COURSES OF STUDY
FOR
POST GRADUATE PROGRAMMES

(2020 – 2022)

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

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NOTE: *Robotics is a multidisciplinary specialization, M.Tech degree will be awarded as per the UG Degree of the student viz. M.Tech in EE/ME/AE etc.

Sponsored (DRDO/Tri Services/DPSUs/PSUs/Industry) only.

$ Applicable for sponsored/self sponsored candidates only.

@ Applicable for MoD sponsored candidates only.

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 2020-21

AUTUMN SEMESTER (August 2020 –Jan 2021)

Sl. No.	Activity	Dates
1	• Registration (M. Tech. / MS (by Research)/ MSc/ PGD/ Ph. D) • Re-examination for Spring semester courses • Add/Drop Courses & Finalizing Electives • Orientation Programme	**27th July – 08 August 2020**
2.	Last date of Late Registration with late fee	**15th August 2020**
3.	Sending Certified list of courses (Regular, Self study, Audit etc) registered by the students - by Jt. Reg. (ACs) to COE	**02nd Sep 2020**
4.	Classes	**29h July- 01st Dec 2020**
5.	Sending the Panel of Examiners to COE	**30th Sep 2020**
6.	Last date of submission of Examination form and Admit Card to COE by the Students.	**16th Oct 2020**
7.	End Semester Examination	**02nd Dec 2020 – 17th Dec 2021**
8.	Oral Examination Committee approved by Vice-Chancellor to be sent to COE(Thesis first Phase evaluation)	**20th Nov 2020**
9.	Seminar Presentation & Evaluation / Practical Examination (M.Tech. 1st Sem) / Thesis first evaluation (M.Tech. 3rd Sem) / PhD progress review by DRMC	**18th Dec – 24th Dec 2020**
10.	Last date for submission of certified Statement of Marks to COE (Courses / Seminar / Lab / Thesis)	**25th Dec 2020**
11.	Winter Vacation	**28th Dec 2020 – 10th Jan 2021.**
12.	Result Declaration – Autumn Semester	**08th Jan 2021**
13.	Seminar Presentation & Evaluation / Practical Examination (M.Tech. 1st Sem) / Thesis first evaluation (M.Tech. 3rd Sem) / PhD progress review by DRMC	**During the period provided for classes without affecting any academic activities.**

ACADEMIC CALENDAR 2020-21

SPRING SEMESTER (Feb-July 2021)

Sl. No.	Activity	Dates
1	Registration (M. Tech. / MS (by Research) / MSc/ PGD /Ph. D) Re-examination for Spring semester courses Add/Drop Courses & Finalizing Electives Orientation Programme	**06^{th} Jan -12^{th} Jan 2021**
2.	Last date of Late Registration with late fee	**29^{th} Jan 2021**
3.	Sending Certified list of courses (Regular, Self study, Audit etc) registered by the students - by Jt. Reg. (ACs) to COE	**05^{th} March 2021**
4.	Classes	**13^{th} Jan – 18^{th} May 2021**
5.	Sending the Panel of Examiners to COE	**19^{th} March 2021**
6.	Last date of submission of Examination form and Admit Card to COE by the Students.	**02^{nd} April 2021**
7.	End Semester Examination	**19^{th} May to 03^{rd} June 2021**
8.	Oral Examination Committee approved by Vice-Chancellor to be sent to COE (Thesis 2^{nd} Phase evaluation)	**30^{th} April 2020**
9.	Seminar Presentation & Evaluation / Practical Examination (M.Tech Thesis Final Evaluation / PhD progress review by DRMC)	**28^{th} May – 03^{rd} June 2021**
10.	Last date for submission of certified Statement of Marks to COE (Courses / Seminar / Lab / Thesis)	**04^{th} June 2021**
11.	Result Declaration	**06^{th} June 2021**
12.	Summer Vacation	**07^{th} June – 04^{th} July 2021**
13.	Outstation Instructional Tour (Optional)	**During the period provided for classes without affecting any academic activities.**

Programmes Structure

&

Syllabus of Courses

Department of Aerospace Engineering

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 L	Credits T/P	Total Credits (*)
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
		Total	**18**	**6**	**24**

Semester II

Sl. No.	Course Code	Course	Credits L	Credits T/P	Total Credits (*)
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
		Total	**18**	**6**	**24**

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

Semester III

Sl. No.	Course Code	Course	Credits L	Credits T/P	Total Credits (*)
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
		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
		Total	**18**	**6**	**24**

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
		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 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
		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
		Total	**18**	**6**	**24**

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
		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 L	Credits T/P	Total Credits (*)
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
		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, 4^{th} Edition, McGraw Hill, 2006.
2. E. L. Houghton and P. W. Carpenter, Aerodynamics for Engineering Students, 5^{th} Edition, Butterworth-Heineman, Oxford, 2003.
3. John D. Anderson, Introduction to flight, 5^{th} 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, 5^{th} Edition, John Wiley & Sons, inc, 2003.
7. John D. Anderson, Modern Compressible Flow: With Historical Perspective, 3^{rd} 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,2^{nd} 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:

14. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, New Delhi, 2001.
15. P Zarchan, Tactical and Strategic Missile Guidance, Vol 199 of Progress in Astronautics and Aeronautics, AIAA, Reston, VA, 2002.
16. P. Garnell, Guided Weapon Control Systems, 2nd Ed, Pergamon Press, London, 1980.
17. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, New York, 2004.
18. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
19. 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 ((α, β)) 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. Numerical solutions. Linear programming problems. Nonlinear programming, Kuhn Tucker condition, Direct optimization by gradient methods. Solutions of static optimization problems 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 condition, 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

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

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.

M. Tech. in Mechanical Engineering (Marine Engineering)

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, 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 third semester and 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 project, which is evaluated by the Internal and External examiners.

Visits to various DRDO labs like NSTL, ARDE, 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 Engg]

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
		Total	**18**	**6**	**24**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits
			L	T/P	
1	ME 607	Computational Fluid Dynamics	3	1	4
2	ME 644	Marine Diesel & Steam Engines	3	1	4
3	ME 645	Marine Gas Turbines	3	1	4
4	ME 646	Nuclear Reactor Engg.	3	1	4
5	--	Elective I	3	1	4
6	--	Elective II	3	1	4
		Total	**18**	**6**	**24**

Semester III

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

****Contact Hours/week**

List of Electives

Sl. No.	Course Code	Course Name
Elective I & II		
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.		Electives from other department

Notes:

1. Department has to decide which subjects should be offered as (i) Elective I, II in Semester II
2. Practice school (Optional) of 4 weeks duration during Summer Vacation is included
3. 1 credit in Theory/Tutorial means one contact hour and 1 credit in Practice/Project Thesis means two contact hours.

Course Name- ***Advanced Mechanics of Materials***
Course Code- ***ME 602***
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/References:

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

Course Name- ***Fluid Flow & Heat Transfer***
Course Code- ***ME 603***
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:

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***

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/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, 4th Edition, Pearson Education.
7. M. P. Grover: Fundamentals of Modern Manufacturing: Materials, Processes & Systems , Prentice Hall.

Course Name- ***Computational Fluid Dynamics (CFD)***
Course Code- ***ME 607***

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.

Unit V: Grid generation, errors and uncertainties, Practical's on CFD software (FLUENT).

Practice in ICEMCFD Software:

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:

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*

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 /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., 4th 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*

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- ***Design for Manufacturability***
Course Code- ***ME 611***

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 /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 Waldron B M and Kenneth J W, Mechanical Design: Theory and Methodology, Spriinger, 1996.

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/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

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/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: Machine Dynamics- Newtonian solution method, Force analysis of linkage, Shaking force and torque, Balancing linkage, Flywheels
Unit III: Gears and gear trains- Terminologies of gears and gear trains, Interface, undercutting, contact ratio, Simple gears and compound gear trains, Planetary gear trains
Unit IV: Cam systems- Cam terminologies, Cam function design and sizing
Unit V: Programmable mechanisms- Introduction to industrial manipulators, Kinematic chains and classifications, Coordinate transformation, Forward and inverse kinematics
Text/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***

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 orthopic 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 Optimisation.

Unit VII: Testing and characterizations 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:

1. Mechanics of composite materials, by Robert. M. Jones, second sedition, Taylor and Francis,1999.
2. 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, Rudd, Long, Kendall and 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*

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/ 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- ***Fatigue, Fracture and Failure Analysis***
Course Code- ***ME 627***

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/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:

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- ***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/ 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***

Unit I: Introduction- Classification of mechanisms – Basic kinematic concepts and definitions – Degree of freedom, Mobility – Kutzbach criterion, Grueblers criterion – Grashofs 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.

Unit V: 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.

Text/References:

1. R L Norton, Design of Machineries, 5th Edition, McGraw Hill Publishers.
2. Uicker, J, Pennock G. and Shigley, J.E., Theory of Machines and Mechanisms, 3rd Ed., 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.
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***
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/References:

1. Ulrich K. T, and Eppinger S.D, Product Design and Development, Tata McGraw Hill

2. Otto K, and Wood K, Product Design, Pearson

3. Engineering of creativity: Introduction to TRIZ methodology of inventive Problem Solving, By SD Savransky, CRC Press.

4. Inventive thinking through TRIZ: a practical guide, By Michael A. Orloff, Springer

5. Systematic innovation: an introduction to TRIZ: By Terninko & Zusman, CRC Press.

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/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/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/CAM***
Course Code- ***ME 635***

Unit I: Criteria for selection of CAD workstations, Shigle Design Process, Design criteria, Geometric modeling, entities, 2D & 3D Primitives.

Unit II: 2D & 3D Geometric Transformations: Translation, Scaling, Rotation, Reflection and Shearing, concatenation. Graphics standards: 302 KS IGES, PDES. Wire frame modeling: Curves: Curve representation. Analytic curves – lines, Circles, Ellipse, Conis. Synthetic curves – Cubic, Bezier, B-Spline, NURBS.

Unit III: Surface entities, Surface Representation. 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, Behavioural Modeling, Conceptual Design & Top Down Design. 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/References:

1. CAD/CAM: Computer-Aided Design and Manufacturing by M Groover and E. Zimmers, Pearson Education, 1983.

2. CAD/CAM in Practice by A J Medland, Springer science and media, 2012.

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/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. Norio Taniguchi, editor Nanotechnology, Oxford University Press, Oxford, UK, 2003.

5. Joseph McGeough, editor Micromachining of Engineering Materials,Marcel Dekker, Inc., New York, 2002.

6. 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/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*

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, Bearings classification, selection, and performance. Theories of design of Journal Bearings and Rolling element bearings with performance and life estimation

Unit IV: Modern Lubrication, Surface treatment.

Texts Books:

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***

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, 4th 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***

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***

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***

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. 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, 6th Ed, Elsevier, 2010.
3. Gas Turbine 2nd 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

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*

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:

IV. Convective Heat Transfer by Adrian Bejan (4^{th} Edition Wiley)
V. Boundary Layer Theory by H Sctllichting (McGraw-Hill)
VI. Heat and Mass transfer by Eckert ERG and Drake RM (Translated by J P Gross, McGrow-Hill)
VII. 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.

Reference/Text books:-

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*

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:
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, InTech, 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***
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, modelling of fouling Resistance design approach, Prevention of fouling, Types of corrosion, corrosion control

Unit IV: Advanced topics: Heat Pipe and Phase change heat exchanger

Heat pipes, construction, working principle, application, analysis. Special heat pipes, Phase change Heat-Exchangers, Phase change heat transfer, Introduction to evaporators and condensers. 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- M. Tech. Dissertation Phase– I
Course Code- ME 651

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

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:

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

2. 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.

Semester I

S. No.	Course Code	Course	Contact Hours/week		Credits
			L	T / P	
1	AM 607	Mathematics for Engineers	3	1	4
2	ME 601	Armament & Combat vehicles-I	3	1	4
3	ME 602	Advanced Mechanics of Materials	3	1	4
4	ME 609	Mechanical Vibrations	3	1	4
5	ME 604	Advanced Materials and Processing	3	1	4
6	ME 605	Introduction to Combat Systems	3	1	4
		Total	**18**	**06**	**24**

Semester II

S. No.	Course Code	Course	Contact hours/week		Credits
			L	T / P	
1	ME 661	Computational Fluid-Structure Interaction and its Applications	3	1	4
2	ME 660	Heat Exchanger Design	3	1	4
3	ME 613	Armour Protection Systems	3	1	4
4	ME 610	Armament & Combat Vehicles-II	3	1	4
5		Elective – I	3	1	4
6		Elective – II	3	1	4
		Total	**18**	**06**	**24**

Semester III

S. No.	Course Code	Course	Contact Hours /week		Credits
			L	T / P	
1	ME 651	M.Tech. Dissertation Phase I	28**		14
		Total	**28**		**14**

Semester IV

S. No.	Course Code	Course	Contact Hours /week		Credits
			L	T / P	
1	ME 652	M.Tech. Dissertation Phase II	28**		14
		Total	**28**		**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

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 (i) Elective I, II in Semester II
2. Core stands for compulsory subjects.
3. Practice school (Optional) of 4 weeks duration during Summer Vacation for scholarship students.
4. Contact Hours for M Tech Dissertation Phase I (ME 651) and M.Tech. Dissertation Phase II (ME 652) are 28 Hrs of each Phase.

Course Name- ***Armament and Combat Vehicles- I***
Course Code- ***ME 601***

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/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: 978-1857530841

Course Name- ***Advanced Mechanics of Materials***
Course Code- ***ME 602***

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/References:

5. Theory of Elasticity, 1970, Timoshenko SN & GoodierJN, McGraw Hill.
6. Advanced Mechanics of Materials, 2nd Ed., 1998 Cook RD & Yound WC, Prentice Hall.
7. Advanced Mechanics of Materials, 5th Ed., 1995 Boresi AP, Sidebottom OM, John Wiley.

Experimental Stress Analysis, 3rd Ed., 2005, Dally JW & Riley WF, College House Enterprises.

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

Course Code- ***ME 604***

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/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, 4th 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***

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/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- *Finite Element Methods*
Course Code- *ME 608*
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:

(iv) Stress Analysis of Plate With Cut-outs using ANSYS/ABAQUS Software

(v) Modal Analysis Of Cantilever Beam using ANSYS/ABAQUS Software

(vi) Case Studies etc.

Text /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., 4th 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*

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***

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.

Texts/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*

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 /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/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, 2nd 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

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/References:
1. Fighting vehicle, 1st 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/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*

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.
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.

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/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. Design of Experiments: An Introduction Based on Linear Models, 1st edition, 2010, Max Morris, Chapman and Hall/CRC, ISBN 978-1584889236
5. Harris Shock and Vibration Handbook, 6th edition, 2009, AG Piersol and Thomas L Paez, McGraw Hill-Professional, ISBN 978-0071508193
6. 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

7. Dynamic Systems: Modelling and Analysis, 1996, Ramin Esfandairi and Hung V Vu, Mc Graw Hill, ISBN 978-0072966619
8. 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***

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/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: Machine Dynamics- Newtonian solution method, Force analysis of linkage, Shaking force and torque, Balancing linkage, Flywheels

Unit III: Gears and gear trains- Terminologies of gears and gear trains, Interface, undercutting, contact ratio, Simple gears and compound gear trains, Planetary gear trains

Unit IV: Cam systems- Cam terminologies, Cam function design and sizing

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

Text/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***

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 orthopic 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 Optimisation.

Unit VII: Testing and characterization 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:

1. Mechanics of composite materials, by Robert. M. Jones, second sedition, Taylor and Francis,1999.
2. 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***

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/ 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.

Texts/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.

Texts/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.

Texts/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/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/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*

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 /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:

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- ***Design of Machinery***

Course Code- ***ME 630***

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.

Outcomes:

Upon completion of this course, the students can able to apply fundamentals of mechanism/machines for the design of new mechanisms/machines and analyse them for optimum design.

Text/References:

1. R L Norton, Design of Machineries, 5th 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- *Heat Exchanger Design*
Course Code- *ME 660*

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:

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

Reference Books:

7. Heat Exchanger design handbook by T. Kuppan
8. Compact Heat Exchangers by William M. Kays and A.L. London, (Krieger Publishing Company)
9. Fundamental of Heat Transfer – Frank P. Incropera, David P. Dewitt

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

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-VI: 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

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

M. Tech. in Robotics

Brief Description: M.Tech. in Robotics is an interdisciplinary Masters Programme composed of 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 multidisciplinary areas like robotics is growing day by day in Indian industries, defence applications, atomic energy, space research, medical research etc. The program is designed for eligible candidates interested in designing, controlling and creating robotic systems.

Eligibility:

1. The eligibility for the M.Tech. in Robotics will be Bachelor’s degree in Mechanical/ Electrical/Electronics/Mechatronics/ Computer Science/ Information Technology Aerospace/Aeronautical/ Control/ Automobile/ Industrial/ and Instrumentation Engineering etc. disciplines from recognized university.
2. This programme is open for GATE qualified civilian 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 in Robotics is a four-semester master’s programme. There are six compulsory courses in the first semester, 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 and External examiners.

Visits to various DRDO Labs are planned to enhance student’s practical understanding of the subject and provide them the opportunity to get hands on experience on various equipments and latest systems. The details of the courses offered under the programme are given below:

Semester I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	ME 664	Introduction to Robotics	3	1	4
2	ME 665	Mechatronics	3	1	4
3	# ME 639/ ## EE 649	Introduction to Mechanisms Or Introduction to Electronics Systems	3	1	4
4	CE 696	Artificial Intelligence and Expert Systems	3	1	4
5	ME 666	Robot Sensors and Actuators and Drives	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
		Total	**18**	**06**	**24**

Note: #ME 639 for (Non – Mechanical students) &##EE 649 for (Non- Electronics students) compulsory subject.

Semester II

Sl. No.	Course Code	Course	Contact hours/week		Credits
			L	T/P	
1	ME 667	Robot Kinematics and Dynamics	3	1	4
2	ME 668	Machine vision and Image Processing for Robots	3	1	4
3	EE 620	Soc and Embedded Systems	3	1	4
4	ME 663	Robotic Path Planning and Control	3	1	4
5		Elective – I	3	1	4
6		Elective – II	3	1	4
		Total	**18**	**06**	**24**

Semester- III

S. No.	Course Code	Course	Credits		Total Credits
			L	T/P	
1	ME 651	M.Tech. Dissertation Phase I	28**		14
		Total	**28**		**14**

Semester-IV

S. No.	Course Code	Course	Credits		Total Credits
			L	T/P	
1	ME 652	M.Tech. Dissertation Phase II	28**		14
		Total	**28**		**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

Sl. No.	Course Code	Course Name(Elective I and II)
1	ME 614	Unmanned ground vehicles
2	ME 628	Design of Hydraulic and Pneumatic System
3	ME 629	Industrial Automation
4	ME 631	Product design and development
5	ME 634	Flexible Manufacturing systems
6	ME 635	CAD/CAM
7	ME 638	Field and service Robots
8	ME 642	Automatic Control System
9	ME 653	Introduction to Mobile Robotics
10	ME 655	Performance testing and Instrumentation
11	ME 669	Humanoid
		Open elective from other department

Detailed Contents

Course Name- Introduction to Robotics
Course Code - ME 664

UNIT I: Evolution of Robot, Laws of Robotics, Robot classification, Types and components of Robot, Anatomy, Robot terminology-Links, joints, 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 II: Robot workcell, Kinamatic systems, spatial descriptions: Position, orientation and frames, Coordinate frames, Mapping between frames, translations, rotations and transformations matrices and Homogeneous Transformation Matrix.

UNIT III: Robot end effectors-classification Grippers, Types of Grippers-Mechanical, finger grippers Magnetic-vacuum/suction, Hooks, scoops and other devices, selection of grippers, gripping mechanisms, Gripper force analysis and design of Drive system for gripper, tools Characteristics and elements of End-of-Arm-Tooling.

UNIT VI: Euler angles for specifying orientation, Euler angles for roll-yaw-roll geometry, Gripper positioning by Euler angles for roll-yaw-roll geometry - Euler angles for roll - pitch - yaw geometry, Cylindrical Robot coordinates, polar Robot coordinates, calculation of cylindrical, polar coordinates,

UNIT V: Robot capabilities and applications- wheeled, tracked, legged, aerial, underwater robots, surgical robots, rehabilitation robots, humanoid robots, Nano Robots, Robotic Accidents and safety, social and environmental impact of robotics, Robot maintenance.

UNIT VI: Repetitive tasks in Industries, In hazardous environments - underwater, space, fire, handling of chemicals, radioactive substances, Tele-operation vs autonomous robots, Rescue robots, Unmanned vehicles, Robot soldiers, Kinamatics and dynamics of mobile robotics, Introduction to Robot Programming, on-line and off-line Programming, Robot Programming Languages.

Practice:

1. Mobile Robot Control and programming.
2. Robot Kinamatics Simulation Software.
3. Industrial Robot operation and programming with teach pendent.
4. Robot Studio: Programmable control of Industrial Robot.
5. Case studies.

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- Mechatronics
Course Code- ME 665

UNIT I: Mechatronics and Signal conditioning: Introduction, Systems, Measurement Systems, Control Systems, Microprocessor - based controllers, Response of systems. The Mechatronics Approach, Digital signals, Multiplexers, Data acquisition systems, Digital signal processing, Pulse modulation, OPAM, measurement systems, Testing and calibration.

UNIT II : Pneumatic and hydraulic actuation system: Actuation systems, Pneumatic and hydraulic systems, Directional control valves, Pressure control valves, Cylinders, Process control valves, rotary actuators.

UNIT III: Mechanical Actuation Systems: Mechanical Systems, Types of Motions, Kinematic chains, Cams, Gear Trains, Ratchet and pawl, belt and chain drives, Bearings, Mechanical aspects of motor selection

UNIT IV: System models: Mathematical models, Mechanical system building blocks, electrical system building blocks, fluid system building blocks, thermal system building blocks , Engineering systems, Rotational-translational systems, Electromechanical systems, Hydraulic-mechanical systems.

