Problem, Assignment Model & Hungarian Algorithm, Network Models, Minimum Spanning Tree Problem, Prim's Algorithm, Kruskal's Algorithm.
**Unit V:** Decision Theory, Forced Decision Matrix, Decision Matrix, Various Criteria for Decision Making.
**Course Name–** ***Acquisition Process –Revenue and Capital***
**Course Code –** ***NA508***

**Unit I: Introduction of Revenue Procurement - GFR 2017 and DFPDS 2016-**Organisation structure in MoD and Service HQ for Revenue Procurement, Schedules of Financial powers and Delegated Financial Powers Annual Revenue Procurement Plan (ARPP).
**Unit II: Integrated Logistics -** Concept of RML (Revolution in Military Logistics), Modernization of Logistics in Armed Forces, e- Logistics Initiatives in Armed Forces and its Impact, Benefits of Integrated Logistics in Armed Forces.
**Unit III:** Formulation of SOC, RFP, TEC, Commercial Bid, Analysis and conduct of CNC, Contract formulation as per DPM, e-Procurement through CPPP and GeM.

**Unit IV: Capital Procurement & DAP -** Classification/Categorization Jargon, Acquisition – Organization/Structure, Acquisition Planning Process, Initiation of project, RFI and SQRs formulation, Process flow, RFP and evaluation, OCPP, Challenges and Sum-up, Challenges in Capital Procurement along with case study.

**Course Name –** ***Artificial Intelligence and Machine Learning***
**Course Code –** ***NA509***

**Unit I: Introduction of Artificial Intelligence (AI)-** History of AI, Researchers Computer Scientists like Alan Turing, John McCarthy, Marvin Minsky and Geoffrey Hinton, Key concepts like the Turing Test Difference between AI and ML.
**Unit II:** Data as lifeblood of AI, Algorithms for finding patterns to work with data in an AI project.
**Unit III: Introduction of Machine Learning -** Traditional Statistical Techniques like Regressions, Algorithms, Overview of Advanced Algorithms such as k-Nearest Neighbor (k-NN) and the Naive Bayes Classifier, Putting together a Machine Learning Model.
**Unit IV: Deep Learning -** Neural Networks to find patterns that mimic the brain, Introduction to Algorithms like Recurrent Neural Networks (RNNs), Convolutional Neural Networks (CNNs), and Generative Adversarial Networks (GANs).

**Course Name–** ***Mechanics of Mechatronics and Robotics***
**Course Code –** ***NA510***

**Unit I: Introduction of Robotics -** Laws of Robotics, Types and Components of Robot, Robot Terminology-Link, Joints, DOF, Work Volume, Robot Geometrical Configuration (PPP, RPP, RRP, RRR, etc).
**Unit II:** Application of Ground, Underwater and Aerial Robots for Defence Sensors for Robotics, Robot Control and Programming, Artificial intelligence and Machine Learning Robot Applications, Lab/Practice Session.
**Unit III: Introduction to Mechatronics Systems**- Working Principles of Sensors and Instrumentation System Mechanisms, Actuators and Drives for Industrial Automation, Motors- DC, Induction & Synchronous with Speed Control, Fluid Power Systems-Pneumatic, Hydraulic and Electro Pneumatic Systems.
**Unit IV:** Industrial Automation-Understanding of Microprocessors, Programmable Logic Controller (PLC), Programming SCADA HMI, Applications of Industry 4.0.

**Course Name –** ***Advance in Marine Propulsion and Materials***
**Course Code –** ***NA511***

**Unit I: Introduction Marine Propulsion -** Propulsion Systems, Transmission Systems and Propellers, Service Conditions and Formulation of Staff Requirements for Propulsion Systems.
**Unit II: Resistance** - Hydrodynamic Resistance, Interaction of Hull and Propeller, Power Demand, Load and Drive Characteristics, Types & Configurations of Propulsion System packages feasible.
**Unit III:** Power Plant Concepts: Direct Drive, Geared Drive, Multiple Shaft and Combined Drives, Electrical Concepts, all Electric ship Concept and Hybrid drives. Matching criteria: Design Speed, Design and Off-Design conditions, Fuel Consumption and Emissions, Technical Evaluation of various equipment of the integrated Propulsion System, Methodology of Propulsion System Integration at Design and Implementation Stages.
**Unit IV: Marine Materials -** Marine Environmental Challenges Dictating Specifications of Marine Materials, Introduction to Corrosion and Corrosion Control Techniques used for Marine Platforms, Specific Marine Material selection at Design Stage for Marine Equipment, Marine Material trends in indigenised Ships/ Submarines and Technical/ Manufacturing Challenges, Future Trends in Marine

Materials for the Newer Platform and the Lifecycle Effects of the same, Indigenised Capabilities of R & D and Industry Partnership.