UNIT V : System Transfer function: First order systems, Second order systems, Transfer functions Block diagrams, signal flow graphs Systems with feedback loops. Elect of pole location on transient response, MATLAB, SIMULINK applications .

UNIT VI Controllers: Micro processor systems, Micro controller systems and applications, Programmable Logic controllers, Basic structure, input/output processing, selection of a PLC Programming and applications.

TEXT BOOKS :

1. W.Bolton,*Mechatronics, Electronic Control Systems in Mechanical and Electrical Engineering,*Pearson Education, Ltd.

REFERENCES:

1. Anthony Esposito,*Fluid Power with Applications*, Pearson Education 2000.
2. Johnson, James L, *Introduction to Fluid Power*, Delmar Publishers, 2003.
3. I J Nagrath, M Gopal, *Systems Modelling and Anlysis*, Tata McGraw Hill,New Delhi, 3rd Edition 2008.
4. K Ogata, *Modern Control Engineering*, 5th Edition,Prentice Hall, 2010.
5. M W Spong and M Vidyasagar, *Robot Dynamics and Control*, John Wiley & sons, NY, USA,2004.

***Course Name- Introduction to Mechanisms* (Non Mechanical)**
Course Code- ME 639

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, Finite Transformation, Transformation Matrix Between Rigid Bodies

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 Various Mechanisms: Ratchet Mechanisms, Overrunning Clutch, Intermittent Gearing, The Geneva Wheel, The Universal Joint.

Practice :

1. Msc adams tutorials
2. Mechanisms Design in Solidworks
3. Analysis Simulations etc.

Reference Text Books:

1. P. Beer& Johnson, *Vector Mechanics for Engineers and Scientists Statics and Dynamics*, Tata McGraw Hill, New Delhi, 2001.
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.
4. Joseph Heitner, *Automotive Mechanics*, Affiliated East West Pvt. Ltd, 2nd, 2013.

Course Name: Introduction to Electronics Systems(Non Electronics)
Course Code: EE649

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.

REFERENCE BOOKS:

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

Course Name- Artificial Intelligence and Expert Systems
Course Code- CE 696

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 Factors
UNIT II: Fuzzy Expert Systems: Introduction to Fuzzy thinking, Linguistics variables and Hedges, Fuzzy Rules, Fuzzy Inference, Defuzzification
UNIT III: Learning: Overview of different forms of learning, Learning Decision Trees, Neural Networks, Natural Language Processing
UNIT IV : Artificial Neural Networks: Basics of Neuron, Perceptron, Multi-layer neural network, Hop-field network, Self- Organizing Neural Networks
UNIT V: Evolutionary Computation: Genetic Algorithms, Evolution Strategies - Hybrid Intelligent Systems: Neuro-Fuzzy, ANFIS; Probabilities, Bayesian Networks
UNIT VI : Applications of AI in Robotics: Subsumption Robots, Subsumption Architecture, Strengths and Weaknesses of the Architecture. Sensors, vision camera etc. for perception and obstacle avoidance

Text/References:

1. Stuart Russell & Peter Norvig, *Artificial Intelligence: A Modern Approach*, Prentice-Hall, 3rd Edition, 2009.
2. E. Rich and K. Knight, *Artificial Intelligence*, 2nd ed., McGraw-Hill, New York, 1991.
3. Morgan Kaufmann, San Mateo, M. Ginsberg, *Essentials of Artificial Intelligence*, Ca. 1993.
4. D. Poole and A. Mackworth, *Artificial Intelligence: Foundations of Computational Agents*, Cambridge University Press, Cambridge, UK, 2010.
5. P. H. Winston, *Artificial Intelligence*, 3rd ed., Addison-Wesley, Reading, Mass., 1992.
6. Brooks, Rodney, *Cambrian Intelligence: The Early History of the New AI.* Cambridge, Massachusetts: The MIT Press. pp. 8–12; 15–16. ISBN 0-262-02468-3, 1999

Course Name- Robotic Sensors, Actuators and Drives
Course Code-ME 666

Unit I: Introduction to sensors, classification, Commonly detectable phenomenon in nature, transducers -common conversion methods, Principle of operation of sensors, Classification, static characteristics, selection criteria, signals conditioning, calibration.

Unit II: Working Principle of operation of industrial sensors, displacement sensors, synchros and resolvers, Temperature measurement sensors, pressure measurement sensors, Proximity sensors, Ultrasonic, magnetic, light sensors, Flow measurement sensors, speed measurement, Tactile sensors, shape memory alloy materials, smart sensing, applications.

Unit III: Principle of operation of actuators, 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, power MOSFET, power BJT, SCR, V- I, turn on, turn off characteristics, triggering methods, PWM methods. Induction motor drives, VSI, CSI, cyclo-converters, static Kramer drive, static Scherbius drive, synchronous motor drives, 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, speed control and drive classification, closed loop control, current limit control, speed control, position control, torque control, PLL control, multi-motor drive control, digital control. DC motor control, speed control, position control, proportional control, PID controllers.

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*” DhanpatRai&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- Mathematics for Engineer
Course Code-AM 607

Unit I : Linear Algebra: General (real) vector spaces, Subspaces, Linear independence, Dimension, Norms, Orthogonal bases and Gram-Schmidt orthogonalization- Principles of floating point computations and rounding errors

Unit II : Systems of Linear Equations: factorization methods, pivoting and scaling, residual error correction method - Iterative methods: Jacobi, Gauss-Seidel methods with convergence analysis, Conjugate gradient methods

Unit III : Nonlinear systems: Newton and Newton like methods - Interpolation: review of Lagrange interpolation techniques, Newton interpolation, piecewise linear, cubic splines and Bezier curves, error estimates - Approximation: uniform approximation by polynomials, data fitting and least squares approximation

Unit IV : Numerical differentiation and integration: Differentiation and integration by interpolation, adaptive quadratures and Gaussian quadrature - Initial Value Problems for Ordinary Differential Equations: Euler, Modified Euler, Runge -Kutta methods, multi - step methods, predictor and corrector methods, stability and convergence analysis

Unit V : Two Point Boundary Value Problems: finite difference methods with convergence results - Solution of PDE: Parabolic, Hyperbolic and Elliptic Equations using finite difference method.

Text/References:

1. Gilbert Strang, *Linear Algebra and its Applications*, Academic Press, 4th Ed., 2008.
2. Thomas S Shores, *Applied Linear Algebra and Matrix Analysis*, Springer, 2007.
3. Richard L. Burden, J. Douglas Faires, Brooks/Cole, *Numerical Analysis*, 9th Ed., 2010.
4. Kendall E. Atkinson, *An Introduction to Numerical Analysis*, John Wiley & Sons, 2nd Ed., 2008.
5. Samuel D Conte and Carl de Boor, *Elementary Numerical Analysis - An Algorithm Approach*, McGraw Hill, 3rd Ed, 2008.
6. M. K. Jain, S.R.K. Iyengar, R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, New Age International Ltd, 6th Ed., 2012.
7. K. W. Morton, D. F. Mayers, *Numerical Solutions of Partial Differential Equations: An Introduction*, Cambridge University Press, 2nd Ed., 2005.
8. Gene H. Golub, J. M. Ortega, *Scientific Computing and Differential Equations: An Introduction to Numerical Methods*, Academic Press, 2nd Ed. 1992.
9. G. Pozrikidis, *Numerical Computation in Science and Engineering*, Oxford University Press, 2nd Ed., 2008.

Course Name- Robot Kinematics and Dynamics
Course Code- ME 667

Unit I: Introduction, position and orientation of objects, objects coordinate frame Rotation matrix, Euler angles Roll, pitch and yaw angles coordinate Transformations, Joint variables and position of end effectors

Unit II : Dot and cross products, coordinate frames, Rotations, Homogeneous coordinates, link coordinates D-H Representation, The ARM equation. Direct kinematic analysis for Four axis, SCARA Robot and six axis Articulated Robots

Unit III : The inverse kinematics problem, General properties of solutions. Tool configuration, Inverse kinematics of four axis SCARA robot and six axis Articulated robot

Unit IV : Workspace Analysis, work envelope of a Four axis SCARA robot and five axis articulated robot workspace fixtures, the pick and place operations, continuous path motion, Interpolated motion, straight line motion

Unit V : Introduction, lagrange's equation kinetic and potential energy. Link inertia Tensor, link Jacobian Manipulator inertia tensor. Gravity, Generalized forces, Lagrange-Euler Dynamic model, Dynamic model of a Two-axis planar robot Newton Euler formulation, Lagrange - Euler formulation, problems.

Practice:

1. Robot Analyzer Platform Experiments
2. Simulation Software for Robotics
3. Case studies

Text/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. P.A. Janaki Raman, *Robotics and Image Processing an Introduction*, Tata Mc Graw Hill Publishing company Ltd., 1995

4. Francis N-Nagy AndrasSiegler, *Engineering foundation of Robotics*, Prentice Hall Inc., 1987
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. John J. Craig, *Introduction to Robotics Mechanics and Control*, Second Edition, Addison Wesly Longman Inc. International Student edition, 1999
8. Bijay K. Ghosh, Ning Xi, T.J. Tarn, *Control in Robtics and Automation Sensor - Based integration*, Academic Press, 1999
9. M.P. Groover , Mitchel Weiss, *"Industrial Robotics: Technology, Programming and Applications"(2e),* McGraw Hill ,2012

Course Name- Machine Vision and Image Processing
Course Code-ME 668

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.Face recognition, vehicle tracking, industrial robot guidance, demonstration of applications using computer vision toolbox and image processing toolbox.

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- SoC AND EMBEDDED SYSTEM
Course Code- EE620

UNIT-I: INTRODUCTION: Definition and Classification, Overview of Processors and hardware units in an embedded system, Software embedded into the system, Exemplary Embedded Systems, Embedded Systems on a Chip (SoC) and the use of VLSI designed circuits.
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 Language 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.

TEXT BOOKS:

1. ARM System-on-Chip Architecture (2nd Edition) Steve Furber.
2. Advanced FPGA Design: Architecture, Implementation, and Optimization, Steve Kilts, IEEE press Wiley 2007.
3. An Embedded software primer David E Simon,Pearson Education Twelfth India reprint,2005
4. Desiging Embedded systems with PIC microcontrollers Principles and Applications ,Tim Wilmshurst, Elsevier (Newnes), first edition 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
1	Simulation of ALP using 8086 Emulator
2	FPGA programming using VHDL.
3	Radar signal generation using FPGA.
4	Creating a custom IP core using the IP Integrator in Vivado IDE
5	Recording and play back of audio signal using Zedboard DMA
6	Peripheral Module Interface using soft core processor Microblaze
7	PWM Applications using PSoC
8	Introduction to CUDA programming and Tesla Processors

Course Name- Robotic Path Planning and Control
Course Code- ME 663

Unit I Path Planning: Processes in Robot Control: Path planning – Trajectory Generation – Robot Control, Bug Algorithms: Bug1, Bug2, Tangent Bug algorithms, Planning motion in C-space, Potential field approach, Visibility Graph method for polygonal obstacles, Gradient method and dynamic window for mobile robots, Cell decomposition method, Approximate cell decomposition method, A* and D* algorithms, Probabilistic roadmap planner, Rapidly exploring random trees.

Unit II Trajectory generation: Cubic polynomial – path with via points – velocities at via points, Higher order polynomials, Linear function with parabolic blends – path with via points, pseudo via points to create a through point, Cartesian space schemes, Cartesian straightline motion

Unit III Linear Robot Control: Independent joint control approximation, 2nd order linear systems, Control law partitioning, Trajectory following controller, Disturbance rejection, PID control, Modeling & control of single joint, Unmodeled flexibilities, Resonant frequencies, Architecture of an industrial robot controller.

Unit IV Nonlinear control of manipulators: Example nonlinear systems, Coulomb friction, Single link manipulator, Multi-input Multi-output control systems, Model based manipulator control scheme, Feedforward nonlinear control, Effects of payload and disturbances, Imperfect knowledge of parameters of manipulator dynamics, Industrial robot control system, Approximations of decoupling control, Lyapunov stability analysis: Nonlinear spring damper, Manipulator, Cartesian based control system, Jacobians in the force domain, Cartesian force based control, Cartesian decoupling scheme, Adaptive control.

Unit V Force control: Framework for control in partially constrained task, Artificial constraints, Hybrid position/force control: Force control of a mass spring, Hybrid position/force control of a cartesian manipulator, Hybrid controller of a 3-dof Cartesian arm, Hybrid position/force controller for a general manipulator, Variable stiffness, Passive compliance through remote centre compliance device, compliance through softening position gains.

References and Text

1. John J. Craig, *Introduction to Robotics Mechanics and Control*, 3rd Edition, Pearson, 2008.
2. K. Ogata, *Modern Control Engineering*, 5th Edition, Prentice Hall, 2010
3. B. Friedland, *Control System Design-An Introduction to State Space Methods*, McGraw-Hill, Singapore, 1987
4. J.J.E Slotine and W. Li, *Aplied Nonlinear Control*, Prentice-Hall, NJ, 1991
5. M. W. Spong and M. Vidyasagar, *Robot Dynamics and Control*, John Wiley & Sons, NY, USA, 2004
6. Howie M Choset, Seth Hutchinson, Kevin M Lynch, George Kantor, Wolfram Burgard, Lydia E Kavraki, Sebastian Thrun *Principles of Robot Motion: Theory, Algorithms, and Implementation*, 2005

LIST OF ELECTIVES

Sr no	Course code	Course Name
1	ME 614	Unmanned ground vehicles
2	ME 628	Design of Hydraulic and Pneumatic System
3	ME 629	Industrial Automation
4	ME 631	Product design and development
5	ME 634	Flexible Manufacturing systems
6	ME 635	CAD/CAM
7	ME 638	Field and service Robots
8	ME 642	Automatic Control System
9	ME 653	Introduction to Mobile Robotics
10	ME 655	Performance testing and Instrumentation
11	ME 669	Humaniod
12		Elective from other Dept.

ME 614 Unmanned Ground vehicles

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/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.

ME 628 Design of Hydraulic and Pneumatic Systems

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 89 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:
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.

ME 629 Industrial Automation

Unit I: Production operations and Automation strategies - Types of production, Functions in manufacturing, Plant Layout, Production concepts and Mathematical models, Automation strategies. Production Economics.

Unit II: Cost in manufacturing, break even analysis, Unit cost of production, Cost of manufacturing lead time and work-in-progress - Detroit - Type automation - Automated flow line, workpart transport, Transfer mechanism, Buffer storage, Control functions, Automation for machining operations, Design and fabrication consideration. Analysis of Automated Flow lines. General terminology and analysis.

Unit III: Analysis of transfer lines without storage, partial automation, Automated flow lines, with storage buffer, simulation of automation flow lines - Numerical Control, Types of NC Systems, Machine tool applications, other applications of NC Systems, Components of NC System, Introduction to NC part programming, Types of part programming, Direct Numerical Control, Computer Numerical Control, Adaptive Control Machining - The assembly process, assembly systems, manual assembly lines.

Unit IV: The line balancing problem, Methods of line balancing, Computerised line balancing method, flexible manual assembly lines. Design for automated assembly, types of automated assembly system, parts feeding devices, Analysis of single station and multistation assembly machine - Automated materials handling: Types of material handling equipment, analysis for material handling systems, design of the system, conveyor system, automated guided vehicle systems. Automated storage systems: Automated storage / Retrieval systems, Carousel storage systems, work-in-process storage, interfacing handling and storage with manufacturing.

References/Texts

1. Mikell.P. Groover, *Automation, Production Systems and Computer Integrated Manufacturing*, Prentice Hall of India Pvt. Ltd., Thirteenth Indian Reprint, 2001.
2. P.N. Rao, 'CAD/CAM Principles and Applications' Tata McGraw Hill Publishing Company Ltd., 2002

ME 631 Product Design and Development

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 books and references:

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.

ME634 Flexible Manufacturing Systems

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.

References/ Texts:

1. N K Jha, *Handbook of Flexible Manufacturing Systems*, Academic Press, 2012.

2. A. Raouf, M. Ben-Daya, *Flexible Manufacturing Systems: Recent Developments*, Elsevier, 09-Feb-1995.

ME 635 CAD/CAM

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. Synthetic curves – Cubic, Bezier, B-Spline, NURBS - Surface entities, 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, Behavioural 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

ME 638 Field and service Robots

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, DavideScaramuzza, *Introduction to Autonomous Mobile Robots*, Bradford Company Scituate, USA, 2004
1. RiadhSiaer, *The future of Humanoid Robots- Research and applications*, Intech Publications, 20

Reference books:

1. Richard D Klafter, Thomas A Chmielewski, Michael Negin, "*Robotics Engineering – An Integrated Approach*", Eastern Economy Edition, Prentice Hall of India P Ltd., 2006.
2. Kelly, Alonzo; Iagnemma, Karl; Howard, Andrew, *Field and Service Robotics*, Springer, 2011.

ME 642 Automatic Control Systems

Unit I: Basic concepts of Automatic Control- Transfer Functions-Modeling of systemsMechanical, 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.

Texts Books:

1. Measurement System, Application & Design, 4thEd, 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.

ME 653 Introduction to Mobile Robotics

Linear Algebra, Robot Control Paradigms, Wheeled Locomotion, Proximity Sensors, Probabilistic Robotics, Probabilistic Motion Models, Probabilistic Sensor Models, Bayes Filter

- Discrete Filter, Particle Filter and MCL, Kalman Filter, Extended Kalman Filter, Grid Maps and Mapping With Known Poses, SLAM - Simultaneous Localization and Mapping, SLAM - Graph-based SLAM, Techniques for 3D Mapping, Iterative Closest Point Algorithm, Path and Motion Planning, Multi-Robot Exploration, Information Driven Exploration.

Text Books:

1. Roland Siegwart, Illah Reza Nourbakhsh and DavideScaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd Edition, 2004.
2. Gregory Ducdeck, Michael Jenkin, *Computational Principles of Mobile Robotics*, Cambridge University Press, 2000.
3. H. R. Everet, *Sensors for Mobile Robots-Theory and Applications*, A.K. Peters, 1995.
4. Phillip McKerrow, *Introduction to Robotics*, Addison-Wesley, 1991.
5. Ronald Arkin, *Behavior Based Robotics*, MIT Press, 1998.

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.

Reference/Text books:-

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 Instrurnentation, John Wiley Eastern Ltd, New Delhi

Course Name- *Humanoid*
Course Code- *ME 669*

Unit I: Introduction to Humanoid Robotics ,state of the art, Kinamatics-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: ZMP and Ground Reaction Forces, Measurement of ZMP Dynamics of Humanoid Robots Humanoid Robot Motion and Ground Reaction Force Momentum Angular Momentum Angular Momentum and Inertia Tensor of Rigid Body Calculation of ZMP from Robot's Motion.

Unit III: Biped Walking, Two Dimensional Walking Pattern Generation, Two Dimensional Inverted Pendulum, Planning a Simple Biped Gait, Extension to a Walk on Uneven Terrain, 3D Walking Pattern Generation, 3D Walking Pattern Generation, ZMP Based Walking Pattern Generation, Stabilizer-Principles of Stabilizing Control

Unit IV: Generation of Whole Body Motion Patterns, Generating Rough Whole Body Motion-Using Motion Capture, Using a Graphical User Interface, Using High Speed Multivariate Search Methods Converting Whole Body Motion Patterns to Dynamically Converting Whole Body Motion Patterns to Dynamically Stable Motion, Remote Operation of Humanoid Robots with Whole Body Motion Generation

Unit V: Dynamic Simulation, Dynamics of Rotating Rigid Body, Spatial Velocity Dynamics of Rigid Body Newton-Euler Equations Dynamics by Spatial Velocity Rigid Body Simulation Based on Spatial Velocity Dynamics of Link System

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

DEPARTMENT OF MECHANICAL ENGINEERING

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:

3. Bachelor's Degree in Mechanical/Production/Automobile/Mechatronics/Metallurgy and materials/Mining/Aerospace Engineering of a recognized Institute/University.
4. 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:

Semester- I

S. 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
		Total	18	06	24

Semester- II

S. No.	Course Code	Course	Credits		Total Credits(*)
			L	T/P	
1	ME 631	Product Design and Development	3	1	4
2	ME 630	Design of Machinery	3	1	4
3	ME 608	Finite Element Methods	3	1	4
4	ME 627	Fatigue, Fracture and Failure Analysis	3	1	4
5		Elective – I	3	1	4
6		Elective – II	3	1	4
		Total	18	06	24

Semester- III

S. No.	Course	Course	Credits	Total

	Code		L	T/P	Credits(*)
1	ME 651	M.Tech. Dissertation Phase I	28**		14
		Total	28		14

Semester-IV

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

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

List of Electives

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

Detailed Contents

Course Name- ***Advanced Mechanics of Materials***
Course Code- ***ME 602***

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/References:

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

Course Name- ***Fluid flow and Heat transfer***
Course Code- ***ME 603***

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.
- Investigation of the effect of external fins on the heat transfer watt density of plain tube bundles in cross flow.
- 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/References:

4. Viscous Fluid Flow, 2005, F. M. White, McGraw-Hill.
5. Boundary Layer Theory, 8th ed, 2000, Herrmann Schlichting, Springer
6. "Introduction to Fluid Mechanics**"** by R.W. Fox and A.T. McDonald, McGraw Hill
7. "Fluid Mechanics" by Kundu & Cohen, Elsevier Publications
8. Heat Transfer by J P Holman and Souvik Bhattacharyya (10th Edition, McGraw Hill Education)

Course Name- *Advanced Materials and Processing*
Course Code- *ME 604*

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/References:

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

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

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 -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, Noise control and acoustics.

Practice:

Any four experiments on topics under unit I, II and III on Vibration Fundamental Trainer.

Text Books:

4. Introductory Course on Theory and Practice of Mechanical Vibrations, J.S.Rao, K.Gupta, Revised second edition, New Age International Publishers
5. Theory of Vibration with Applications, William T. Thomson, Marie Dillon Dahleh, Pearson Low Price Edition.

6. Mechanical Vibrations, J.B.K. Das & P.L.S.Murthy, Sapna book house.

Reference Books:

2. 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- ***Composite Structures***
Course Code- ***ME 618***

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 Optimisation.

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:

3. Mechanics of composite materials, by Robert. M. Jones, second sedition, Taylor and Francis,1999.
4. Experimental characterization of advanced composites materials, third edition, Donald f Adams, Lief A. Carlsson and R. Byron pipes. CRC press.

Reference books:

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

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

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:

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.

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

"Product Design and Product Development is a course that covers fundamental design insights, modern tools, methods & stages of Product development from concept to Launch"

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 /References*:*

6 Ashby, M. F. "Materials Selection in Mechanical Design", Pergaman Press, 1992.

7 Bralla J., "Handbook of Product Design for Manufacture", McGraw Hill, 1988.

8 Levy S., and Dubois, L. H, "Plastics Production Design Engineering Handbook, Methuen Inc., 1985.

9 Dieter G E, Engineering Desing, McGraw-Hill, 1991.

10 Yotaro Hatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.

11 Ertas Atilia and Jones J C, The Engineering Design Process, John Wiley & Sons, 1996.

12 Waldron B M and Kenneth J W, Mechanical Design: Theory and Methodology, Spriinger, 1996.

13 Ian Gibson, David W. Rosen and Brent Stucker, Additive manufacturing technologies: rapid prototyping to direct digital manufacturing, Springer, 2010.

Course Name- *Design of Machinery*
Course Code- *ME 630*

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

Outcomes:

Upon completion of this course, the students can able to apply fundamentals of mechanism/machines for the design of new mechanisms/machines and analyse them for optimum design.

Text/References:

1. R L Norton, Design of Machineries, 5th 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- *Finite Element Methods*
Course Code- *ME 608*

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. Axi-symmetric 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:

(vii) Stress Analysis of Plate With Cut-outs using ANSYS/ABAQUS Software

(viii) Modal Analysis Of Cantilever Beam using ANSYS/ABAQUS Software

(ix) Case Studies etc.

Text /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., 4th 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- *Fatigue, Fracture and Failure Analysis*
Course Code- *ME 627*

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 /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.

Electives

Course Name- *Computational Fluid Dynamics (CFD)*
Course Code- *ME 607*

Unit I: Basic of Computational Fluid Dynamics. Governing Equations of fluid mechanics and heat transfer, physical boundary conditions, basic aspects of Discretization.

Unit II: Finite Difference and Finite Volume formulation of steady/transient one-dimensional conduction equation., Finite Volume formulation of steady one-dimensional convection and diffusion problems,

Unit III: Solution algorithms for pressure-velocity coupling in steady and unsteady flows. discretization equations for two dimensional convection and diffusion.

Unit IV: Numerical methods for the Navier-Stokes equation. Turbulence models: mixing length model, Two equation (k-epsilon) models – Grid generation. Practicals on CFD software (FLUENT).

Practice:

7. Turbulent Flow in a 2D elbow. (use water)
8. Laminar Flow in a 2D Pipe. (use water)
9. Flow over an Airfoil. (use air)
10. Laminar flow over a flat plate.

Text/References:

3. An introduction to Computational Fluid Dynamics, 2nd edition, 2007, HK Versteeg & W Malalasekera, Pearson Education.
4. Introduction to Computational Fluid Dynamics, 2005, Anil W Date, Cambridge University Press, NY, USA.
5. Computational Fluid Dynamics & Heat Transfer, 1984, Anderson, Dale A, John C Tanehill and Richard H Pletcher, McGraw Hill.

6. Numerical Heat Transfer and Fluid Flow, 1980, Patankar SV, Hemisphere, New York.

Course Name- *Design for Manufacturability*
Course Code- *ME 611*

"Design for Manufacturability elaborates on the integration of design, engineering, management principles and digital tools to proactively enable ease of manufacturability with better quality and optimised cost"

Unit I: Manufacturing Considerations Overview-

- Design for manufacture overview
- 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 II: Design for Manufacturing (DFM):

- Fundamental principles of DFM
    - Standardization
    - Acceptable tolerances
    - Complexity reduction
    - Commonization/elimination of tools and manufacturing processes.
- Concurrent engineering approach

Unit III: Design for Assembly (DFA) :

- Fundamental principles of DFA
    - Optimization of assembly operations.
    - Standardization
    - Modular design practices etc
- Concurrent engineering approach

Unit IV: Design Evaluation Tools/Softwares:

- "CAD integrated Design for Manufacturability softwares & Other tools"
- Software Approach on Identification of downstream issues early in design stage.

Post analysis/ Real time feedback for cast, forged, machined, sheet metal, rubber parts for ease of manufacturability with quality.

Text /References*:*

14 Ashby, M. F. "Materials Selection in Mechanical Design", Pergaman Press, 1992.
15 Bralla J., "Handbook of Product Design for Manufacture", McGraw Hill, 1988.
16 Levy S., and Dubois, L. H, "Plastics Production Design Engineering Handbook, Methuen Inc., 1985.
17 Dieter G E, Engineering Desing, McGraw-Hill, 1991.
18 Yotaro Hatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.

19 Ertas Atilia and Jones J C, The Engineering Design Process, John Wiley & Sons, 1996.
20 Waldron B M and Kenneth J W, Mechanical Design: Theory and Methodology, Spriinger, 1996.

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/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- ***Tribology for Design***
Course Code- ***ME 619***

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/ 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- ***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, Case Studies.

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- Case Studies.

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, Case Studies.

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,Case Studies.

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- ***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. Response Surfaces & Optimization

Unit IV: Optimal Designs and Model Uncertainty; Designs with Random Effects: Split Plots, Crossover Designs; Conjoint Designs;

Unit V: Design and Analysis of Computer Experiments; Design for Nonlinear Models; Sequential Designs

Text/ 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 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/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/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/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/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 Vessel***
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, Non-circular Sections.

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.
Case Studies.

Text/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, Pre

ASME Pressure Vessels and Piping Conference, 1997.

Course Name- ***Convective Heat & Mass Transfer***
Course Code- ***ME 654***

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:

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

Reference Books:
1. Convective Heat Transfer by Adrian Bejan (4th Edition Wiley)
2. Boundary Layer Theory by H Sctllichting (McGraw-Hill)
3. Heat and Mass transfer by Eckert ERG and Drake RM (Translated by J P Gross, McGrow-Hill)
4. Convective Heat Transfer: Solved Problems by Michel Favre-Marinet and Sedat Tardu (Wiley)

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, InTech, 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*

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:

10. Fundamentals of Heat Exchanger Design by Ramesh K. Shah & Dusan P. Sekulic (John Wiley & Sons)

11. Heat Exchangers: Selection, Rating, and Thermal Design by Sadik Kakaç, Hongtan Liu, Anchasa Pramuanjaroenkij (CRC Press)
12. Heat Exchanger Design by Arthur P. Fraas, Fraas (Wiley)

Reference Books:

13. Heat Exchanger design handbook by T. Kuppan
14. Compact Heat Exchangers by William M. Kays and A.L. London, (Krieger Publishing Company)
15. Fundamental of Heat Transfer – Frank P. Incropera, David P. Dewitt

Course Name: CAM
Course Code: *ME662*
Unit I: Computer Aided Manufacturing
CAM Concepts, Objectives & scope, Nature & Type of manufacturing system, Evolution, Benefits of CAM, Role of management in CAM, Concepts of Computer Integrated Manufacturing, Impact of CIM on personnel, Role of manufacturing engineers, CIM Wheel to understand basic functions.

Unit II: NC/CNC Machine Tools
NC and CNC Technology: Types, Classification, Specification and components, Construction Details, Controllers, Sensors and Actuators, CNC hardware: Re circulating ball screw, anti friction slides, step/servo motors. Axis designation, NC/CNC tooling. Fundamentals of Part programming, Types of format, Part Programming for drilling, lathe and milling machine operations, subroutines, do loops, canned Cycles, parametric sub routines

Unit III: Programmable Logic Controllers:
Relay Device components, Programmable controller architecture, programming a programmable controller, tools for PLC logic design

Unit IV:Group Technology and CAPP
Introduction, part families, part classification and coding systems: OPITZ, PFA, FFA, Cell design, rank order clustering, composite part concepts, Benefits of group technology. Approaches to Process Planning, Different CAPP system, application and benefits

Unit V:Flexible Manufacturing System
Introduction & Component of FMS, Needs of FMS, general FMS consideration, Objectives, Types of flexibility and FMS, FMS lay out and advantages. Automated material handling system: Types and Application, Automated Storage and Retrieval System, Automated Guided Vehicles, Cellular manufacturing, Tool Management, Tool supply system, Tool Monitoring System, Flexible Fixturing, Flexible Assembly Systems.

Unit VI: Robot Technology
Introduction: Robot Anatomy, Laws of Robot, Human System and Robotics, Coordinate system, Specifications of Robot. Power sources, actuators and Transducers, Robotic Sensors, Grippers, Robot Safety, Robot Programming and Robot Applications, Economic Considerations of Robotics system, Robot Kinematics and Dynamics, Robot Arm Dynamics. Concepts of Computer Vision and Machine Intelligence.

Unit VII: Integrated Production Management System:
Introduction, PPC fundamentals, Problems with PPC, MRP-I, MRP-II. Just in Time philosophy:

JIT & GT applied to FMS, concepts of Expert System in Manufacturing and Management Information System

Text/References:

1. CAD/CAM: Computer-Aided Design and Manufacturing by M Groover and E. Zimmers, Pearson Education, 1983.
2. CAD/CAM in Practice by A J Medland, Springer science and media, 2012.

Department of Computer Science & Engineering

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

The department of Computer Science and Engineering was established in 1987. The department of Computer Engineering offers M. Tech., M.Sc.(by Research) and Ph.D. programs for DRDO scientists, tri-services and GATE qualified students. Currently, there are 06 faculty members in the department. Five faculty members have PhD degrees and one is pursuing the PhD programs in DIAT. Currently, the department has 20 PhD research scholars and 47 M.Tech. students.

The thrust areas of the department are Cyber Security, Ethical Hacking, Information Warfare, Network Centric Warfare, Cryptography, Network Security, Information Security Management Systems, Digital Forensics, Malware Analysis, Multimedia Security, Wireless Security. The faculty are also actively working in the following domains: Computational Intelligence, Machine Learning, Artificial Intelligence, SAR Imaging, Data Mining, Trusted Computing, Secure Software Engineering, Cloud Security, Program Analysis, Malware Analysis, High Performance Computing, Soft Computing, Modeling and Simulation, Social Network Analysis etc.

The department has successfully organized Two Weeks short term training course on Artificial Intelligence and Machine Learning for NTRO (National Technical Research Organization) in Oct 2019; NCECE 2016 (National Conference on Electronics and Computer Science – Theme: Defence Applications) Sponsored by BEL and NCSDAQC 2017(National Cyber Security Seminar, Debate and Quiz Contest) during July 2017 sponsored by DRDO. The Department has also conducted several workshops on Ethical Hacking, Cyber Security, Nine Algorithms, IT and Defence etc. The department had received NVIDIA academic research grant, 2018 for deep learning based research activities.

The department of Computer Engineering is associated with the data center activities to facilitate the email, WiFi, internet, web hosting, etc. to the DIAT campus. The establishment of National Knowledge Network facility, Virtual Classroom with Video Conferencing, campus-wide Wi-Fi connectivity, PHMC CCTV facility in DIAT are important initiatives of Computer Engineering department.

The M. Tech. degree in Computer Science and Engineering had started in the academic year 2009 and the two batches have passed out till June 2012. The department has started M.Tech. with specialization in Cyber Security since July 2011. The first batch passed out in June 2013. The department has started M.Tech. with specialization in Software Engineering and Intelligent Systems since July 2017. More than, 120 students have been graduated with M.Tech. degree from the department till now. The department has very good relations with industry, DRDO labs and other academic institutes, hence has a strong placement record.

M.Tech. in Computer Science and Engineering (Cyber Security)

Brief Description:

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.

Program Objectives:

The MTech(Cyber Security) programme aims at developing Human Resources in the field of Cyber Security with a thrust on defence related problems. The present programme is conceived to understand, assimilate & use the advanced technologies to design and develop secure systems, comprehend different types of cyber attacks, methods and technologies to develop secure IT infrastructure. Advanced technologies from domains such as Network security, Cryptography, Ethical Hacking, Digital Forensic, Malware Analysis, Information Security Management and Trusted Computing techniques have been selected. After completing this course, students are expected to understand and practice the essential concepts related to Information Security, Incident Responses, Digital Evidence Analysis, Cyber Attacks, Design and Development of secure systems, Penetration Testing etc.

Pre-requisites/Eligibility: Fulltime BE/B.Tech. in Computer Science/Electronics /Electrical/ Communication/Telecommunication/ Information Technology or Fulltime M.Sc./MCA in Computer Science with valid gate score in CS/ECE.

Program Outcome: To generate highly skilled manpower, not only to research, design, develop and test reliable secure systems but also to install, deploy, utilize & maintain them throughout their life span to support information security throughout the organization.

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 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 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.

<u>Semester I</u>

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	CE660	Advanced Computer Networks	3	1	4
2	CE662	Operating System Security	3	1	4
3	CE663	Applied Cryptography	3	1	4
4	CE665	Security Standards & Audits	3	1	4
5	CE680	Data Mining Techniques	3	1	4
6	AM607	Mathematics for Engineers	3	1	4
		Total	18	6	24

<u>Semester II</u>

Sl. No.	Course Code	Course	Contact hours / week		Credits
			L	T/P	
1	CE664	Network Security	3	1	4
2	CE682	Secure Software Engineering	3	1	4
3	CE69C	Ethical Hacking and Penetration Testing	3	1	4
4	CE684	Digital Forensics	3	1	4
5		Elective-I	3	1	4

6		Elective-II	3	1	4
		Total	18	6	24

* 04 week industrial practice school during summer vacation for scholarship students.

Semester III

Sl. No.	**Course Code**	**Course**	**Contact Hours /week**		**Credits**
			L	**T/P**	
1	CE 651	M.Tech. Dissertation Phase I			14
		Total			14

Semester IV

Sl. No.	**Course Code**	**Course**	**Contact Hours /week**		**Credits**
			L	**T/P**	
1	CE 652	M.Tech. Dissertation Phase II			14
		Total			14

List of Electives Semester-II

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	AM 625	Digital Image Processing
8	AM 628	Computational Number Theory and Cryptography
9	EE 612	Advanced Wireless Communication
10	EE 613	Electronic Warfare
11	EE 618	DSP System Design
12	TM 609	System Engineering
13	TM 611	Software Projects Management
14	CE 667	Trustworthy Computing
15	CE 688	Game Theory
16	CE 692	Computational Geometry & Applications
17	CE 694	Big data Analysis & Algorithms
18	CE 695	Cyber-Physical & Self-Organising Systems
19	CE 69F	Theory of Computation
20	CE 697	Biometric Security
21	CE 698	Multimedia Security
22	CE 699	Internet of Things
23	CE 69B	Network Forensics
24	CE 604	Computational Intelligence
25	CE 632	Computer Vision
26	CE 70A	Formal Specification and Verification of Programs
27	CE 70B	Advanced Algorithms
28	CE 700	Quantum Computing
29	CE 70D	Computer Network Audit & Forensics

30	CE 70E	Machine Learning in Python
31	CE 70F	Cloud Computing
32	CE 70G	Blockchain Technology
33	CE70H	Cyber Security and Cryptography for Embedded Systems

CE 660 Advanced Computer Networks

Course Objective:
To meet end-user, Network-Administrator & Network-Designer perspectives, develop skill sets to be resourceful in the area of Cyber-Security. Enhance analytical capabilities to evaluate a Network and Network Enabled Operations to analyze Network Centric Operations.

Prerequisites:
Preliminary knowledge Electronic Communications (Graduation Level), Computer Networks (Graduation Level) & IPV4, Networking Devices, Finite State Automata, Socket Programming, Algorithms

Teaching Method:
Class room instructions, learning through assignments, learning through hands-on sessions, learning through online recommended courses to complement the class room instructions

Short Recapitulation on topics before the start of the Course: Architecture of Computer Networks, ISO/OSI and TCP/IP model, IP protocol, transport protocols (TCP, UDP), basic services of computer networks (short recapitulation)

Course Contents:

Unit I
Basic Network-Application Architectures: n-tier, Peer-to-peer networks; Routing in Structured and Unstructured P2P systems and hybrid P2P networks
Unit II
Packet Analysis, Packet Analysis Tools, Network Audit & tools,Network Traffic Engineering, Network Forensics, Network-Audit, Network Analysis and Analytics
Unit III
Advanced features of IPv6 protocol: Mobility and Security, ICMPv6, IPv6 support in applications
Unit IV
Advanced Routing Mechanisms: distance vector, link state and path vector routing; Router Architecture; MPLS, MPLS labels assignment and distribution, MPLS routing
Unit V
AI-Enabled Network Environments, Network Virtualization, SDNs, Sensor Networks, IoT, Evolution in Computing Environments like Cloud, Edge, Fog, Ubiquitous, Pervasive; Futuristic Networks

Text Book:

1. James Kurose & Keith Ross, Computer Networking: A Top-Down Approach (6th Edition), ISBN-13: 978-0132856201 ISBN-10: 0132856204
2. Wireshark Tool Notes, Packet Analysis.

Recommended Readings:

1. "Security Problems in the TCP/IP Protocol Suite" by Steven M. Bellovin, AT&T Labs—Research (http://users.ece.cmu.edu/~adrian/630-f04/readings/bellovin-tcp-ip.pdf). (A look back paper by author is also available at https://www.cs.columbia.edu/~smb/papers/ipext.pdf)
2. "End-To-End Arguments in System Design" by J.H.SALTZER, D.P. REED and D.D. CLARK, Massachusetts Institute of Technology Laboratory for Computer Science. (http://groups.csail.mit.edu/ana/Publications/PubPDFs/End-toEnd%20Arguments%20in%20System%20Design.pdf)
3. Hubert Zimmermann, OSI Reference Model--The ISO Model of Architecture for Open Systems Interconnection. Communications, IEEE Transactions on (Volume: 28, Issue: 4), Apr 1980, pp. 425 - 432
4. Topic based Research Papers assigned during classroom discussions

References

1. RFCs and Internet Drafts, available from Internet Engineering Task Force.
2. William Stallings, Data and Computer Communications, ISBN 0-13-243310-9.8thEdition
3. Behrouz A. Forouzan, Data Communications and Networking. Latest Edition
4. Andrew S. Tanenbaum, Computer Networks, ISBN 0-13-066102-3. 5th ed
5. Anurag Kumar, D. Manjunath, and Joy Kuri, Communication Networking: An Analytical Approach; Published by Morgan Kaufman Publishers.
6. TCP/IP Illustrated, Volume 1: The protocols by W. R. Stevens, Addison Wesley, 2005
7. TCP/IP Illustrated, Volume 2: The Implementation by G. R. Wright,Addison Wesley, 2005.
8. TCP/IP Illustrated, Volume 3: TCP for Transactions, HTTP, NNTP, and the Unix Domain Protocols, W. R. Stevens, Addison Wesley, 2003.
9. ATM Networks: Concepts, Protocols, Applications by R. Handel, M. N. Huber, and S. Schroeder, Addison Wesley, 1998.(latest 2006)
10. Mobile IP: Design Principles and Practices by C. E. Perkins, B. Woolf, and S. R. Alpert, Addison Wesley, 1997.
11. Design And Validation of Computer Protocols, Gerard J. Holzmann.

CE662 Operating System Security

Objectives:
This course examines what it takes to build a secure operating system and explores the major systems development approaches applied towards building secure OS's including virtualization.

From this course, students will learn:

- Theoretical concepts of operating system security
- Security architectures of current operating systems
- Details of security implementation
- Concept of virtualization
- Security mechanisms in virtual machines

Prerequisites: Operating System Concepts

Syllabus:
Operating System Fundamentals: Process management – Process states, runtime environment, IPC; Memory management – Memory organization, virtual memory concept; File

System; OS kernel architecture. **Introduction to Secure Operating Systems**: Security goals, Trust model, Threat model. **Access Control Fundamentals:** Protection system, Reference monitor concept, Discretionary protection system, Mandatory protection system, Rule-based access control, Role-based access control. **Multics:** Multics security fundamentals, protection system models, vulnerability analysis. **Security in Unix-like and Windows OS:** protection system, authorization, security analysis. **Verifiable Security Goals:** Information flow models, secrecy models, integrity models. **Secure Capability Systems:** Capability system fundamentals, Building secure capability systems. **Security Kernels:** Scomp architecture, Kernel data structure analysis. **Security in Commercial Operating Systems:** Security in Commercial Operating Systems - Microkernel systems, UNIX systems. **Kernel level attack vectors:** Memory exploits, code based attacks. **Case Studies:** Solaris Trusted Extensions, SE Linux, Android security features. **Secure Virtual Machine Systems:** Separation kernels, sandboxing, Multiple Independent Levels of Security, VAX/VMM security kernel architecture.

Text Book:

1. Jaeger, T., “Operating System Security”, Morgan & Claypool (online), 2008.

Reference Material:

1. Morrie Gasser: "Building a Secure Computer System"
2. Silberschatz and Galvin: "Operating System Concepts", Addison Wesley, 2006
3. Virgil Gligor’s Lectures on Security Policies.