**Course Name– *Infrastructure Management of Navy***
**Course Code – *NA512***

**Unit I: Infrastructure Management of Navy -**Conceptualization / Necessarily of project, study in detail actions from Approval in Principal (AIP) to Letter of Acceptance (LoA) (NIT for EoI, Shortlisting of Consultants, Finalisation of SoW/ RFP, Pre-Bid Meeting, Opening and Evaluation of T-Bid/ Q-Bids, LoA),
**Unit II:** Study in detail actions from Letter of Acceptance (LoA) to Draft Project Report (DPR). Issue of WO, Contract Conclusion, Kick Off Meeting/ Site Meeting, Land Utilisation and Feasibility Report, Finalisation of DPR, NOC from various agencies, Environmental Clearance.
**Unit III:** Processes and formalities for Project Sanction, Execution and Completion, Life Cycle Management of Infrastructure Project.
**Unit IV:** Visit to DGNP (Mbi/ Vzg), Case Study of completed / ongoing / future ATWP Projects including guarantee/ payments / legal issues if any.

**Course Name– *Naval Planning Process***
**Course Code – *NA513***

**Unit I: Basics of Planning-** Why We Plan, Military Planning, Planning Principles, Military Planning Logic.
**Unit II: Naval Operational Planning-** The Naval Process, The Naval Component Planning, Execution Co-ordination, Planning Products, Additional Service Responsibilities.
**Unit III: Joint Operation Planning**- National Response, Military Action, Joint Operations Planning Processes, Campaign Planning, Ready to Fight Prepared through Planning.
**Unit IV: Military and Political Planning Structure**- Flexible decision making and Command, Logical Framework within Naval Staff, Evaluation of the Situation, Translation of decision into Subordinate Action.

**Course Name– *Maritime Workshop***
**Course Code – *NA514***

**Unit I: Maritime Cooperation-** Maritime Information, Maritime Piracy, Human and Drug Trafficking, Legal Aspects of Combating These Challenges.
**Unit II: Indian Ocean Region (IOR)-** World Trade and Economic Prosperity of Nations, Multi-National Activities at Sea, Collaborative Approach to Maritime Security, Security Challenges in the IOR.
**Unit III:** Maritime Domain Awareness (MDA), Maritime Manoeuvre, Maritime Strike, Indian Maritime Doctrine.
**Unit IV:** National Values, Policy and Plans, Sea Control, white Shipping Information, Indian Ocean Naval Symposium (IONS).

**Course Name– *Naval Operational Logistics***
**Course Code – *NA515***

**Unit I: Basic Element of Naval Logistics.** Nature and fundamental of Naval Logistics, Scope of Logistics, Levels of Logistics Support, Functional Area of Logistics, Process Element, Principles of Logistics.
**Enhanced Reach Logistics Sustainability-** Longer Operational Cycles, Force Mixed Ratio, Logistics Support, Extended Air Reach, Operational Turn Round Facilities (OTR), Co-operative Logistics, Through Life Support.

**Unit II: Operational Logistics-** Critical List of Spares and Equipment, Review and Refine the Maintenance Philosophy, Technical Practices and Logistics Support Structures, Quality Maintenance and Logistics Support, Effective Budget Management for Logistics support.
**Unit III: Naval Logistics Planning-** Logistics Planning Considerations, Logistics Planning Process, Crisis Action Planning, Multinational Planning.
**Unit IV: Logistics Command and Control Systems-** Naval Logistics System Organisation, Logistics Command and Control Ashore /Afloat, Logistics Information System.