CE663 Applied Cryptography

Course Objectives: Understanding of basic encryption schemes and issue related to cryptanalysis

- Private keys encryption schemes
- Public keys encryption schemes
- Elliptic Curve Cryptography
- Hash algorithms

Be able to determine the strength and weakness of the encryption schemes.
Course Prerequisites: Basic understanding of Mathematics concept like Prime numbers, Group, Ring and Fields

Syllabus:
Classical Encryption Techniques and their Cryptanalysis : Symmetric cipher model, Substitution techniques, Transposition techniques, Rotor machine, Steganography, One-Time Pad (Vernam’s Cipher), Limitations of Perfect Secrecy, Shannon’s Theorem. **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 Known Attacks on Full DES, Increasing the Key size for DES, Modes of Operation. **Number Theory:** Prime numbers and factoring, modular arithmetic, computations in finite fields, Discrete logarithms. **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. **Hash Functions:** Definition and Properties, Constructions of Collision-Resistant Hash Functions, Popular Uses of Collision-Resistant Hash Functions, Random Oracle Model. Hash algorithms: MD5, SHA-256. **Message**

Authentication: Message Authentication Codes Definitions, Constructions of Secure Message Authenticate Codes, Practical Constructions of Message Authentication Codes. **Digital Signatures and Applications:** Definitions, Constructions, Certificates and Public-Key Infrastructure, Combining Encryption and Signatures – SignCryption. Quantum techniques in Cryptography.

New Additions: AES and Quantum Cryptography

Text Book:

1. "Cryptography & Network Security" by William Stallings 4th Edition, 2006, Pearson Education Asia.
2. Kahate A, "Cryptography & Network Security", Tata McGraw Hill, 2004.

Reference Books

1. "Applied Cryptology" by Schiner Bruce, John Wiley & Sons, 2001.
2. "Introduction to Cryptography with Coding Theory" by Wade Trappe & Lawrence CWashington, New Jersey, Pearson Education, 2006.
3. Charlie Kaufman, Radia Perlman and Mike Speciner, "Network Security: PrivateCommunication in a Public World", Prentice Hall of India Private Limited.
4. Behrouz A. Forouzan, "Cryptography and Network Security", McGraw Hill
5. Jonathan Katz and Lindell, "Introduction to Modern Cryptography: Principles and Protocols",Chapman and Hall/CRC

CE665 Security Standards & Audits

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. Student will learn various countermeasures/tools/mechanisms/best practices used for implementing and managing information security. Students will also learn to design, implement, integrate and manage various security infrastructure components through hands-on activities in Information Security Laboratory.

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 and cyberlaws.

Prerequisites: Basic computer networking, operating systems and computer programming knowledge is required.

Syllabus:

Introduction to Information security, Concepts, Threats, Attacks, and Assets, Security Functional Requirements, A Security Architecture for Open Systems, Computer Security, Access Control Principles, Access Rights, Discretionary Access Control, Role-Based Access Control, Mandatory Access Control, Trusted Computing and Multilevel Security, Security Models for Computer Security, Countermeasures, Cryptographic Tools, Database Security, Intrusion Detection and Intrusion Prevention Systems, Software Security, Operating System Security, Digital rights management, Identity Management, privacy protection, Information Assurance, pillar of information assurance, Defense-In-Depth strategy , Orange Book, Common Criteria for

Information Technology Security Evaluation, COMSEC policies, Information security management systems (ISMS), ISO27000 standards, Management responsibility, Responsibilities of Chief Information Security Officer (CISO), Security audits and assurance, Information Security Policy, Standards, and Practices, Asset Management, Human Resource Security, Security awareness training, Physical Security, Operations Security, Incident Response Management, Risk Management, contingency planning, Business continuity planning, Disaster Recovery planning.

Text Book:

1. Michael E Whitman, Herbert J Mattord, “Principles of Information Security”, Course Technology, 3rd Edition, 2008.
2. William Stallings and Lawrie Brown, “Computer Security: Principles and Practice”, 2nd edition, Pearson, 2012.
3. Krutz, R. L. & Vines, R. D., “The CISSP and CAP Prep Guide”, Platinum Edition, New York, Wiley Publishing., 2006.
4. Nina Godbole, “Information Systems Security: Security Management, Metrics, Frameworks and Best Practices”, Wiley India Pvt Ltd, 2012.

Reference Books:

1. Various Security Standards - ISO 27000 series published by ISO.
2. Department of Defense Standard, Department of Defense, “Trusted Computer System Evaluation Criteria”, Orange Book.
3. Dieter Gollmann, “Computer Security”, John Wiley and Sons, Inc., 3rd edition, 2011
4. Dhavale, S. V. (2019). Constructing an Ethical Hacking Knowledge Base for Threat Awareness and Prevention (pp. 1-305). Hershey, PA: IGI Global.

Research paper for study (if any) - White papers on information security assurance from IEEE/ACM/IBM sources. Important website for reference & Study (if any) - ISACA website.

CE 680 Data Mining Techniques

Course Objectives:

- To learn the advanced techniques w.r.t. the applications in different fields
- To implement those techniques using MATLAB/C/C++ and test them on bench-marked datasets.
- To validate their understanding in terms of developing atleast 2/3 functionalities in Cyber Security domain using Open-Source Tool

Pre- Requisites:

Knowledge of Statistical Techniques, Probability Theory, Data Structures and Algorithms.

Syllabus:

Unit I: Introduction to Data Mining and Pattern Recognition Systems.

Unit II: Classification: Linear Classifiers and Non-Linear Classifiers, Bayes Decision Theory, Decision Trees, Random Forest Trees, Neural Networks, Support Vector Machines

Unit III: Association Rules and Pattern Mining: Apriori algorithm, Frequent Pattern Mining using FP growth algorithm, Basic concepts of Temporal Data Mining.

Unit IV: Clustering Algorithms: Partitioning Methods, Hierarchical Methods, Density based Methods, Grid Based Methods, Model Based Methods, Clustering high dimension data**.**

Unit V:Data Mining for Cyber Security: Adversarial Learning methods for Intrusion detection, Fraud Detection, Anomaly detection, Spam detection, Malware Detection.

Text Book:

1. Jiawei*Han,* MichelineKamber, and Jian Pei, Data Mining: Concepts and Techniques, 3rd Edition, Morgan Kaufmann, 2011.

Reference Books:

1. S Theodoridis and K Koutroumbas, ―Pattern Recognition‖, 4th Edition, Academic Press, 2009.
2. http://www.cs.ubc.ca/~nando/540-2013/lectures/l8.pdf
3. http://www.cs.ubc.ca/~nando/540-2013/lectures/l9.pdf
4. Roddick, J., Spiliopoulou, M. ―A Survey of Temporal Knowledge Discovery Paradigms and Methods‖, In IEEE Transactions of Knowledge and Data Engineering, vol. 13, 2001.
5. Anoop Singhal, ―Data Warehousing and Data Mining Techniques for Cyber Security‖, Springer US, 2007.
6. N. Dalvi, P. Domingos, Mausam, S. Sanghai, and D. Verma. Adversarial classification. KDD '04
7. Richard ODudaand Peter EHart, ―Pattern Classification‖, 2ndEdition,Wiley-Interscience, 2000.

CE664 Network Security

Course Objectives: Understanding of basic issues, concepts, principles, and mechanisms in network security.

- Basic security concepts
- Authentication
- Access control
- IPsec and Internet key management
- SSL/TLS
- Firewall
- Malicious Software
- Intruder Detection Systems

Be able to determine appropriate mechanisms for protecting networked systems.

Course Prerequisites: Basic understanding of Computer Networking and Cryptography

Introduction: OSI security Architecture, Security Principles, Security Attacks, A model of Network Security, Qualities of Good Network, **Security at the Application Layer:** Email Architecture, PGP, S/MIME, **Security at the Transport Layer:** SSL Architecture, TransportLayerSecurity, SecureElectronicTransactions, **Security at Network Layer:** Internet Key Exchange(ISKMP), **Intruder Detection:** Intruder Detection Systems, **Malicious**

Software: Password Management Viruses and related threats, Virus Counter Measures, Distributed Denial of service attack, **Firewall:** Firewall design principles, Trusted systems, Security Evaluation Common criteria, **Authentication:** Kerberos V4, Kerberos V5, X.509 Authentication, Public Key Infrastructure, **PhysicalLayer Security:** Securecommunicationovernoisychannel, Channelcodingforsecrecy, Secretkeyagreement, Activeattacks, Physicallayersecurityandclassicalcryptography, **Networking Security:** Networkcodingbasics, Systemaspectsofnetworkcoding, Practicalnetworkcodingprotocols, SecurityVulnerabilities, Securingnetworkcodingagainstpassiveattacks, Fundamentalsofcodingtheory, **WirelessSecurity:** WirelessLANSecurity, **WebSecurity:** SSL/TLS, SecureHTTP, **Gathering Information:** Network Reconnaisance, Traceroute, Port Scanning, ICMP Scanning, Sniffing, Probing Routers, **Attacks:** DOS Attacks, IP Spoofing, TCP Wrappers, Password Cracking, Windowsand Unixattacks, Keylogger ,inputvalidationattacks, BufferOverflowattacks, Logfilehacking, Game Theory and Network Security.Cloud Security.

Text Books:

1. B. Menezes, “Network Security and Cryptography”, Cengage, 2013.
2. B.A. Forouzan and D. Mukhopdhyay, “Cryptography and Network Security”, 2nd Edition, McGraw Hill,2010.

Reference Books:

1. Fadia, “Network Security: A Hacker’s Perspective”, Second Edition, Macmilan, 2013.
2. W. Stallings, “Network Security Essentials”, 2nd Edition, Pearson Education.
3. Bragg et al, “ Network Security: The complete Reference”, McGraw Hill Osborne, 2003.

CE682 Secure Software Engineering

Course Objectives:

Students will acquire an understanding of the fundamental concepts for developing secure systems

- Introduce security requirements, Security Policies, Architecture of Secure Software and Boot Integrity
- Attacker models
- Fundamentals of data protection and privacy.

Course Prerequisites:

C programming and debugging. Basic concept of Operating Systems.

Syllabus : Fundamentals of Software Engineering: Requirements Engineering, Design Concepts, Software Testing Fundamentals. Confinement, Boot integrity, Architectural approaches to building secure Software, Dynamic Root of trust for Measurement, Run- time enforcement of Security Policies, Software only root of trust (SWORT), Usable and Secure Password, Security Protocols and Verification, Static Analysis of software, Combining static and dynamic analysis, Control Flow Integrity, Language based Approaches to building Secure Software.VAPT analysis, secure coding techniques,

Text / Reference Books:

1. Software Engineering - Roger S Pressman - 5th edition.
2. An Integrated Approach to Software Engineering, PankajJalote Third Edition, NarosaPublishing House
3. The security Development Lifecycle, by Michael Howard and Steve Lipner

4. Security in Computing, By Charles P. Pfleeger , Shari Lawrence Pfleeger, Publisher: PrenticeHall Print ISBN-10: 0-13-239077-9
5. Threat Modeling by Frank Swiderski, Window Snyder, Microsoft Press, ISBN-10:0735619913
6. Research Paper and Articles in Journals and Conference Proceedings.

CE 69C Ethical Hacking & Penetration Testing

Course Objectives:

The threats from hackers, spies, terrorists, and criminal organizations against our information assets are undeniable. The serious consequences like identity theft, theft of sensitive/proprietary information/trade secrets or loss of reputation/credibility in the market; may result from these attacks. A single malicious attempt by your enemies can bring down any reputed organization or financial institution to a halt, by causing a great damage may be costing in millions of dollars per hour.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 is becoming a need of future cyber security world. The objective of course will be as:
1. To facilitate individual in gaining ethical hacking knowledge base in order to promote a more secure cyberspace interactions.
2. To learn how intruders escalate privilege, how various kinds of attacks like Network Intrusion, DDOS, Malware attacks, Session Hijacking are carried out successfully by attackers.
3. To train individual to become a competent information security professional by learning both theoretical as well as practical ethical hacking knowledge base.

Prerequisites: Basic computer networking, operating systems and computer programming knowledge is required.

Syllabus:

Setting up own virtual ethical hacking lab for experimentation, Ethical Hacking Basics - Hacking terminology & attacks, Ethics, Legality, Phases - Reconnaissance, Scanning, Gaining access, Maintaining access, Covering tracks; Hacktivism, Types of Hacker Classes, Testing Types, Ethical Hacking Report; 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 Scans detecting OS fingerprinting, banner grabbing, Null Sessions, SNMP/DHCP/DNS enumeration, Proxy Servers, Anonymizers, HTTP Tunneling Techniques, IP Spoofing Techniques; Cryptographic Techniques; Attacking System and Maintaining Access – Password/hash cracking, NetBIOS DoS Attacks, Password-Cracking 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- Web server based attacks, Session Hijacking, ARP Poisoning, MAC Flooding, DNS Spoofing; Windows Hacking; Linux Hacking; Web and Database Hacking; Google Hacking; Wireless Hacking; Mobile Hacking; Physical Site Security; Penetration Testing - Penetration Testing Methodologies Security Assessments, Penetration Testing Methodologies, Penetration Testing Steps, Pen-Test Legal Framework , Automated Penetration Testing Tools like Kali Linux, Metasploit ,Pen-Test Deliverables. Clockwork, LDRA and parasoft.

Text Book:

1. Dhavale, S. V. (2019). Constructing an Ethical Hacking Knowledge Base for Threat Awareness and Prevention (pp. 1-305). Hershey, PA: IGI Global.
2. Patrick Engebretson, The Basics of Hacking and Penetration Testing, Elsevier, 2011.
3. Stuart McClure, Joel Scambray, George Kurtz, “Hacking Exposed:n/w sec secrets and solutions”, Mcgraw Hill, 2012
4. CEH official Certified Ethical Hacking Review Guide, Wiley India Edition

Reference Books:

1. David Kennedy, Jim O’Gorman, Devon Kearns, and Mati Aharoni, ”Metasploit pentest guide”, No starch Press, san Francisco, 2011
2. Bastian ballman, “Understanding n/w hacks:attack and defense with python”, Springer,2012
3. Certified Ethical Hacker: Michael Gregg, Pearson Education
4. Certified Ethical Hacker: Matt Walker, TMH.
5. Rich Annings, Himanshu Dwivedi, Zane Lackey, ”Hacking Exponsed Web 2.0”, Tata Mcgraw hill Edition

Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/IBM/EC-Council sources.

CE 684 Digital Forensics

Course Objectives:

- To get into the depth of different domains of digital crimes
- Practically able to detect digital attacks using Commercial/Open -source/Freeware tools
- To build the case-oriented procedures for new-scenerios.

Prerequisites: Knowledge of OS, Assembly Languages like Python, Number System and their Conversions, Internal Structure of CD/DVD.

Syllabus:

Unit I : Introduction to legal issues, context, and digital forensics; Stages of Forensic: acquisition or imaging of exhibits, Preservation, Analysis and reporting standards.

Unit II : Introduction to Computer Forensics: Digital Devices with rudimentary computing power. Acquisition or imaging of Onboard Memory and Static Memory. Online and Live Forensics

Unit V: Media Analysis: disk structure, file systems (NTFS, EXT 2/3, HFS), and physical layer issues; Tools for digital forensics;

Unit III: Database forensics: forensic study of databases and their metadata. Investigative use of database contents, log files and in-RAM data in order to build a time-line or recover relevant information;

Unit IV: Network forensics: Evidence or Intrusion detection from internet logs, monitoring and analysis of network traffic. Introduction to IoT Forensics.

Unit VI: Mobile device forensics: recovery of digital evidence or data from a mobile device.

List of Experiments:

1. Perform Imaging and Analysis of Non-Volatile Memory using Open Source Tools in the absence of Write-Blockers.
2. Perform Imaging and Analysis of Non-Volatile Memory using EnCase/Other Open Source Tools With and Without Write Blockers.
3. Perform Imaging and Analysis of Volatile Memory using EnCase/Other Open Source Tools
4. MFT & Registry Hives Extraction from Windows OS through Tools and Scripts.
5. Data Carving Using Open Source Tools
6. Data Recovery and Secure deletion on Storage media.
7. Hiding Data into Slack Space.
8. Information gathering and network traffic analysis using TCP DUMP and WIN DUMP
9. Attacks and Forensics using IoT devices
10. Explore the Phases of Ethical Hacking in terms of implementing some attack.
11. Solving Case Study using online datasets from digitalcorpora.org

Text Books:

1. Kanellis, Panagiotis, “Digital Crime and Forensic Science in Cyberspace”, IGI Publishing, ISBN 1591408733.
2. Brain Carrier, “File System Forensics Analysis”, Addison-Wesley Professional, 1st Edition, 2005
3. Marshell, Angus M. (2008), “Digital Forensics: Digital Evidence in Criminal Investigation”, Wiley-Blackwell, ISBN 0470517751.

Reference Books:

1. Paul Crowley Dave Kleiman, “CD and DVD Forensics”, Syngress Publishing Inc, 2007
2. Chris Prosise, Kevin Mandia “ INCIDENT RESPONSE & COMPUTER FORENSICS”, McGraw-Hill, 2nd Edition, 2003.
3. Rick Ayers, WayneJansenetal.,"Cell Phone Forensic Tools: An Overview andAnalysis", NISTIR 7250,2010.
4. Paul CrowleyDaveKleiman, “CD and DVD Forensics”,SyngressPublishing Inc,2007.

Elective-I/II

CE669 Reverse Engineering and Malware Analysis

Course Objectives: The course introduces reverse engineering techniques and explores the techniques for detecting, analyzing, reverse engineering and eradicating malware.
Upon completion of the course, students should be able to:

- Have a good understanding of reverse engineering techniques and tools
- Identify the different types of malware analysis methods
- Setup an environment for malware analysis
- Recognize common malware characteristics

Prerequisites: Assembly language programming, OS fundamentals.

Syllabus:

Introduction to reverse engineering, Low level software, Assembly language primer, Compilers, Execution Environments, Windows OS fundamentals, Executable file formats, Static & Dynamic reverse engineering, Reversing tools, Disassemblers, Debuggers, Decompilers, System monitoring tools, Reversing program binaries, Anti-reversing techniques, Breaking protections, Reversing '.NET', De-compilation, Introduction to malware, Software vulnerabilities – buffer overflow, integer overflow, vulnerabilities exploitation, mitigation; Return oriented programming; Reversing malware – Static & Dynamic malware analysis techniques, Packers & compression, Sandboxing executables& runtime analysis; Malware classification.

Text Book:

1. EldadEilam, "Reversing: Secrets of Reverse Engineering", Wiley publishing, 2005.

Reference Books:

1. Michael Ligh, Steven Adair, "Malware Analysts's cookbook & DVD", Wiley publishing
2. Michael Sikorski and Andrew Honig, Practical Malware Analysis, No Starch Press, 2012.
3. Erik Buchanan, Ryan Roemer, HovavShacham, and Stefan Savage. 2008. "When good instructions go bad: generalizing return-oriented programming to RISC."

CE 681 Mobile Computing

Course Objectives: Course provides introduction to the fundamentals of mobile computing, mobile application development as well as wireless communication and security. Students will gain a sound understanding of the core concepts of mobile networks and the design of cellular networks including approaches to maximize the available capacity. The course will look at some current research in mobile computing security and wireless security. Students will learn android application development framework and use it to implement their assignments.

Course Prerequisites: Students are required to gain knowledge of basics of computer networking.

Syllabus:

Principle of Cellular Communication, Overview 1G, 2G, 3G, 4G, LTE, 5G technologies. Wireless Transmission: Frequencies for radio transmission, Signals, Antennas, Signal Propagation, Multiplexing. Modulation, Spread spectrum, Cellular systems. Medium Access Control: Motivation for a specialized MAC, SDMA, FDMA, TDMA, CDMA, Comparison. GSM: Cellular Systems, Mobile Services, System Architecture, Radio Interface, Protocols, Localization and calling, Handover, Security. Data services: GPRS, HSCSD Mobility management: Handoff, Roaming Management, Handoff Detection Strategies, Channel Assignment, Radio Link transfer, GSM Location Update, Mobility Databases, Failure Restoration, VLR Overflow Control. Satellite Systems: GEO, LEO, MEO, Routing, Localization, Handover. Wireless LAN: Infrared and radio transmission, Infrastructure and Ad-hoc network, IEEE 802.11, Bluetooth. Mobile Device Platforms: Mobile OS, Palm Os, Win CE and Symbian. Mobile Network Layer: Mobile IP, Mobile Ad-hoc Networks, Cellular Digital Packet Data (CDPD), Wireless Local Loop (WLL) systems. Mobile Transport Layer: Traditional TCP, Classical TCP Improvements, Mobile-TCP. Wireless Application Protocol (WAP): WAP Architecture, Wireless Markup Language (WML), WML-Script, WAP 2.0. Wireless Network Security: IEEE 802.11 Wireless LAN Attacks, Different Attack Tools, Different Types of Security Mechanisms, Wired Equivalent Privacy (WEP), Wi-Fi Protected Access (WPA), Wi-Fi Protected Access –II (WPA-2), Deploying Secure Wireless networks, Security in Bluetooth, Security in Adhoc Networks. Case Study: Android Application Development, Android Security.

Text/Reference Books:

1. Jochen Schiller, "Mobile Communication", 2nd Edition, Pearson Education.
2. Yi Bing Lin and ImrichChlamtac, "Wireless and Mobile Networks Architecture", John Wiley & sons, 2001.
3. Ed Burnette, "Hello Android", Pragmatic Bookshelf; Third Edition edition, 2010.

4. Yan Zhang, Jun Zheng, Miao Ma, “Handbook of Research on Wireless Security”, Volume 1, Idea Group Inc (IGI), 01-Jan-2008.
5. Raj Kamal, “Mobile Computing”, illustrated edition, Oxford University Press, Oxford higher education, 2007.

CE683 Information Warfare

Prerequisites to study the subject - Students are required to gain knowledge of computer networking and basic concepts of Cyber Security.

Objective of the course/subject - This course will help students in gaining the knowledge of information warfare domain concepts including principles of information warfare (IW), Cyber warfare (CW), Offensive and defensive IW, military espionage, economic espionage, communications eavesdropping, computer break-ins, Open source intelligence, Covert Communication, Surveillance, ethical and legal concepts in the context of CW, Command and Control, Psyops and perception management. They will learn about different countermeasures, ethical hacking tools and techniques. They will form two teams (Red and Blue). One team carries out offensive operations against the; while other team will carry out defensive operations to protect the same information systems.

Syllabus:

Introduction to Information Warfare, Principles of Information Warfare, Conventional Warfare vs. Cyber Warfare, Information Warfare Elements (Information, Media, Computing Facilities, Communication Network, Operations, Warriors/Human Factors), Offensive and Defensive Information Warfare Operations, National Security Threats from State and Non-state Actors, Cyber-Terrorism, Information Warfare Policy, International Laws Governing Information Warfare, Law of War and Cyber Attack, Edward Snowden Revelations, ANT Catalogue, Supply Chain Risks, Open Sources, Open Source Intelligence (OSINT), Active Cyber Defenses, Competitive Intelligence, Piracy and Intellectual Property Rights, Watermarks, Steganography, Covert Communication, Privacy Protection, Subversion Techniques, Psyops and Perception Management, Military Deception, Espionage and Signals Intelligence, Insider Threat, Economic, Corporate, and Military Espionage, Traffic Analysis, Packet Sniffing, Keystroke Monitoring, Environmental Surveillance, Computer Hacking and Cybercrime, Hacking Tools and Techniques, Attacks (Denial of Service, Spoofing, Masquerade, Identity Theft, Trojan Horses, Viruses, Worms, Fraud, Physical Destruction), Security Measures (Anonymity, Sanitization, Trash Disposal, Shielding, Biometrics, Location based Authentication, Digital Signatures, Access controls, Surveillance), Communications Intercepts, Electronic Warfare, Command and Control, C4ISR, Network Centric Warfare, Wireless Security, Adhoc Network Mechanisms for Net Centric Operations, Information Warfare Case studies.

Text Books –

1. D. Denning, "Information Warfare and Security", Addison-wesely, 1999.

Reference Books –

1. Wg Cdr MK Sharma, “Cyber Warfare: The Power of Unseen”, KW Publishers, New Delhi, 2011.
2. Emory A. Anderson, Cynthia E. Irvine, and Roger R. Schell, Roger R,.; “Subversion as a Threat in Information Warfare”, http://calhoun.nps.edu/bitstream/handle/10945/7123/04paper_subversion.pdf
3. Philip A. Myers, “Subversion: The Neglected Aspect of Computer Security”, Phd Thesis, Naval Postgraduate School, California, June 1980, http://csrc.nist.gov/publications/history/myer80.pdf
4. Dr. Roger R. Schell, “Information Security: Science, Pseudoscience, and Flying Pigs”, https://www.acsac.org/invited-essay/essays/2001-schell.pdf

5. NSA ANT Catalog: NSA's ANT Division Catalog of Exploits for Nearly Every, http://leaksource.info/2013/12/30/nsas-ant-division-catalog-of-exploits-for-nearly-every-major-software-hardware-firmware/
6. Research paper for study (if any) - White papers on cyberwarfare from IEEE/ACM/IBM sources.
7. Important website for reference & Study (if any) - ISACA website.

CE 689 Fault Tolerant Computing System

Syllabus

1. Introduction: Motivation, System view of high availability design, Terminology
2. Hardware redundancy: Basic approaches, Static & Dynamic, Voting, Fault tolerant interconnection network. Application: FTMP
3. Error detection techniques: Watchdog processors, Heartbeats, Consistency and capability checking, Data audits, Assertions, Control-flow checking Application: DHCP
4. Software fault tolerance: Process pairs, Robust data structures, N version programming, Recovery blocks, Replica consistency & reintegration, Multithreaded programs Application: HP Himalaya Servers
5. Network fault tolerance: Reliable communication protocols, Agreement protocols, Database commit protocols Application: Distributed SQL server
6. Practical steps in design of high availability networked systemsApplication: Web services, Highly available clusters
7. Check pointing& Recovery Application: Microcheckpointing
8. Attack dimension to failures, byzantine generals problem, in context of side-channel attacks study fault induced leads to catastrophic failure
9. Case Studies

Text Book:

1. Koren and C. Mani Krishna, Fault-tolerant Systems, 1st edition, 2007, Morgan Kaufmann.

Reference Book:

1. D. P. Siewiorek and R. S. Swarz, Reliable Computer Systems - Design and Evaluation, 3rd edition, 1998, A.K. Peters, Limited.
2. D. K. Pradhan, ed., Fault Tolerant Computer System Design, 1st edition, 1996, Prentice-Hall.

CE 690 Parallel and Distributed Systems

Course Objective

To meet end-user, Administrator & Designer perspectives. Enhance analytical capabilities to evaluate a system.

About the Course: The study of Parallel and Distributed Systems investigates software architectures to support flexible parallel and distributed applications, which can adapt themselves for execution in dynamically changing, heterogeneous environments. The study targets the diverse environments ranging from scalable clusters of commodity workstations to dynamic aggregations of computing and information resources, emphasizing the interactions between hardware, operating systems, and applications. The study includes efforts to build fault-tolerant programming systems, compiler-assisted object caching systems, application-structuring mechanisms for adaptation in dynamic environments, and transparent secure distribution middleware for general-purpose applications. These projects encompass a gamut of approaches from fundamental research through prototypes, up to working usable systems.

Pre-requisites: CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations, Fundamental Computer architecture, programming environments, computer networks

Syllabus:

Unit I: Introduction to various Network Enabled Operations, Network Centric Operations, n-tier, P2P Systems; State of Art Examples and their types: GIS systems, MIS systems, Nature of Parallelism and Distributed Environment Models.

Unit I:Unit II: Parallel Architecture, Parallel Algorithms, Parallel Databases, Distributed Architecture, Distributed Systems, Distributed Databases

Unit III: Systems modeling and Virtualization, Clusters for Scalable Parallel Computing, Virtual Machines, Virtualization Of Clusters

Unit IV: Data Centers, Computing Clouds, Service-Oriented Architectures, Service-Oriented Architectures for Distributed Computing

Unit V: Cloud Programming and Software Environment, Grids, P2P, Future Internet, Peer-To-Peer Computing and Overlay Networks, Ubiquitous Cloud and Internet of Things. Fog and Edge Computing.

Unit VI: Adhoc Distributed & Self-Organising Environments, Pervasive and Ubiqutious Computations, Environments

Text book:

1. Kai Hwang, Geoffrey C. Fox, and Jack J. Dongarra, —*Distributed and Cloud Computing: From Parallel Processing to the Internet of Things*‖, MorganKaugmann Publications, 2012
2. Hwang, Kai, and Zhiwei Xu. *Scalable parallel computing: technology, architecture, programming*. McGraw-Hill, Inc., 1998.

Papers:

1. Fox, Geoffrey C. "Large scale data analytics on clouds." *Proceedings of the fourth international workshop on Cloud data management*. ACM, 2012.
2. Shanker, Udai, Manoj Misra, and Anil K. Sarje. "Distributed real time database systems: background and literature review." *Distributed and parallel databases* 23.2 (2008): 127-149.
3. Research Papers discussed in the classroom discussions.

CE 691 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:

Part 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.

Part 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

Part 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.

CE667 Trustworthy Computing

Course Prerequisites: Basic understanding of Boot Process, Shell Programming and Formal Methods, Fundamentals of OS.

Course Objectives: Understanding of TPM capabilities, as well as other trusted computing standards and technologies

- Secure/Trusted/ Verified Boot
- Remote Attestation
- Use of open source tools for development of trusted process

Be able to maintain and to develop trusted systems.

Syllabus:

Introduction to trusted computing, Techniques for recording platforms state: Recording code identity, Recording dynamic properties. Use of platform information: Secure boot, Storage access control based on code identity. Information from platform states. Roots of trust: General-purpose tamper- resistant and Tamper-responding devices, General –purpose devices without dedicated physical defenses, Special-purpose minimal devices, Research solutions without hardware support. Challenges in bootstrapping trust in secure hardware: Problem definition, Potential solutions. Validating the process. Implementing trust bootstrapping: Open source tools. Human factors & usability, Limitations: Load-time versus run-time guarantees , Hardware attacks.

Text Books:

1. Bryan ParnoJonathan M. McCune, Adrian Perrig, "Bootstrapping trust in ModernComputers", Springer Briefs in ComputerScience.
2. D.Challener,K.Yoder,R.Catherman,D.Safford,andL.vanDoorn,"APracticalGuide toTrusted Computing", IBM Press, 2008.

Reference Books:

1. DynamicsofaTrustedPlatform:ABuildingBlockApproach,DavidGrawrock,IntelPress;1stedition, ISBN:1934053171.

CE 688 Game Theory

Course Objectives: To understand the concepts of Game Theory and get an overview. To learn and appreciate the applications of game theory in Network Security.

Prerequisites: Basic understanding of Computer Networking and Network Security

Syllabus:

Network Security Concepts: Networks and Security Threats, Networks and World Wide Web, Security Threats, Attackers, Defenders, and their Motives, Attackers, Defenders, Defense Mechanisms, Security Tradeoffs and Risk Management, Security Tradeoffs, Security Risk Management, **Introduction to Game Theory**: What is Game Theory? Game Theory Classification, Introduction to Non-Cooperative Game Theory, General Formulation for Non-cooperative Games, Existence of Nash and Saddle-Point Equilibria in Finite Games, Existence and Uniqueness of Equilibria in Infinite Games, Prisoner's Dilemma, Co-operative Game Theory, Shapley Value, **Deterministic Security Games**: Security Game Model, Intrusion Detection Games, Matrix Games, Games with Dynamic Information, Sensitivity Analysis, Modeling Malicious Behavior in Social Networks, Security Games for VehicularNetworks, Vehicular Network Model, Attack and Defense Model, Game Formulation and Numerical Analysis, Security Games in Wireless Networks, Random Access Security Games,Interference Limited Multiple Access Security Games, Revocation Games, Discussion and Further Reading, **Stochastic Security Games**: Markov Security Games, Markov Game Model, Solving Markov Games, Stochastic Intrusion Detection Game, Security of Interconnected Systems, Analysis of an Illustrative Example, Linear Influence Models, Malware Filter Placement Game, Stochastic Game Formulation, Simulations. **Decision Making for Network Security**, **Security Risk Management** , Quantitative Risk Management, Risk in Networked Systems and Organizations, A Probabilistic Risk Framework, Dynamic Risk Mitigation AndControl, Security Investment Games, Influence Network and Game Model, Equilibrium and Convergence Analysis, Incentives and Game Design, Cooperative Games for Security Risk Management, Coalitional Game Model, Coalition Formation under Ideal Cooperation**Resource Allocation for Security:** An Optimization Approach To Malware Filtering, Traffic Centrality Measures, Filtering Problem Formulations, A Robust Control Framework for Security Response, Network Traffic Filtering Model, Derivation of Optimal Controller and State Estimator, Optimal and Robust Epidemic Response, Epidemic Models, Feedback Response for Malware Removal, Multiple Networks, **Machine Learning for Intrusion and Anomaly Detection:** Intrusion and Anomaly Detection, Intrusion Detection and Prevention Systems, Open Problems and Challenges, Machine Learning for Security: An Overview, Overview of Machine Learning Methods, Open Problems and Challenges, Distributed Machine Learning, SVM Classification and Decomposition, Parallel Update Algorithms, Active Set Method and A Numerical Example, Behavioral Malware Detection.

Text Books:

1. T. Alpcan and T. Basar, “Network Security: A decision and Game Theoritic Approach”, Cambridge University Press.
2. M. Osborne, “AN Introduction to Game Theory”, Oxford University Press, 2003.

Reference Books:

1. Bragg et al, “ Network Security: The complete Reference”, McGraw Hill Osborne, 2003.
2. B. Singh, “Network Security and Management”, Third Edition, PHI, 2013.
3. B.A. Forouzan and D. Mukhopdhyay, “Cryptography and Network Security”, 2nd Edition, McGraw Hill, 2010.
4. A. Dixit et al., “Games of Strategy”, Third Edition, W Norton Publishers, 2009.

CE 692 Computational Geometry and Applications

Pre-requisites:

The students are assumed to have a basic knowledge of the design and analysis of algorithms and data structures. No knowledge of the application domains is required, and hardly any knowledge of geometry. The analysis of the randomized algorithms requires very elementary knowledge of probability theory.

Syllabus:

Geometric primitives, Line intersection, randomized incremental concepts, Triangulation and visibility, Linear programming in two and three dimensions, Orthogonal range searching, Point location and Binary Space Partitions, Voronoi diagrams and Delaunay triangulation, Convex hulls, Non-orthogonal range searching

Text Book:

1. "*Computational Geometry: Algorithms and Applications*", Third Edition (March 2008),Mark de Berg, TU Eindhoven (the Netherlands), Otfried Cheong, KAIST (Korea), Marc van Kreveld, Mark Overmars, Utrecht University (the Netherlands), Springer-Verlag

CE 694 Big Data Analysis & Algorithms

Course Objective

To meet end-user, Administrator & Designer perspectives, develop skill sets to be resourceful in the area of knowledge, information systems. Enhance analytical capabilities to evaluate a domain specific technical and expertise areas. Multi-Disciplinary Course useful to any engineering discipline who use a computer.

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.

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 SophosLabs, 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.

Intended Audience:CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations

Pre-Requisites: Basic programming knowledge, Data Structure, Programming, Statistical Techniques

Course Contents:

Unit I : Introdution to big data analysis: Evolution of data, data streams, structured & unstructured data, database models, graph data, normalizations

Unit II: Big data analytics platforms: Architectures, Frameworks that enable big data analytics

Unit III: Big data analytics storage & processing: 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 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, 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 V: Big data analytics tools, HDFS, NOSQL, SQL environments

Text Book:

1. 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

References:

1. Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006
2. Introduction To Algorithms, Thomas H. Cormen, Charles E. Leiserson, Ronaldo L. Rivest, Clifford Stien 2nd Edition
   Course
3. Research Papers discussed in the classroom discussions.

Course links & References:

1. https://iveybusinessjournal.com/publication/why-big-data-is-the-new-competitive-advantage/
2. https://www.datameer.com/company/datameer-blog/challenges-to-cyber-security-and-how-big-data-analytics-can-help/
3. https://www.iss.nus.edu.sg/executive-education/discipline/detail/analytics-and-intelligent-systems

<u>CE 695 Cyber-Physical & Self-Organising Systems</u>

Brief About the Subject: 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 immediately that in CPS, the computational element (cyber) and the environment (physical) are tightly coupled, with one influencing the other. 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. 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).

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 from colliding; its role in Command and Control environments.

Pre-requistes: CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations, Theoretical knowledge of Computer Science and Engineering

<u>Syllabus:</u>

Unit I: CPS**:** Introduction Main Concepts, Challenges; Background role of Computer Networks, Data, Algorithms

Unit II: Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software,

Unit III: Agents and Multi-Agent Systems Computing trends, Data device proliferation, Confluence of trends

Unit IV: 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,

Unit V: Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems

Unit VI: Applications of Self-organising Software, Self-organisation in Constraint Problem Solving, Adaptive Trust Management, Security in Artificial Systems

Text Books:

1. 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
2. “Principles of Cyber-Physical Systems” - Rajeev Alur, MIT Press, 2015
3. Research Papers discussed in the classroom discussions.

Reading assignments:

1. **Introduction:** Brief history of CPS. Motivating problems in CPS.
2. K. Kim and P.R. Kumar, \CyberPhysical Systems: A Perspective at the Centennial," Proceedings of the IEEE , vol. 100, May 2012, p. 1287{1308.
3. E. Lee, \Cyber Physical Systems: Design Challenges", Proceedings of the IEEE Symposium on Object Oriented Real-Time Distributed Computing (ISORC), 2008, p. 363{369.
4. R. Rajkumar, \A Cyber-Physical Future,"Proceedings of the IEEE, vol. 100, May 2012, p. 1309{1312.
5. S. Barnum, S. Sastry, and J. Stankovic, \Roundtable: Reliability of Embedded and Cyber-Physical Systems," IEEE Security and Reliability , September / October 2010, p. 27{32.

Modeling: Continuous systems and discrete event systems.

6. Lygeros, Sastry, and Tomlin, Chapter 2
7. P. Derler, E. Lee, and A. Sangiovanni-Vincentelli, \Modeling Cyber-Physical Systems," Proceedings of the IEEE, Vol.100, no. 1, January2012, p.13{28.

Control over networks

8. R. Alur, A. D'Innocenzo, K. Johansson, G. Pappas, and G. Weiss, \Compositional Modeling and Analysis of Multi-Hop Control Networks," IEEE Transactions on Automatic Control, vol. 56, no. 10, October 2011, p. 2345{2357.
9. J. Hespanha, P. Naghshtabrizi, and Y. Xu, \A Survey of Recent Results in Networked Control Systems," Proceedings of the IEEE, vol. 95, no. 1, January 2007, p. 138{162.
10. Pajic, R. Mangharam, G. Pappas, and S. Sundaram, \Topological Conditions for In-Network Stabilization of Dynamical Systems,"IEEE Journal on Selected Areas in Communications, vol. 31, no. 4, April 2013.
11. G. Hackmann, W. Guo, G. Yan, Z. Sun, C. Lu, and S. Dyke, \Cyber-Physical Codesign of Distributed Structural Health Monitoring with Wireless Sensor Networks,"IEEE Transactions on Parallel and Distributed Systems , vol. 25, no. 1, p. 63{72, January 2014.

Stability of Hybrid and Switched Systems

12. R. A. Decarlo, M. S. Branicky, S. Pettersson, and B. Lennartson, \Perspectives and Results on the Stability and Stabilizability of Hybrid Systems," Proceedings of the IEEE ,vol. 8, no. 7, p. 1069{1082, July 2000.
13. D. Liberzon and A. S. Morse, \Basic problems in stability and design of switched systems," IEEE Control Systems Magazine , vol. 19, no. 5, pp. 59{70, October 1999.
14. M. Branicky, \Multiple Lyapunov functions and other analysis tools for switched andhybrid systems," IEEE Transactions on Automatic Control , vol. 43, no. 4, p. 75{482, April 1998.

15. J. Hespanha, \Uniform Stability of Switched Linear Systems: Extensions of LaSalle'sInvariance Principle," IEEE Transactions on Automatic Control , vol. 49, no. 4, p.470{482, April 2004

Reference Links: https://www.cs.cmu.edu/~aplatzer/course/fcps16.html

CE 69F Theory of Computation

Syllabus:

1. **Introduction**: Motivation, , Terminology, History
2. **Computers and Science of Computing:** Computability, Undecidability, Intractability, and Intelligence
3. **Automata**: Construction, Finite Automata, Limitations of Finite Automata
4. **Non-Deterministic Finite Automata**, Moore Machine, Mealy Machine
5. **Regular Languages and Expressions**: Equivalence, Regular expressions in practice
6. **Grammars**: Parsing and Derivation, Grammar for regular languages, Converting Regular grammar to Automata
7. **Nature of Regular Languages:** Closure properties, Peigeonhole principle, Pumping Lemma, Adversarial Game
8. **Context Free Languages and Grammars**: Context Free Behaviour, CFGs, Ambiguity, Chomsky Normal Form, Simple, Linear and other grammars
9. **Pushdown Automata**: Stack Behviour, Constructing PDAs, CFGs to PDAs, CFL-CFG-PDA Triad
10. **Nature of Context Free Languages**: Closure properties
11. **Turing Machines**: Construction, Definition, Complex Turing Machines, Church Turing Thesis, Universal Turing Machines
12. **The Chomsky Hierarchy**: Languages, Grammars and Machines, Recursive Languages, Idea of Context
13. **Computability and Undecidability**: Halting Problem, P = NP?

Text Book:

1. K. Mahesh, “Theory of Computation: A problem solving approach”, Wiley publishers. 2015

2. Hopcroft, Motwani & Ullman, “Introduction to Automata Theory, Languages and Computation”, 3rd Edition, Pearson, 2007.

Reference Book:

1. M. Sipser, “Introduction to Theory of Computation”, 3rd Edition, Wordsworth Publishing, 2012.

CE 697 Biometric Security

Course Objectives:

Biometrics has emerged as a specialized field in criminal forensics, public safety surveillance, user authentication and identification. Expansions of biometric modalities are ranged from fingerprint, face and other traits to multimodal biometric traits. Objectives of this course to introduce the students different modality based biometric identification systems, to help them to understand the difference between advanced biometric techniques with respect to traditional authentication mechanisms. Students after learning this course would be able to design and develop biometric systems by utilizing inter-disciplinary knowledge related to fields like Pattern Recognition, Image Processing and Machine Learning etc.

Syllabus:

1. **Introduction:** History of Biometrics, Multimodal Biometric Systems, Recent Advances
2. Authentication Technologies, Access Control
3. **Finger Print Biometrics**: Sensors, Dactyloscopy, Types, Algorithms
4. **Handwriting biometrics**: Static and Dynamic Recognition
5. **Iris Biometrics**: Retinal Scanning, Visible and Near Infra red Imaging, Operating Principle, Advantages and Shortcomings
6. **Voice Biometrics**: Verification versus Identification, Text Dependent and Text Independent, Technology, Applications
7. **Face Recognition**: Techniques for Face Acquisition/Recognition, Advantages and Disadvantages, History, Anti-facial recognition
8. **DNA finger printing/ Profiling**: Process, DNA Database, DNA evidence,
9. **Statistical Measures for Biometrics**:
10. **Biometric Devices**: Personal, Handheld, Biometric spoofing, Accuracy

Text Book:

1. P. Reid, “Biometrics for Network Security”, Prentice Hall, 2014.
2. J. Chirrillo and S. Blaul, “Implementing Biometric Security”, Wiley, 2013.