**Course Name– *Sustenance Planning at Sea***
**Course Code – *NA516***

**Unit I: Exploitation Pattern of Machinery-** Engine Exploitation Factor **(**EEF), Running Hrs Base Routines, Calendar Hrs Based Routines, Periodic Health Checks, Safety Devices Checks, First Line Maintenance.
**Unit II: Planning of Maintenance Routines and Maintenance Periods-** Scheduling of Routines including Second and Third Line Support, Defect Rectification at Foreign Ports, Management of Operational Defects, Compliance to Maintenance Schedule, Forecast List (FCL) of Spares.
**Unit III: Onboard Inventory Management**- Critical List of Spares for Long Term Sustenance, Onboard Spares (OBS), Repair of Store Items, Preservation of Spares, Demand and Survey for Replenishment of Spares.
**Unit IV: Stowage and Management of POL-** International Standards (NATO and GOST) for POL, Shelf Life Considerations, Testing of POL, Introduction to NAS Standards, Handling of POL, Safety of POL, SOP for safe handling and suitable PPE against inadvertent ingestion.

**Course Name– *Naval Operations***
**Course Code – *NA517***

**Unit I: Maritime Security Strategy in Perspective-** Strategy for Shaping Favorable and Positive Maritime Environment, Strategy for Coastal and Offshore Security, Power Projection and Sea Control.
**Unit II: Maritime Security imperatives and Influences**- India’s Maritime Outlook and Geography, Neighbors and Relations, Maritime Economy. Sea Lines of Communication, Overseas Maritime Investments, Area of Maritime Interest.
**Unit III:** Maritime Threats, Traditional Threats and Sources, Non-Traditional Threats and Sources, Maritime Terrorism, Piracy and Arm Robbery at Sea, Unregulated Activities at Sea, Climate Change and Natural Disasters, Crucial Common Requirements for Maritime Security.
**Unit IV: Strategy for Deterrence and Conflict –** India’s Deterrence Strategy, Nuclear, Conventional Deterrence, Force Structure and Capabilities, Threat Assessment Contingency Planning, Strategic Situational Awareness and Maritime Domain Awareness, Strategic Communication, Preparedness and Presence, Operational Principles/ Enablers, Operational Actions, Force Projections.
**Unit V: Strategy for Maritime Force and Capability Development-** Conceptual Capability Development, Force Levels and Capability Development, Indegenisation for Self-Reliance and Self Sufficiency, Standardisation and Modularity, Maritime Domain Awareness.

**Course Name– *Geopolitical Studies***
**Course Code – *NA518***

**Unit I: Physical and Economic Components of India’s Geography-** Physical Component, Location, The Northern Belt, The Eastern Region, The Central Plains, The Deccan Plateau, The Coastal Belt, The Western Thar Desert, The Western Plains, Island Territories, Different Economic Components.
**Unit II: Human Component of India’s Geography-** Population – Size, Growth Rate and Distribution, Social Structure, Population and Social Characteristics, Religion, Language, Literacy, Cultural Environment.

**Unit III: Geographical Imperatives for India's Security-** Imperatives from Physical, Economical and Human Components of Geography.
**Unit IV: India's Military Elements as it exists Today-** Composition of India's Armed Forces, Organisation Command And Control, Recruitment and Training, Territorial Army and Para Military Forces, Weapons And Equipment- Manufacturing and Procurement Policies, Mobilisation and Deployment, Nuclear Option Factor, Missile Technology and Development, Defence Research and Development Infrastructure.
**Unit V: Relationship Between India's Geographic Element and its Military Element-** Force Projection, Use of Military Assets, Necessity for Sturdy Weapons and Equipment, regional Based Employment Philosophy, India's Role in Assisting Regional Stability.

**Course Name– *Naval Procurement Management***
**Course Code – *NA519***

**Unit I: Acquisition Management and Contract Administration-** Acquisition Planning, Market Research, Source Selection Planning, Proposal development, Tender/ Solitation Management, Source Selection Evaluation and Contract Award. Advance Contracting principles.
**Unit II: Contingency Contracting: Contracting In Battle Field-** Contract in Country for the Leasing of Vehicles, Guard Services, Interpreter Services, Trash Collection, Cooks Maintenance, Construction, Bridge and Road Repair, Humanitarian Assistance.
**Unit III: Contract Pricing and Negotiations-** Study and Application of Pricing Theory and Strategies, Cost Methods, Cost and Price Analysis, Cost Principles, Analytical Tools for Cost and Price Analysis, Negotiations Skills.
**Unit IV: Defence System Contracting-** Contracting for Major Systems, Multi-Year Procurement, Acquisition Environment and Strategy, Source Selection, Incentive Contracting, Risk Management, Post Award System Contract Administration, Government Electronic Procurement,
**Unit V: International Negotiations-** Complexities Related to Cross Cultural Negotiations, Preparations for Negotiations, Strategies and Tactics for Negotiations.