Reference Book:

2. AK Jain, “Introduction to Biometrics”, Springer, 2011.
3. J. Ashborn, “Biometrics: A Complete Guide”, Springer, 2003

CE 698 Multimedia Security

Course Objectives:

1. To facilitate individual in gaining knowledge on digital watermarking, steganographic and encryption techniques on multimedia signals like image, audio and video for digital rights management applications.
2. To facilitate individual in gaining knowledge on forensics on multimedia signals like image, audio and video for multimedia tamper/forgery detection applications.
3. To teach biometric security concepts. Student will learn and implement various algorithms using MATLAB, Python during hands-on activities carried in the Laboratory.

Prerequisites: Basic computer programming knowledge is required.

Syllabus:

Steganaography and Steganalysis; Information Hiding, Digital Watermarking – Basics of host Image/Video/Audio signals, Multimedia compression and decompression, Lossless compression, Models of watermarking, watermark detection by correlation; message coding, Mapping message in message vectors, Error correction coding, Detecting multi-symbol watermarks, Watermarking with side information, Informed embedding, Informed coding; Structured dirty-paper codes, Analyzing errors, Message errors, ROC curves, The effect of whitening on error rates, Analysis of normalized correlation, Using perceptual mode, Evaluating perceptual impact of watermarks; General forms of perceptual model, Perceptual adaptive watermarking, Robust watermarking, Spread Spectrum Watermarking, DCT-Domain Watermarking, A Buyer-Seller Watermarking Protocol, Text/Image/Video/Audio watermarking, Watermark security and cryptography, Content authentication, Applications: Digital Right Management Products & Laws, copyright protection; traitor tracing; tamper proofing; copy control; Signal processing attacks. Machine learning approaches in multimedia security, Intelligent Techniques for watermarking.

Multimedia Encryption, Image/audio/video Forensic and forgery detection, Biometric Security-Introduction to Biometrics, Fingerprint Recognition, Face Recognition, Iris Recognition, Hand Geometry Recognition, Gait Recognition, The Ear as a Biometric, Voice Biometrics, A Palm print Authentication System, Online Signature Verification; Introduction to Multi biometrics, Multi biometrics Using Face and Ear, The Law and the Use of Biometrics, Biometric System Security, Spoof Detection Schemes, Linkages between Biometrics and Forensic Science, Biometrics in the Government Sector, Biometrics in the Commercial Sector, Biometrics Standards, Biometrics databases

Text Book:

1. Cox I., M. Miller, J. Bloom, J. Fridrich and T Kalker, "Digit Watermarking and Steganography", Second Edition, Morg Kaufmann Publishers, 2008.
2. Jain, Anil K.; Flynn, Patrick; Ross, Arun A. (Eds.), Handbook of Biometrics, Springer, 2008.
3. Borko Furht and Darko Kirovski, “Multimedia Security Handbook”, 2004 by CRC Press ISBN 9780849327735
4. Stefan Katzenbeisser. Fabien A. P. Petitcolas (Eds). “Information Hiding Techniques for Steganography and Digital Watermarking.” Artech House Books

Reference Books:

1. Chun-Shien Lu, “Multimedia Security: Steganography and Digital Watermarking Techniques for Protection of Intellectual Property”, IDEA GROUP PUBLISHING, 2004

2. Frank Y. Shih, "Multimedia Security: Watermarking, Steganography, and Forensics", March 29, 2017 by CRC Press ISBN 9781138072541
3. Sunita Dhavale, "Advanced Image-Based Spam Detection and Filtering Techniques", IGI Global, Hershey, PA, USA, March 2017.
4. Shigno Lian, "Multimedia Content and Encryption: Techniques and Applications", 2017 by Auerbach Publication ISBN 9781420065275
Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/IBM sources.

CE 699 : Internet of Things

Objective

To meet end-user, Network-Administrator & Designer perspectives, develop skill sets to be resourceful in the area of Cyber-Security. Enhance analytical capabilities to evaluate a deployment and realisation.

About the Course:

The Internet of Things (IoT) is predicted to be the single most important factor impacting fundamental business logic in the coming decades. Government, academia, and industry are involved in different aspects of research, implementation, and business with IoT. IoT cuts across different application domain verticals ranging from civilian to defence sectors. These domains include agriculture, space, healthcare, manufacturing, construction, water, and mining, which are presently transitioning their legacy infrastructure to support IoT. Today it is possible to envision pervasive connectivity, storage, and computation, which, in turn, gives rise to building different IoT solutions. IoT-based applications such as innovative shopping system, infrastructure management in both urban and rural areas, remote health monitoring and emergency notification systems, and transportation systems, are gradually relying on IoT based systems. Therefore, it is very important to learn the fundamentals of this emerging technology & enable the students to anticipate and acknowledge the security concerns and vulnerabilities in the cyberspace. The impact of poor IoT security is being felt like a monsoon as these devices are compromised and then used to flood targets with DDOS traffic. As we move forward into this IoT era, it is imperative that we take steps as individuals to protect our Networks.

Intended Audience:

CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations Pre-Requisites : Basic programming knowledge

Course Contents:

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

IoT enablingTechnologies, 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 & Cloud offerings, Software environments, NEO, Security

Text Book

1. "Internet of Things: A Hands-on Approach", by Arshdeep Bahga and Vijay Madisetti (Universities Press), 2014

References

2. "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by Pethuru Raj 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.

CE69B Network Forensics

Course Objective To meet end-user, Network-Administrator & Network-Designer perspectives, develop skill sets to be resourceful in investigating the crimes in the area of Cyber-Security. Enhance analytical capabilities to evaluate a network.

About the Course: Computer and Network Forensics studies cyber-attack prevention, planning, detection, response, and investigation with the goals of counteracting cybercrimes, and making the responsible persons/groups accountable. The topics covered in this course include fundamentals of Network forensics, Network forensic duplication and analysis, Network Surveillance, Network Intrusion Detection and Response, Incident Response, Anti-Forensics Techniques, Anonymity and Pseudonymity, Network Cyber Law, Computer Security Policies and Guidelines, Court Report Writing and Presentation, and Case Studies. Pre-requisites: Computer Networks, Basics of OS

Syllabus:

Unit I: Forensics: An Overview, Scope of Network Forensic, Network Forensics Basics

Unit II: Network Enabled Operations, Network Controlled Operations, Network Offences, Network Criminalistics

Unit III: Basics of host devices on networks: Inter-Network Devices, OS and Networking: A Review

Unit IV: Advanced Topics in Computer Network Forensics, Network Forensic Modelling and Principles, Network Forensic Duplication, Network Forensics Analytics, Network File Carving, Network & Cyber Forensics Tools and the Testing of host devices in a network, Mobile Network Device Forensics, IPV6, Network Surveillance and Accountability, Network Attack Traceback and Attribution, Multicast Fingerprinting, Multimedia Forensics

Unit V: Intrusion and Online Frauds Detection

Unit VI: Peer-2-Peer Networks, Cryptocurrency and Blockchain

Unit VII: Network Traffic & Traffic engineering, Network Traffic & Traffic engineering for the Steganography & Steganalysis

Unit VIII: Anonymity/Pseudonymity/P2P environments, Network Forensic Challenges in adhoc environments, Network Forensic challenges in IoTs

Unit IX: Legal Perspective: Cyber Law, Security and Privacy Policies and Guidelines

Unit X: Case Studies, and ethical issues Unit XI: Court Testimony and Report Writing Skills

Course Materials

There will be no textbooks. Most readings are from the lecture notes and papers published in recent years from top security/forensics conferences/workshops or journals, reference books, and related Internet web sites. Two reading lists will be given. The required readings are 30-35 papers and a suggested reading list includes 130+ papers published within the last 10 years.

Reference books:

1. Bruce Middleton, Cyber Crime Investigator's Field Guide, Boca Raton, Florida:Auerbach Publications, 2001, ISBN 0-8493-1192-6.

2. Brian Carrier, File System Forensic Analysis, Addison-Wesley, 2005, ISBN 0-321-26817-2.

3. Chris Prosise and Kevin Mandia, Incident Response: Investigating Computer Crime, Berkeley, California: Osborne/McGraw-Hill, 2001, ISBN 0-07-213182-9.

4. Warren Kruse and Jay Heiser, Computer Forensics: Incident Response Essentials, AdditionWesley, 2002, ISBN 0-201-70719-5.

5. Stephen Northcutt, Mark Cooper, Matt Fearnow, and Karen Frederick, Intrusion Signatures and Analysis, Indianapolis, Indiana: New Riders, 2001, ISBN 0-7357-1063-5.

6. Rebecca Gurley Bace, Intrusion Detection, Indianapolis, Indiana: Macmillan Technical, 2000, ISBN 1578701856.

7. Edward Amoroso, Intrusion Detection: An Introduction to Internet Surveillance, Correlation, Trace Back, Traps, and Response, Intrusion.Net Books, 1999, ISBN 0-9666700-7-8.

8. Ross Anderson, Security Engineering: A Guide to Building Dependable Distributed Systems, John Wiley & Sons, 2001, ISBN: 0471389226.

9. Alberto Leon-Garcia and Indra Widjaja, Communication Networks: Fundamental Concepts and Key Architectures, First Edition, McGraw-Hill Companies, Inc., 2000, ISBN 0-07-022839-6.

CE604 COMPUTATIONAL INTELLIGENCE

Course Objectives:
The course goal is to make students familiar with basic principles of various computational methods of computational intelligence (CI) like nature-inspired methods (neural nets, evolutionary algorithms), fuzzy systems, as well as various probabilistic methods under uncertainty (e.g. Bayesian models) and machine learning methods (e.g. reinforcement learning). After the course the students will be able to conceptually understand the important terms and algorithms of CI, such that they would be able to choose appropriate method(s) for a given task.

Prerequisites: Basic image processing knowledge/computer programming knowledge is required.

Syllabus:
Unit I: Introduction to Computational Intelligence: Computational Intelligence Paradigms, Artificial Neural Networks, Evolutionary Computation, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, Supervised, unsupervised classification and regression analysis.
Unit II: Dimensionality Reduction & Feature Selection Methods: Linear Discriminant Analysis and Principal Component Analysis; Data Pre-Processing, Regression, Universal Approximation
Unit III: Evolutionary Computation: An Overview of Combinatorial Optimization, An Introduction to Genetic Algorithms,Theoretical Foundations of Genetic Algorithms, Genetic Algorithms in Engineering and Optimization, Genetic Algorithms in Natural Evolution,
Unit IV: Swarm Intelligence: Particle Swarm Optimization, Ant Colony Optimization.
Unit V: Nature Inspired Algorithms for optimization: Differential Evolution, Simulated Annealing, Multi-objective Optimization, Hybrid Optimization Algorithms

Text Book:
1. Eberhart& Shi, “Computational Intelligence: Concepts to Implementations”, Morgan Kaufmann, 2007
2. Xin-She Yang, “Nature Inspired Optimization Algorithms”, Elsevier, 2014

Reference Books:
1. AndriesEngelbrecht (2007), “Computational Intelligence: an Introduction”, Wiley
2. Amit Konar (2005), “Computational Intelligence: Principles, Techniques, and Applications”, Springer-Verlag Berlin Heidelberg

3. Stuart Russell, Peter Norvig (2009), "Artificial Intelligence – A Modern Approach", Pearson Elaine Rich & Kevin Knight (1999), "Artificial Intelligence", TMH, 2nd Edition
4. NP Padhy (2010), "Artificial Intelligence & Intelligent System", Oxford
5. ZM Zurada (1992), "Introduction to Artificial Neural Systems", West Publishing Company
6. Timothy J Ross (2004), "Fuzzy Logic with Engineering Applications", John Wiley & Sons Ltd.

CE632 Computer Vision

Course Objectives:

This course examines the tools and techniques required for learning computer vision framework. This course will provide an introduction to the subject and its various applications. Student will learn to implement CI algorithms for solving various problems.
Prerequisites: Basic image processing knowledge/computer programming knowledge is required.

Syllabus:

UNIT I IMAGE PROCESSING FOUNDATIONS: Review of image processing techniques – classical filtering operations – thresholding techniques – edge detection techniques – corner and interest point detection – mathematical morphology – texture
UNIT II SHAPES AND REGIONS: Binary shape analysis – connectedness – object labeling and counting – size filtering – distance functions – skeletons and thinning – 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
UNIT III HOUGH TRANSFORM: Line detection – Hough Transform (HT) for line detection – foot-of-normal method – line localization – line fitting – RANSAC for straight line detection – HT based circular object detection – accurate center location – speed problem – ellipse detection – Case study: Human Iris location – hole detection – generalized Hough Transform (GHT) – spatial matched filtering – GHT for ellipse detection – object location – GHT for feature collation
UNIT IV APPLICATIONS: Application: Face detection – Face recognition – Eigen faces – Application: Surveillance – foreground-background separation – particle filters – Chamfer matching, tracking, and occlusion – combining views from multiple cameras – human gait analysis Application: In-vehicle vision system: locating roadway – road markings – identifying road signs – locating pedestrians

Text/Reference Books:

1. E. R. Davies, "Computer & Machine Vision", Fourth Edition, Academic Press, 2012.
2. R. Szeliski, "Computer Vision: Algorithms and Applications", Springer 2011.
3. Simon J. D. Prince, "Computer Vision: Models, Learning, and Inference", Cambridge University Press, 2012.
4. Mark Nixon and Alberto S. Aquado, "Feature Extraction & Image Processing for Computer Vision", Third Edition, Academic Press, 2012.
5. D. L. Baggio et al., "Mastering OpenCV with Practical Computer Vision Projects", Packt Publishing, 2012.
6. Jan Erik Solem, "Programming Computer Vision with Python: Tools and algorithms for analyzing images", O'Reilly Media, 2012.

CE 70A Formal Specification and Verification of Programs

Objectives:

To study methods and techniques for stating and proving the correctness statements. Studying Mathematical Logic (Symbolic Logic), Mathematical models for programs. (Programming Language Semantics) and Justification of the verification techniques.

On successful completion of the module, the students

- should have a good knowledge and understanding of soundness, correctness of static analysis.
- should be able to understand the use of logic as a formal language for the specification of systems.
- understand the use of symbolic execution, and the main verification techniques used in symbolic model checking, and be able to verify simple systems
- study some of the issues that arise in deploying these techniques in practice, and solution strategies for them.

Syllabus

Reasoning about sequential programs: Programs as (possibly infinite) state transition systems; Specifying program correctness using pre- and post-conditions; partial and total correctness semantics; Hoare logic and its rules for a simple imperative sequential language; weakest pre-condition and strongest post-condition semantics; central importance of invariants in program verification. Brief introduction to lattices and the theory of abstract interpretation; some numerical abstract domains: intervals, difference bound matrices, octagons, polyhedra; computing abstract post-conditions and abstract loop invariants; refining abstractions and counterexample-guided abstraction refinement; Predicate abstraction and boolean programs; converting assertion to a location reachability problem; location reachability using predicate abstraction for simple programs and for programs with (possibly recursive) function calls; Introduction to temporal logics: LTL and CTL; Kripke structures as models of reactive (hardware and software) systems; LTL and CTL model checking algorithms and some applications

Text Reference:

1. Logic in Computer Science: Modeling and Reasoning about Systems, M. Huth and M. Ryan, Cambridge University Press, 2004
2. Chapter 15, Methods and Logics for Proving Programs by P. Cousot, in Handbook of Theoretical Computer Science, Vol B (Formal Models and Semantics), edited by Jan Van Leeuwen, The MIT Press, 1994
3. Research papers and survey articles to be announced in class

CE70B Advanced Algorithms

Syllabus:

Unit I: Basics
Data Structures, Abstract Data Types, Dictionaries, Parameters of Algorithms, Growth Functions, Asymptotic Notations & Complexity analysis, Complexity measures.

Unit II: Algorithms
Classic Algorithms, Purpose (S, S, SM, PF, Opti, Prob, Rand), Examples of each, Types of Algorithms, P Type, NP Type, Open Problems, Examples of Algorithms for Internet Search, Web Contents Organization and retrieval

Unit III: Soft-Computing Based Algorithms
Need, Modularity, Sequential, PRAM models, Classic Vs Soft Computing Algorithms, AI enabled Examples of Algorithms for Internet Search, Web Contents Organization and retrieval

Unit IV:Algorithms for AI & Special Applications: Classic Algorithms, Light-Weight Algorithms & Techniques, Self-Organization & Fault-Tolerance Techniques, Nature Inspired Algorithms

Unit V:Futuristic Trend: Computations in Cyber Physical Systems CPS, CPS based parallel & distributed Algorithms, Quantum Computing, Concepts of Qubits, Quantum Algorithms, Quantum Search-Space optimization

Laboratory Work:
Total V Practical Assignments. Lab Assignment based on each Unit.

Text Books:

1. T. H Cormen, C E Leiserson, R L Rivest and C Stein: Introduction to Algorithms, 2nd Edition, Prentice-Hall of India, 2009 (Latest Publication available during training)

Reference Books:

1. Ellis Horowitz, Sartaj Sahni, S.Rajasekharan: Fundamentals of Computer Algorithms, University Press, 2007. Kenneth A. Berman, Jerome L. Paul: Algorithms, Cengage Learning, 2002.
2. R.Sedgewick, “Algorithms in C++ : Fundamentals, Data Structures, Sorting, Searching, Parts 1-4 (English) 3rd Edition, Pearson.
3. Recommended Research papers during instruction

CE 700 Quantum Computing

About this Course

"Quantum Computing" is among those terms that are widely discussed but often poorly understood. The reasons of this state of affairs may be numerous, but possibly the most significant among them is that it is a relatively new scientific area, and it's clear interpretations are not yet widely spread. The main obstacle here is the word "quantum", which refers to quantum mechanics - one of the most counter-intuitive ways to describe our world. But fear not! This is not a course on quantum mechanics. We will gently touch it in the beginning and then leave it apart, concentrating on the mathematical model of quantum computer, generously developed for us by physicists. This doesn't mean that the whole course is mathematics either (however there will be enough of it). We will build a simple working quantum computer with our bare hands, and we will consider some algorithms, designed for bigger quantum computers which are not yet developed. The course material is designed for those computer scientists, engineers and programmers who believe, that there's something else than just HLL programming, that will move our computing power further into infinity.

Prerequisites are complex numbers and linear algebra

Course Contents:

1. **Unit I**: Introduction,Information and Computations, Characteristics of Computational Systems, Computability and Algorithms, Computational Complexity, Quantum Computing parameters and units, The Multiverse Interpretation of Quantum Mechanics
2. **Unit II:** Mathematical Model of Quantum Computing, Qubit, Qubit Measurement, Systems with Multiple Qubits, Measuring the Multiple Qubits Systems, Quantum System Evolution & Computations
3. **Unit III:** Quantum Computer and Quantum Algorithms,Deutsch's Problem, Quantum Computer Prototype, Suitable Algorithms
4. **Unit IV:** Shor's Algorithm, Factoring and the RSA, Factoring and Period Finding, Quantum Fourier Transform
5. **Unit V:** Grover's Algorithm. A Quantum Computer Application Boundaries, Grover's Algorithm, Challenges
6. **Unit VI:** Quantum environments, Search Spaces, Search Optimisation, Storage Optimisation, Quantum Resources, Future, Challenges

Text Book:

1. Nielsen, Michael A.; Chuang, Isaac L. (June 2012). Quantum Computation and Quantum Information (10th anniversary ed.). Cambridge: Cambridge University Press. ISBN 9780511992773. OCLC 700706156.

2. **References:** Research Papers as discussed in the class room.

CE 70D Computer Network Audit & Forensics

Course Objective:
To meet end-user, Network-Administrator & Network-Designer perspectives, develop skill sets to be resourceful in the area of Cyber-Security. Enhance analytical capabilities to evaluate a Network and Network Enabled Operations to analyze Network Centric Operations.

Prerequisites:
Preliminary knowledge Electronic Communications (Graduation Level), Computer Networks (Graduation Level) & IPV4, Networking Devices, Finite State Automata, Socket Programming, Algorithms

Teaching Method:
Class room instructions, learning through assignments, learning through hands-on sessions, learning through online recommended courses to complement the class room instructions

Short Recapitulation on topics before the start of the Course: Architecture of Computer Networks, ISO/OSI and TCP/IP model, IP protocol, transport protocols (TCP, UDP), basic services of computer networks (short recapitulation)

Course Contents

Unit I: Basics of host devices on networks: Inter-Network Devices, OS and Networking: A Review, n-tier, peer-to-peer Network architectures

Unit II: Network Protocols, Network Enabled Operations, Network Controlled Operations, Network Offences, Network Criminalities

Unit III: Packet Analysis, Packet Analysis Tools, Network Audit & tools,Network Traffic Engineering, Network Analysis and Analytics

Unit IV: Network Forensics: An Overview, Scope of Network Forensic, Network Forensics Basics

Unit IV: Computer Network Forensic Modelling and Principles, Network Forensic Duplication, Network Forensics Analytics, Network File Carving, Network & Cyber Forensics Tools and the Testing of host devices in a network, Mobile Network Device Forensics, IPV6, Network Surveillance and Accountability

Unit V: Futuristic Networks, Dependable Networks, AI-Enabled Network Environments, Network Virtualization, SDNs, Sensor Networks, IoT, Evolution in Computing Environments like Cloud, Edge, Fog, Ubiquitous, Pervasive

Text Books:

1. James Kurose & Keith Ross, Computer Networking: A Top-Down Approach (6th Edition), ISBN-13: 978-0132856201 ISBN-10: 0132856204
2. Packet Analysis Tools, Network Audit Tools and Courseware

Recommended Mandatory Readings:

1. "Security Problems in the TCP/IP Protocol Suite" by Steven M. Bellovin, AT&T Labs—Research (http://users.ece.cmu.edu/~adrian/630-f04/readings/bellovin-tcp-ip.pdf). (A look back paper by author is also available at https://www.cs.columbia.edu/~smb/papers/ipext.pdf)
2. "End-To-End Arguments in System Design" by J.H.SALTZER, D.P. REED and D.D. CLARK, Massachusetts Institute of Technology Laboratory for Computer Science. (http://groups.csail.mit.edu/ana/Publications/PubPDFs/End-toEnd%20Arguments%20in%20System%20Design.pdf)
3. Hubert Zimmermann, OSI Reference Model--The ISO Model of Architecture for Open Systems Interconnection. Communications, IEEE Transactions on (Volume: 28, Issue: 4), Apr 1980, pp. 425 - 432
4. Topic based Research Papers assigned during classroom discussions

Reference books:

1. Bruce Middleton, Cyber Crime Investigator's Field Guide, Boca Raton, Florida:Auerbach Publications, 2001, ISBN 0-8493-1192-6.
2. Brian Carrier, File System Forensic Analysis, Addison-Wesley, 2005, ISBN 0-321-26817-2.
3. Chris Prosise and Kevin Mandia, Incident Response: Investigating Computer Crime, Berkeley, California: Osborne/McGraw-Hill, 2001, ISBN 0-07-213182-9.
4. Warren Kruse and Jay Heiser, Computer Forensics: Incident Response Essentials, AdditionWesley, 2002, ISBN 0-201-70719-5.
5. Stephen Northcutt, Mark Cooper, Matt Fearnow, and Karen Frederick, Intrusion Signatures and Analysis, Indianapolis, Indiana: New Riders, 2001, ISBN 0-7357-1063-5.
6. Rebecca Gurley Bace, Intrusion Detection, Indianapolis, Indiana: Macmillan Technical, 2000, ISBN 1578701856.
7. Edward Amoroso, Intrusion Detection: An Introduction to Internet Surveillance, Correlation, Trace Back, Traps, and Response, Intrusion.Net Books, 1999, ISBN 0-9666700-7-8.
8. Ross Anderson, Security Engineering: A Guide to Building Dependable Distributed Systems, John Wiley & Sons, 2001, ISBN: 0471389226.
9. Alberto Leon-Garcia and Indra Widjaja, Communication Networks: Fundamental Concepts and Key Architectures, First Edition, McGraw-Hill Companies, Inc., 2000, ISBN 0-07-022839-6.

CE 70E Machine Learning in Python

Course Objectives:
This course examines the tools and techniques required for learning machine learning algorithms. This course will provide an introduction to the subject and its various applications. Student will learn to implement ML algorithms in python for solving various problems.
Prerequisites: basics of probability & statistics is required.
Syllabus:
UNIT I Basic programming in Python, Introduction: Basic definitions, types of learning, hypothesis space and inductive bias, evaluation, cross-validation.
UNIT II Linear regression, Decision trees, overfitting.

UNIT III Instance based learning, Feature reduction, Collaborative Filtering based recommendation.
UNIT IV Probability and Bayes learning.
UNIT V Logistic Regression, Support Vector Machine, Kernel function and Kernel SVM.
UNIT VI Neural network: Perceptron, multilayer network, backpropagation, introduction to deep neural network.
UNIT VII Clustering: k-means, Gaussian mixture model.

Text/Reference Books:

1. Geron Aurelien, “Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems”, OReilly, 2017.
2. Jerome H. Friedman, Robert Tibshirani, and Trevor Hastie, “The Elements of Statistical Learning”, Springer, 2001.
3. Sebastian Raschka, “Python Machine Learning”, Packt, 1st Edition, 2015

CE 70F Cloud Computing

Course Objectives:
This course will introduce various aspects of cloud computing, including fundamentals, management issues, security challenges and future research trends. This will help students and researchers to use and explore the cloud computing platforms.
Prerequisites: Basics of computer architecture and Organisation is required.
Syllabus:
UNIT I : Introduction to Cloud Computing, Cloud Computing Architecture
UNIT II: Service Management in Cloud Computing, Data Management in Cloud Computing
UNIT III : Resource Management in Cloud, Cloud Security
UNIT IV : Open Source and Commercial Clouds, Cloud SimulatorWeek 8 : Research trend in Cloud Computing, Fog Computing
Text/Reference Books:

1. Cloud Computing from Beginning to End by Ray J Rafaels
2. Cloud Computing: Concepts, Technology & Architecture by Zaigham Mahmood, Ricardo Puttini, Thomas Erl.
3. OpenStack Cloud Computing Cookbook by Kevin Jackson.

CE 70G Blockchain Technology

Objective: Blockchain is an emerging technology platform for developing decentralized applications and data storage, The basic tenet of this platform is that it allows one to create a distributed and replicated ledger of events, transactions, and data generated through various IT processes with strong cryptographic guarantees of tamper resistance, immutability, and verifiability. The technology itself holds much more promise in various areas such as time stamping, logging of critical events in a system, recording of transactions, trustworthy e-governance etc. Many researchers are working on many such use cases such as decentralized public key infrastructure, self-sovereign identity management, registry maintenance, health record management, decentralized authentication, decentralized DNS, etc. Considering the need to disseminate the emerging concepts for students, we proposed a new course on blockchain technology, includes the fundamental design and architectural primitives of

Blockchain, the system and the security aspects, along with various use cases from different application domains.

Pre-requisite: Expertise in Programming, Basic Knowledge of Computer Security, Cryptography, Networking.

Syllabus:

Unit1: Basic Cryptographic primitives used in Blockchain – Secure, Collison-resistant hash functions, digital signature, public key cryptosystems, zero-knowledge proof systems

Unit2: Basic Distributed System concepts – distributed consensus and atomic broadcast, Byzantine fault-tolerant consensus methods.

Unit3: Basic Blockchain – concepts to Bitcoin and contemporary proof-of-work based consensus mechanisms, operations of Bitcoin blockchain, crypto-currency as application of blockchain technology

Unit4: Hyperledger fabric platform- Decomposing the consensus process , Hyperledger fabric components, Chaincode Design and Implementation Hyperledger Fabric

Unit5: Beyond Cryptocurrency – applications of blockchain in cyber security, integrity of information, E-Governance and other contract enforcement mechanisms

Unit6: Security and Research Aspects

Text/Reference Books:

1. "S. Shukla, M. Dhawan, S. Sharma, S. Venkatesan, 'Blockchain Technology: Cryptocurrency and Applications', Oxford University Press, 2019.
2. Josh Thompson, 'Blockchain: The Blockchain for Beginnings, Guild to Blockchain Technology and Blockchain Programming', Create Space Independent Publishing Platform, 2017.

CE70H **Cyber Security & Cryptography for Embedded Systems**

Objective: Developed the knowledge of security concepts, cyber attacks and technologies to develop secure embedded systems.
Prerequisites: Basic understanding of Number Theory, Fundamentals of Operating Systems and Knowledge of programming language.

The course contains following topics:

Introduction to Security, Introduction to Embedded Security. Vulnerability types, Taxonomy of Attacks, Defense Mechanisms, Mathematics of Cryptography, Basics of symmetric versus asymmetric key encryption. Early ciphers - Substitution, permutation and product ciphers. Block versus stream ciphers. Basics of entropy and perfect secrecy, Mathematical foundations of the discrete logarithm problem, Diffie-Hellman Key Exchange, Mathematical foundations of RSA, Encryption using Elliptic curve The cryptographic hash – properties, Data Integrity, The cryptographic hash - construction, the Birthday paradox, Message Authentication, digital signature. Side Channels attacks on Embedded Systems, Embedded Cryptography, A5 Encryption for GSM, Hardware based Security. Transport layer security (TLS/SSL), FPGA based encryption and Decryption.

Text Books:

1. "Hardware Security: Design, Threats and Safeguards" by Debdeep Mukhopadhyay and Rajat Subhra Chakrabarty, CRC Press,2015.
2. "Cryptography & Network Security" by William Stallings4th Edition, 2006, Pearson Education Asia.
3. "Cryptography and Network Security" by Behrouz A. Forouzan, Mc Graw Hill.
4. "Cryptography & Network Security" by Kahate A, Tata Mc Graw Hill, 2004.
5. Morrie Gasser: Building a Secure Computer System
6. Michael Ligh, Steven Adair, Malware Analysts's cookbook, Wiley publishing

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 a thrust 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 from domains such as deep learning, robotics, machine learning, computer vision, video surveillance, text analytics, speech analytics have been selected.

Pre-requisites/Eligibility: Minimum CPI of 6.5 or 60% of marks or first class in qualifying degree. Bachelors degree in Engineering/Technology or Equivalent in CS/IT/ECE/ETC/EE or in relevant Disciplines and a valid GATE Score in CS in case of Regular Category.

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 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 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.

Semester I

Sr. No.	Course Code	Course	Contact Hours / Week		Credits
			L	T/P	
1	CE696A	Artificial Intelligence and DSS	3	1	4
2	CE604	Computational Intelligence	3	1	4
3	CE615A	Intelligent Algorithms	3	1	4
4	CE634	Natural Language Processing	3	1	4
5	AM604	Advanced Statistical Techniques	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
		Total	18	6	24

Semester II

Sr. No.	Course Code	Course	Contact Hours / Week		Credits
			L	T/P	
1	CE631	Deep Learning	3	1	4
2	CE694	Big Data Analysis & Algorithms	3	1	4
3	CE632	Computer Vision	3	1	4
4		Elective II	3	1	4
5		Elective III	3	1	4
6	TM649	Scientific/Engg. Practices and Skills	3	1	4
		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			14
		Total			14

Semester IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	CE 652	M.Tech. Dissertation Phase II			14
		Total			14

List of Electives Semester-II

Sr.No.	Course Code	Course
1	CE608	Semantic based System & Web Intelligence
2	CE610	Information Retrieval Systems
3	CE630	Virtual Reality
4	CE633	Pattern Recognition
5	CE680	Data Mining Techniques
6	CE695	Cyber-Physical & Self-Organising Systems
7	AM 625	Digital Image Processing
8	AM 628	Computational Number Theory and Cryptography
9	AM623	Machine Learning
10	AM625	Digital Image Processing
11	ME626	Introduction to Robotics
12	ME628	Robot Kinematics and Dynamics
13	CE 688	Game Theory
14	CE 692	Computational Geometry & Applications
15	~~CE 694~~	~~Big data Analysis & Algorithms~~
16	CE 695	Cyber-Physical & Self-Organising Systems
17	CE 69F	Theory of Computation
18	CE 697	Biometric Security
19	CE 698	Multimedia Security
20	CE 699	Internet of Things
21	CE 69B	Network Forensics
22	CE 604	Computational Intelligence
23	CE 70A	Formal Specification and Verification of Programs
24	CE 70B	Advanced Algorithms
25	CE 700	Quantum Computing
26	CE 70D	Computer Network Audit & Forensics
27	CE 70E	Machine Learning in Python
28	CE 70F	Cloud Computing
29	CE 70G	Blockchain Technology
30	CE70H	Cyber Security and Cryptography for Embedded Systems

COURSE CURRICULUM

SEMESTER I - CORE COURSES

CE696 ARTIFICIAL INTELLIGENCE & DECISION SUPPORT SYSTEMS

Syllabus:

Unit I: Introduction to AI, Decision Support Systems, Knowledge-based Intelligent Systems, Rule based Expert Systems;

Unit II: Uncertainty Management in rule-based expert systems: Introduction to Uncertainty, Basic Probability Theory, Bayesian reasoning, Certainty Factors;

Unit III: Learning: Overview of different forms of learning, Artificial Neural Networks: Basics of Neuron, Perceptron, Multi-layer neural networks, Back Propagation Algorithm;

Unit IV: Decision Support and Business Intelligence: Decision Support Systems and Business Intelligence, Decision Making Systems, Modeling, and Support, Knowledge Engineering and Data Mining: KDD Process, Pattern Recognition Systems, and Applications of Data Mining in Intelligent Systems.

Unit V: Fuzzy Expert Systems: Introduction to Fuzzy thinking, Linguistics variables and Hedges, Fuzzy Rules, Fuzzy Inference, Defuzzification.

Text Book:

1. MichealNegnivitsky, *Artificial Intelligence: A Guide to Intelligent Systems,* Addison-Wesley, 3nd Edition, 2011
2. Clyde W. Holsapple, Andrew B. Whinston (2010), "Decision Support Systems-A Knowledge-Based Approach", West Pub. Co.

Reference Books:

1. Stuart Russell & Peter Norvig, *Artificial Intelligence: A Modern Approach,* Prentice-Hall, Third Edition (2009)
2. E. Rich and K. Knight, *Artificial Intelligence*, 2nd ed., McGraw-Hill, New York, 1991.
3. M. Ginsberg, *Essentials of Artificial Intelligence*, Morgan Kaufmann, San Mateo, Ca., 1993.
4. D. Poole and A. Mackworth, *Artificial Intelligence: Foundations of Computational Agents*, Cambridge University Press, Cambridge, UK, 2010.
5. P. H. Winston, *Artificial Intelligence*, 3rd ed., Addison-Wesley, Reading, Mass., 1992.
6. Efraim Turban, Jay E. Aronson (2008), Ting-Peng Liang, Ramesh Sharda, "Decision Support and Business Intelligence Systems" 8th Edition, Pearson-Prentice Hall

CE604 COMPUTATIONAL INTELLIGENCE

Syllabus:

Unit I: Introduction to Computational Intelligence: Computational Intelligence Paradigms, Artificial Neural Networks, Evolutionary Computation, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, Supervised, unsupervised classification and regression analysis.

Unit II: Dimensionality Reduction & Feature Selection Methods: Linear Discriminant Analysis and Principal Component Analysis; Data Pre-Processing, Regression, Universal Approximation

Unit III: Evolutionary Computation: An Overview of Combinatorial Optimization, An Introduction to Genetic Algorithms, Theoretical Foundations of Genetic Algorithms, Genetic Algorithms in Engineering and Optimization, Genetic Algorithms in Natural Evolution,

Unit IV: Swarm Intelligence: Particle Swarm Optimization, Ant Colony Optimization.

Unit V: Nature Inspired Algorithms for optimization: Differential Evolution, Simulated Annealing, Multi-objective Optimization, Hybrid Optimization Algorithms

Text Book:

3. Eberhart& Shi, "Computational Intelligence: Concepts to Implementations", Morgan Kaufmann, 2007
4. Xin-She Yang, "Nature Inspired Optimization Algorithms", Elsevier, 2014

Reference Books:

7. AndriesEngelbrecht (2007), "Computational Intelligence: an Introduction", Wiley

8. Amit Konar (2005), “Computational Intelligence: Principles, Techniques, and Applications”, Springer-Verlag Berlin Heidelberg
9. Stuart Russell, Peter Norvig (2009), “Artificial Intelligence – A Modern Approach”, Pearson Elaine Rich & Kevin Knight (1999), “Artificial Intelligence”, TMH, 2nd Edition
10. NP Padhy (2010), “Artificial Intelligence & Intelligent System”, Oxford
11. ZM Zurada (1992), “Introduction to Artificial Neural Systems”, West Publishing Company
12. Timothy J Ross (2004), “Fuzzy Logic with Engineering Applications”, John Wiley & Sons Ltd.

CE615A EFFICIENT ALGORITHMS

Syllabus:

Unit I: Basics

Data Structures, Abstract Data Types, Dictionaries, Parameters of Algorithms, Growth Functions, Asymptotic Notations & Complexity analysis, Complexity measures.

Unit II: Algorithms

Classic Algorithms, Purpose (S, S, SM, PF, Opti, Prob, Rand), Examples of each, Types of Algorithms, P Type, NP Type, Open Problems, Examples of Algorithms for Internet Search, Web Contents Organization and retrieval

Unit III: Soft-Computing Based Algorithms

Need, Modularity, Sequential, PRAM models, Classic Vs Soft Computing Algorithms, AI enabled Examples of Algorithms for Internet Search, Web Contents Organization and retrieval

Unit IV:Algorithms for AI& Special Applications: Classic Algorithms, Light-Weight Algorithms & Techniques, Self-Organization & Fault-Tolerance Techniques, Nature Inspired Algorithms

Unit V: Efficient Algorithms: Computations in Cyber Physical Systems CPS, CPS based parallel & distributed Algorithms, Quantum Computing, Concepts of Qubits, Quantum Algorithms, Quantum Search-Space optimization

Laboratory Work:

1.Total V Practical Assignments. Lab Assignment based on each Unit.

Text Books:

2. T. H Cormen, C E Leiserson, R L Rivest and C Stein: Introduction to Algorithms, 2nd Edition, Prentice-Hall of India, 2009 (Latest Publication available during training)

Reference Books:

4. Ellis Horowitz, SartajSahni, S.Rajasekharan: Fundamentals of Computer Algorithms, University Press, 2007. Kenneth A. Berman, Jerome L. Paul: Algorithms, Cengage Learning, 2002.
5. R.Sedgewick, “Algorithms in C++ : Fundamentals, Data Structures, Sorting, Searching, Parts 1-4 (English) 3rd Edition, Pearson.
6. Recommended Research papers during instruction

CE634 NATURAL LANGUAGE PROCESSING (NLP)

Syllabus:

Introduction: Language Structures and Levels; Morphological processing; Syntactic analysis – parsing; Regular Expressions, demonstrations of use on corpus; Part of Speech Tagging, Supervised Learning, Hidden Markov Models, Unsupervised POS tagging; Grammars - CFG grammars - rule-based parsing difficulties; Discovering grammars from patterns in text; Semantic modeling: Classical ontology-driven approaches, Latent Semantic Analysis; Word discovery from real situations, Aligning unsupervised syntax with sensory structures; Machine Translation; Acquiring structures from Parallel Corpora; Spatial Language and Semantics.

Text References:

1. Dan Jurafsky, JH Martin, Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition, 2nd Ed, Pearson 2009.
2. CH Manning, H Schütze, Foundations of Statistical Natural Language Processing, MIT Press, 1999.
3. CH Manning, P Raghavan, H Schütze, Introduction to Information Retrieval, Cambridge University Press, 2008.
4. Kiraz, George Anton; Computational Nonlinear Morphology: With Emphasis on Semitic Languages Cambridge University Press, 2001.
5. Recent papers from journals, conferences and arxiv.org

SEMESTER II CORE COURSES

CE631 DEEP LEARNING

Syllabus:

Unit I: Introduction : Overview of machine learning, linear classifiers, loss functions

Unit II: Optimization : Stochastic gradient descent and contemporary variants, back-propagation

Unit III: Feedforward networks and training : Activation functions, initialization, regularization, batch normalization, model selection, ensembles

Unit IV: Convolutional neural networks : Fundamentals, architectures, pooling, visualization

Unit V: Deep learning for spatial localization : Transposed convolution, efficient pooling, object detection, semantic segmentation

Unit VI: 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

Unit VII: Deep generative models : Auto-encoders, variational auto-encoders, generative adversarial networks, autoregressive models, generative image models, unsupervised and self-supervised representation learning

Unit VIII: Deep reinforcement learning : Policy gradient methods, Q-Learning : Project presentations

Text/Reference Books:

1. I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, MIT Press, 2016. http://www.deeplearningbook.org.
2. K. P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012.
3. C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.

CE694 BIG DATA ANALYSIS AND ALGORITHMS

Unit I :Introdution to big data analysis: Evolution of data, data streams, structured & unstructured data, database models, graph data, normalizations

Unit II: Big data analytics platforms: Architectures, Frameworks that enable big data analytics

Unit III: Big data analytics storage & processing: 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 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, 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 V: Big data analytics tools, HDFS, NOSQL, SQL environments

Text Book:

2. Big Data Fundamentals: Concepts, Drivers & Techniques (Prentice Hall Service Technology) Paperback – Import, **5 Jan 2016** by Thomas Erl (Author),WajidKhattak (Author),Paul Buhler (Author), Publisher: Prentice Hall (5 January 2016), 240 pages , ISBN-10: 0134291077 , ISBN-13: 978-0134291079

References:

4. Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006
5. Introduction To Algorithms, Thomas H. Cormen, Charles E. Leiserson, Ronaldo L. Rivest, Clifford Stien 2nd Edition
   Course
6. Research Papers discussed in the classroom discussions.

Course links & References:

7. https://iveybusinessjournal.com/publication/why-big-data-is-the-new-competitive-advantage/
8. https://www.datameer.com/company/datameer-blog/challenges-to-cyber-security-and-how-big-data-analytics-can-help/
9. https://www.iss.nus.edu.sg/executive-education/discipline/detail/analytics-and-intelligent-systems

CE632 Computer Vision

Course Objectives:

This course examines the tools and techniques required for learning computer vision framework. This course will provide an introduction to the subject and its various applications. Student will learn to implement CI algorithms for solving various problems.

Prerequisites: Basic image processing knowledge/computer programming knowledge is required.

Syllabus:

UNIT I IMAGE PROCESSING FOUNDATIONS: Review of image processing techniques – classical filtering operations – thresholding techniques – edge detection techniques – corner and interest point detection – mathematical morphology – texture

UNIT II SHAPES AND REGIONS: Binary shape analysis – connectedness – object labeling and counting – size filtering – distance functions – skeletons and thinning – 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

UNIT III HOUGH TRANSFORM: Line detection – Hough Transform (HT) for line detection – foot-of-normal method – line localization – line fitting – RANSAC for straight line detection – HT based circular object detection – accurate center location – speed problem – ellipse detection – Case study: Human Iris location – hole detection – generalized Hough Transform (GHT) – spatial matched filtering – GHT for ellipse detection – object location – GHT for feature collation

UNIT IV APPLICATIONS: Application: Face detection – Face recognition – Eigen faces – Application: Surveillance – foreground-background separation – particle filters – Chamfer matching, tracking, and occlusion – combining views from multiple cameras – human gait analysis Application: In-vehicle vision system: locating roadway – road markings – identifying road signs – locating pedestrians

Text/Reference Books:

7. E. R. Davies, “Computer & Machine Vision”, Fourth Edition, Academic Press, 2012.
8. R. Szeliski, “Computer Vision: Algorithms and Applications”, Springer 2011.
9. Simon J. D. Prince, “Computer Vision: Models, Learning, and Inference”, Cambridge University Press, 2012.
10. Mark Nixon and Alberto S. Aquado, “Feature Extraction & Image Processing for Computer Vision”, Third Edition, Academic Press, 2012.
11. D. L. Baggio et al., “Mastering OpenCV with Practical Computer Vision Projects”, Packt Publishing, 2012.
12. Jan Erik Solem, “Programming Computer Vision with Python: Tools and algorithms for analyzing images”, O'Reilly Media, 2012.