**Course Name: - *Skill Development***
***(Prezi, Power BI, Advance Excel, AI and Data Science)***
**Course Code – *NA554***

**(A) Skill Enhancement - Prezi Presentation-**
**Unit I: Introduction -** Prezi versus Power Point - An Introduction to Non-Linear Presentations.
**Unit II: Planning & Designing Prezi** - The Importance of Planning, Useful Techniques - Mind Mapping, Brain Dump, Lists, BIG Picture, Best practice when choosing imagery.
**Unit III:** Working with Basic Content, Prezi Basics, Creating your Prezi, Using the Theme wizard, Frames - Inserting and grouping with Frames, Contents - Inserting Text, Images, Shapes, Diagrams, Video, Sound, Web-Link, Re-arranging content with favorites, Arranging and Zooming elements, Understanding 3D Background.
**Unit IV:** Preparing for a Coaching Session, Collaborating with other on Prezi, Presentation options and Considerations - Portable Prezi, Desktop App, Remote option, Sharing and Publishing your Prezi.

**(B) Skill Enhancement - Power BI**
**Unit I:** Getting Started with Power Query, Starting with 99 Functions (Text, Date, Number), Appending Clean Data in Power Query.
**Unit II:** Merging data in Power Query - DON'T USE VLOOKUP, Transformation of data in Power Query without coding, Conditional Columns and Flash fill, Custom Columns.
**Unit III**: Stop to Understand the Confusing things in Power Query, Automating your daily routine task with Power Query, Exploring other visuals.

**Unit IV:** Working with Interactive Slicers in Power BI, Working with Powerful Filters in Power BI, Using objects to Enhance reports in Power BI.
**Unit V:** Introduction to Power BI Service, Creating a Dashboard in Power BI Service, Automating Reports and Dashboards, Introduction to Power Pivot.

**(C) Skill Enhancement – Advance MS Excel**
**Unit I** - Basic of Excel Sheets, Tables and Conditional formatting
**Unit II** - Getting Started with Basic Excel Functions, Working with Advanced Excel Functions
**Unit III**- Working with Data, Lookup Functions
**Unit I**V- Hyperlink, Introduction to Charts, Graphs and Maps
**Unit V**- Introduction to World of Pivot Table and Pivot Charts, Print Settings and Security

**(D) Skill Enhancement – Artificial Intelligence and Data Science**
**Unit I:** Artificial Intelligence, Natural Language Processing, Speech Recognition, Computer Vision, Artificial Neural Networks, Automatic Programming. Planning and Decision Support/ Expert Systems.
**Unit II:** Linear Algebra Linear Algebra: Scalars, Vectors, Matrices and Tensors, Matrix Multiplication, Identity and Inverse Matrices, Linear Dependence and Span, Norms, Special Kinds of Matrices and Vectors, Eigen Decomposition, Principal Component Analysis. Chain Rule, Partial Differential Equations-Applications in finding the Minima and Maxima of a function.
**Unit III:** Statistics for Data Science Types of Statistics, Correlation, Covariance, The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Sampling distributions (Chi-Square, t, F, z). Test of Hypothesis- Testing for Attributes –Mean of Normal Population – One-tailed and two-tailed tests, Analysis of variance ANOVA.
**Unit IV:** Bayesian and Perceptron Learning, Probability Bayesian learning, Maximum Likelihood Hypothesis, Naïve Bayes Classifier, Artificial Neural Networks- Perceptron's, Feed forward Neural Networks, Back Propagation. Fuzzy Logic
**Unit V: Probability Theory-** Random variables, Probability Distributions, Marginal Probability, Conditional Probability, Chain Rule of Conditional Probabilities, Expectation, Variance and Covariance, Common Probability Distributions.
**Unit VI: Image Processing-** Image Processing Fundamentals, Different Types of Images, Image Enhancement in Spatial Domain. Spatial Filtering using Convolution Filters. Histogram processing – Basics of Spatial Filtering–Smoothing and Sharpening.