SEMESTER II ELECTIVE COURSES

CE608 Semantic Based System & Web Intelligence

Syllabus:

Unit I - Web Intelligence: Thinking and Intelligent Web Applications, The Information Age ,The World Wide Web, Limitations of Today's Web, The Next Generation Web, Machine Intelligence, Artificial Intelligence, Ontology, Inference engines, Software Agents, Berners-Lee www, Semantic Road Map, Logic on the semantic Web.

Unit II - Knowledge Representation for the Semantic Web: Ontologies and their role in the semantic web, Ontologies Languages for the Semantic Web – Resource Description Framework(RDF) / RDF Schema, Ontology Web Language(OWL),UML,XML/XML Schema.

Unit III - Ontology Engineering: Ontology Engineering, Constructing Ontology, Ontology Development Tools, Ontology Methods, Ontology Sharing and Merging, Ontology Libraries and Ontology Mapping, Logic, Rule and Inference Engines.

Unit IV- Semantic Web Applications, Services and Technology: Semantic Web applications and services, Semantic Search, e-learning, Semantic Bioinformatics, Knowledge Base ,XML Based Web Services, Creating an OWL-S Ontology for Web Services, Semantic Search Technology, Web Search Agents and Semantic Methods,

Unit V - Social Network Analysis and semantic web: What is social Networks analysis, development of the social networks analysis, Electronic Sources for Network Analysis – Electronic Discussion networks, Blogs and Online Communities, Web Based Networks. Building Semantic Web Applications with social network features.

References:

1. Thinking on the Web - Berners Lee, Godel and Turing, Wiley interscience,2008.
2. Social Networks and the Semantic Web, Peter Mika,Springer,2007.
3. Semantic Web Technologies, Trends and Research in Ontology Based Systems, J.Davies, R.Studer, P.Warren, John Wiley & Sons.
4. Semantic Web and Semantic Web Services -Liyang Lu Chapman and Hall/CRC Publishers,(Taylor & Francis Group)
5. Information Sharing on the semantic Web - Heiner Stuckenschmidt; Frank Van Harmelen, Springer Publications.
6. Programming the Semantic Web,T.Segaran,C.Evans,J.Taylor,O'Reilly,SPD.

CE610 Information Retrieval Systems

Syllabus:

Introduction: Basic Concepts, Retrieval Process Modeling – A Formal Characterization of IR Models, Classic Information Retrieval (Boolean model, Vector Model, Probabilistic Model), Alterative Set Theoretic Models, Alternative Algebraic Models (Generalized Vector Space Model, Latent Semantic Indexing Model). Query Languages and Operations: Keyword based Querying, Pattern Matching, Structural Queries, User Relevance Feedback. Text Operations: Document Preprocessing, Document Clustering, Text Compression. Evaluation in Information Retrieval: Retrieval Performance Evaluation Recall, Precision, Mean average Precision, F-

Measure, User Oriented Measures, Discounted Cumulated Gain. TREC Web Collections. Searching the Web: Characterizing the web, Crawling the Web, Mercator: A Scalable, Extensible Web Crawler, Parallel Crawlers, Different Types of Web Crawler, Anatomy of a Large-Scale Hyper textual Web Search Engine, Page Rank Algorithm. IR Applications: Summarization and Question Answering.

Text Book:

1. Ricardo Baeza-Yate, Berthier Ribeiro-Neto (2011), “Modern Information Retrieval”, Second Edition, Addison Wesley.

Reference Books:

1. G. G. Chowdhury (2003), “Introduction to Modern Information Retrieval”, Second Edition, NealSchuman Publishers.
2. David A. Grossman, Ophir Frieder (2004), “Information Retrieval: Algorithms and Heuristics”, Springer.

CE630 Virtual Reality

Syllabus:

UNIT I: **Introduction of Virtual Reality:** Fundamental Concept and Components of Virtual Reality. Primary Features and Present Development on Virtual Reality

Unit II: **Multiple Modals of Input and Output Interface in Virtual Reality:** Input -- Tracker, Sensor,Digital Glove, Movement Capture, Video-based Input, 3D Menus & 3DScanner etc. Output -- Visual / Auditory / Haptic Devices

Unit III :**Visual Computation in Virtual Reality:** Fundamentals of Computer Graphics. Software and Hardware Technology on Stereoscopic Display. Advanced Techniques in CG: Management of Large Scale Environments & Real Time Rendering

Unit IV: **Environment Modeling in Virtual Reality:** Geometric Modeling, Behavior Simulation, Physically Based Simulation

Unit V: **Interactive Techniques in Virtual Reality:** Body Track, Hand Gesture, 3D Manus, Object Grasp

Unit VI: **Introduction of Augmented Reality :**System Structure of Augmented Reality. Key Technology in AR.

Unit VII: **Application of VR in Digital Entertainment :**VR Technology in Film & TV Production.VR Technology in Physical Exercises and Games.

Textbook(s) and other required material:

1. Burdea, G. C. and P. Coffet. ***Virtual Reality Technology**,* Second Edition. Wiley-IEEE Press, 2003/2006.

References:

2. Sherman, William R. and Alan B. Craig. Understanding Virtual Reality – Interface, Application, and Design, Morgan Kaufmann, 2002.
3. Fei GAO. Design and Development of Virtual Reality Application System, Tsinghua Press, March 2012.

CE633 Pattern Recognition

Syllabus:

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

CE680 Data Mining Techniques

Syllabus:

Introduction pattern recognition, Linear Classifiers: Bayes Decision Theory, Least square methods, Support Vector Machines, Non Linear Classifiers: Back Propagation Algorithm, Radial Basis Function Networks, Decision Trees, Random Forest Trees, Combining Classifiers. Algorithm Association Rules Mining: A priori algorithm , Partition algorithm, Dynamic in set counting algorithm, FP– tree growth algorithm, Generalized association rule, **Temporal Data**

mining: Basic concepts of temporal data Mining, GSP Algorithm, Template Matching Techniques. **Clustering Algorithms:** Sequential Algorithms, Hierarchical clustering algorithms, Clustering algorithms based of cost function optimization. Clustering algorithms based on Graph Theory, Clustering algorithms based on competitive learning. Data Mining for Intrusion detection, Futuristic Technologies for Cyber Security.

Text Books:

1. Richard ODudaand Peter EHart, ―Pattern Classification‖, 2ndEdition,Wiley-Interscience, 2000.
2. Jiawei*Han,* MichelineKamber, and Jian Pei, Data Mining: Concepts and Techniques, 3rd Edition, Morgan Kaufmann, 2011.

ReferenceBooks:

1. S Theodoridis and K Koutroumbas, ―Pattern Recognition‖, 4th Edition, Academic Press, 2009.
2. http://www.cs.ubc.ca/~nando/540-2013/lectures/l8.pdf
3. http://www.cs.ubc.ca/~nando/540-2013/lectures/l9.pdf
4. Roddick, J., Spiliopoulou, M. ―A Survey of Temporal Knowledge Discovery Paradigms and Methods‖, In IEEE Transactions of Knowledge and Data Engineering, vol. 13, 2001.
5. AnoopSinghal, ―Data Warehousing and Data Mining Techniques for Cyber Security‖, Springer US, 2007.

CE695 Cyber-Physical & Self-Organising Systems

Brief Overview:

This course examines a new class of computational systems called Cyber-Physical Systems. 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 Cyber-Physical Systems (CPS): their ability **monitor** 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 immediately that in CPS, the computational element (cyber) and the environment (physical) are tightly coupled, with one influencing the other. Cyber-Physical Systems 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. 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).

Syllabus:

Introduction, Main Concepts and Background, Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software, Agents and Multi-Agent Systems

Computing trends, Data device proliferation, Confluence of trends, 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, Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems Applications of Self-organising Software, Self-organisation in Constraint Problem Solving, Adaptive Trust Management, Security in Artificial Systems

Text Books:

1. 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 Reading assignments:

Introduction: Brief history of CPS. Motivating problems in CPS.

2. K. Kim and P.R. Kumar, \CyberPhysical Systems: A Perspective at the Centennial," Proceedings of the IEEE , vol. 100, May 2012, p. 1287{1308.
3. E. Lee, \Cyber Physical Systems: Design Challenges", Proceedings of the IEEE Symposium on Object Oriented Real-Time Distributed Computing (ISORC), 2008, p. 363{369.
4. R. Rajkumar, \A Cyber-Physical Future, "Proceedings of the IEEE, vol. 100, May 2012, p. 1309{1312.
5. S. Barnum, S. Sastry, and J. Stankovic, \Roundtable: Reliability of Embedded and Cyber-Physical Systems," IEEE Security and Reliability , September / October 2010, p. 27{32

Modeling: Continuous systems and discrete event systems.

6. Lygeros, Sastry, and Tomlin, Chapter 2
7. P. Derler, E. Lee, and A. Sangiovanni-Vincentelli, \Modeling Cyber-Physical Systems," Proceedings of the IEEE, Vol.100, no. 1, January2012, p.13{28.

Control over networks

8. R. Alur, A. D'Innocenzo, K. Johansson, G. Pappas, and G. Weiss, \Compositional Modeling and Analysis of Multi-Hop Control Networks," IEEE Transactions on Automatic Control, vol. 56, no. 10, October 2011, p. 2345{2357.
9. J. Hespanha, P. Naghshtabrizi, and Y. Xu, \A Survey of Recent Results in Networked Control Systems," Proceedings of the IEEE, vol. 95, no. 1, January 2007, p. 138{162.
10. Pajic, R. Mangharam, G. Pappas, and S. Sundaram, \Topological Conditions for In-Network Stabilization of Dynamical Systems,"IEEE Journal on Selected Areas in Communications, vol. 31, no. 4, April 2013.
11. G. Hackmann, W. Guo, G. Yan, Z. Sun, C. Lu, and S. Dyke, \Cyber-Physical Codesign of Distributed Structural Health Monitoring with Wireless Sensor Networks,"IEEE Transactions on Parallel and Distributed Systems , vol. 25, no. 1, p. 63{72, January 2014.

Stability of Hybrid and Switched Systems

12. R. A. Decarlo, M. S. Branicky, S. Pettersson, and B. Lennartson, \Perspectives and Results on the Stability and Stabilizability of Hybrid Systems," Proceedings of the IEEE ,vol. 8, no. 7, p. 1069{1082, July 2000.
13. D. Liberzon and A. S. Morse, \Basic problems in stability and design of switched systems," IEEE Control Systems Magazine , vol. 19, no. 5, pp. 59{70, October 1999.
14. M. Branicky, \Multiple Lyapunov functions and other analysis tools for switched andhybrid systems," IEEE Transactions on Automatic Control , vol. 43, no. 4, p. 75{482, April 1998.

15. J. Hespanha, \Uniform Stability of Switched Linear Systems: Extensions of LaSalle's Invariance Principle," IEEE Transactions on Automatic Control , vol. 49, no. 4, p.470{482, April 2004

CE 688 Game Theory

Course Objectives: To understand the concepts of Game Theory and get an overview. To learn and appreciate the applications of game theory in Network Security.

Prerequisites: Basic understanding of Computer Networking and Network Security

Syllabus:

Network Security Concepts: Networks and Security Threats, Networks and World Wide Web, Security Threats, Attackers, Defenders, and their Motives, Attackers, Defenders, Defense Mechanisms, Security Tradeoffs and Risk Management, Security Tradeoffs, Security Risk Management, **Introduction to Game Theory**: What is Game Theory? Game Theory Classification, Introduction to Non-Cooperative Game Theory, General Formulation for Non-cooperative Games, Existence of Nash and Saddle-Point Equilibria in Finite Games, Existence and Uniqueness of Equilibria in Infinite Games, Prisoner's Dilemma, Co-operative Game Theory, Shapley Value, **Deterministic Security Games**: Security Game Model, Intrusion Detection Games, Matrix Games, Games with Dynamic Information, Sensitivity Analysis, Modeling Malicious Behavior in Social Networks, Security Games for VehicularNetworks, Vehicular Network Model, Attack and Defense Model, Game Formulation and Numerical Analysis, Security Games in Wireless Networks, Random Access Security Games,Interference Limited Multiple Access Security Games, Revocation Games, Discussion and Further Reading, **Stochastic Security Games**: Markov Security Games, Markov Game Model, Solving Markov Games, Stochastic Intrusion Detection Game, Security of Interconnected Systems, Analysis of an Illustrative Example, Linear Influence Models, Malware Filter Placement Game, Stochastic Game Formulation, Simulations. **Decision Making for Network Security**, **Security Risk Management** , Quantitative Risk Management, Risk in Networked Systems and Organizations, A Probabilistic Risk Framework, Dynamic Risk Mitigation AndControl, Security Investment Games, Influence Network and Game Model, Equilibrium and Convergence Analysis, Incentives and Game Design, Cooperative Games for Security Risk Management, Coalitional Game Model, Coalition Formation under Ideal Cooperation**Resource Allocation for Security:** An Optimization Approach To Malware Filtering, Traffic Centrality Measures, Filtering Problem Formulations, A Robust Control Framework for Security Response, Network Traffic Filtering Model, Derivation of Optimal Controller and State Estimator, Optimal and Robust Epidemic Response, Epidemic Models, Feedback Response for Malware Removal, Multiple Networks, **Machine Learning for Intrusion and Anomaly Detection:** Intrusion and Anomaly Detection, Intrusion Detection and Prevention Systems, Open Problems and Challenges, Machine Learning for Security: An Overview, Overview of Machine Learning Methods, Open Problems and Challenges, Distributed Machine Learning, SVM Classification and Decomposition, Parallel Update Algorithms, Active Set Method and A Numerical Example, Behavioral Malware Detection.

Text Books:

3. T. Alpcan and T. Basar, "Network Security: A decision and Game Theoritic Approach", Cambridge University Press.
4. M. Osborne, "AN Introduction to Game Theory", Oxford University Press, 2003.

Reference Books:

5. Bragg et al, " Network Security: The complete Reference", McGraw Hill Osborne, 2003.

6. B. Singh, “Network Security and Management”, Third Edition, PHI, 2013.
7. B.A. Forouzan and D. Mukhopdhyay, “Cryptography and Network Security”, 2nd Edition, McGraw Hill, 2010.
8. A. Dixit et al., “Games of Strategy”, Third Edition, W Norton Publishers, 2009.

CE 692 Computational Geometry and Applications

Pre-requisites:

The students are assumed to have a basic knowledge of the design and analysis of algorithms and data structures. No knowledge of the application domains is required, and hardly any knowledge of geometry. The analysis of the randomized algorithms requires very elementary knowledge of probability theory.

Syllabus:

Geometric primitives, Line intersection, randomized incremental concepts, Triangulation and visibility, Linear programming in two and three dimensions, Orthogonal range searching, Point location and Binary Space Partitions, Voronoi diagrams and Delaunay triangulation, Convex hulls, Non-orthogonal range searching

Text Book:

2. “*Computational Geometry: Algorithms and Applications*”, Third Edition (March 2008),Mark de Berg, TU Eindhoven (the Netherlands), Otfried Cheong, KAIST (Korea), Marc van Kreveld, Mark Overmars, Utrecht University (the Netherlands), Springer-Verlag

CE 69F Theory of Computation

Syllabus:

14. **Introduction**: Motivation, , Terminology, History
15. **Computers and Science of Computing:** Computability, Undecidability, Intractability, and Intelligence
16. **Automata**: Construction, Finite Automata, Limitations of Finite Automata
17. **Non-Deterministic Finite Automata**, Moore Machine, Mealy Machine
18. **Regular Languages and Expressions**: Equivalence, Regular expressions in practice
19. **Grammars**: Parsing and Derivation, Grammar for regular languages, Converting Regular grammar to Automata
20. **Nature of Regular Languages:** Closure properties, Peigeonhole principle, Pumping Lemma, Adversarial Game
21. **Context Free Languages and Grammars**: Context Free Behaviour, CFGs, Ambiguity, Chomsky Normal Form, Simple, Linear and other grammars
22. **Pushdown Automata**: Stack Behviour, Constructing PDAs, CFGs to PDAs, CFL-CFG-PDA Triad
23. **Nature of Context Free Languages**: Closure properties
24. **Turing Machines**: Construction, Definition, Complex Turing Machines, Church Turing Thesis, Universal Turing Machines

25. **The Chomsky Hierarchy**: Languages, Grammars and Machines, Recursive Languages, Idea of Context
26. **Computability and Undecidability**: Halting Problem, P = NP?

Text Book:

3. K. Mahesh, "Theory of Computation: A problem solving approach", Wiley publishers. 2015

4. Hopcroft, Motwani & Ullman, "Introduction to Automata Theory, Languages and Computation", 3rd Edition, Pearson, 2007.

Reference Book:

4. M. Sipser, "Introduction to Theory of Computation", 3rd Edition, Wordsworth Publishing, 2012.

CE 697 Biometric Security

Course Objectives:

Biometrics has emerged as a specialized field in criminal forensics, public safety surveillance, user authentication and identification. Expansions of biometric modalities are ranged from fingerprint, face and other traits to multimodal biometric traits. Objectives of this course to introduce the students different modality based biometric identification systems, to help them to understand the difference between advanced biometric techniques with respect to traditional authentication mechanisms. Students after learning this course would be able to design and develop biometric systems by utilizing inter-disciplinary knowledge related to fields like Pattern Recognition, Image Processing and Machine Learning etc.

Syllabus:

11. **Introduction:** History of Biometrics, Multimodal Biometric Systems, Recent Advances

12. Authentication Technologies, Access Control

13. **Finger Print Biometrics**: Sensors, Dactyloscopy, Types, Algorithms

14. **Handwriting biometrics**: Static and Dynamic Recognition

15. **Iris Biometrics**: Retinal Scanning, Visible and Near Infra red Imaging, Operating Principle, Advantages and Shortcomings

16. **Voice Biometrics**: Verification versus Identification, Text Dependent and Text Independent, Technology, Applications

17. **Face Recognition**: Techniques for Face Acquisition/Recognition, Advantages and Disadvantages, History, Anti-facial recognition

18. **DNA finger printing/ Profiling**: Process, DNA Database, DNA evidence,

19. **Statistical Measures for Biometrics**:

20. **Biometric Devices**: Personal, Handheld, Biometric spoofing, Accuracy

Text Book:

3. P. Reid, "Biometrics for Network Security", Prentice Hall, 2014.

4. J. Chirrillo and S. Blaul, "Implementing Biometric Security", Wiley, 2013.

Reference Book:

5. AK Jain, "Introduction to Biometrics", Springer, 2011.
6. J. Ashborn, "Biometrics: A Complete Guide", Springer, 2003

CE 698 Multimedia Security

Course Objectives:

1. To facilitate individual in gaining knowledge on digital watermarking, steganographic and encryption techniques on multimedia signals like image, audio and video for digital rights management applications.
2. To facilitate individual in gaining knowledge on forensics on multimedia signals like image, audio and video for multimedia tamper/forgery detection applications.
3. To teach biometric security concepts. Student will learn and implement various algorithms using MATLAB, Python during hands-on activities carried in the Laboratory.

Prerequisites: Basic computer programming knowledge is required.

Syllabus:

Steganaography and Steganalysis; Information Hiding, Digital Watermarking – Basics of host Image/Video/Audio signals, Multimedia compression and decompression, Lossless compression, Models of watermarking, watermark detection by correlation; message coding, Mapping message in message vectors, Error correction coding, Detecting multi-symbol watermarks, Watermarking with side information, Informed embedding, Informed coding; Structured dirty-paper codes, Analyzing errors, Message errors, ROC curves, The effect of whitening on error rates, Analysis of normalized correlation, Using perceptual mode, Evaluating perceptual impact of watermarks; General forms of perceptual model, Perceptual adaptive watermarking, Robust watermarking, Spread Spectrum Watermarking, DCT-Domain Watermarking, A Buyer-Seller Watermarking Protocol, Text/Image/Video/Audio watermarking, Watermark security and cryptography, Content authentication, Applications: Digital Right Management Products & Laws, copyright protection; traitor tracing; tamper proofing; copy control; Signal processing attacks. Machine learning approaches in multimedia security, Intelligent Techniques for watermarking.

Multimedia Encryption, Image/audio/video Forensic and forgery detection, Biometric Security- Introduction to Biometrics, Fingerprint Recognition, Face Recognition, Iris Recognition, Hand

Geometry Recognition, Gait Recognition, The Ear as a Biometric, Voice Biometrics, A Palm print Authentication System, Online Signature Verification; Introduction to Multi biometrics, Multi biometrics Using Face and Ear, The Law and the Use of Biometrics, Biometric System Security, Spoof Detection Schemes, Linkages between Biometrics and Forensic Science, Biometrics in the Government Sector, Biometrics in the Commercial Sector, Biometrics Standards, Biometrics databases

Text Book:

1. Cox I., M. Miller, J. Bloom, J. Fridrich and T Kalker, "Digit Watermarking and Steganography", Second Edition, Morg Kaufmann Publishers, 2008.
2. Jain, Anil K.; Flynn, Patrick; Ross, Arun A. (Eds.), Handbook of Biometrics, Springer, 2008.
3. Borko Furht and Darko Kirovski, "Multimedia Security Handbook", 2004 by CRC Press ISBN 9780849327735
4. Stefan Katzenbeisser. Fabien A. P. Petitcolas (Eds). "Information Hiding Techniques for Steganography and Digital Watermarking." Artech House Books

Reference Books:

1. Chun-Shien Lu, "Multimedia Security: Steganography and Digital Watermarking Techniques for Protection of Intellectual Property", IDEA GROUP PUBLISHING, 2004
2. Frank Y. Shih, "Multimedia Security: Watermarking, Steganography, and Forensics", March 29, 2017 by CRC Press ISBN 9781138072541
3. Sunita Dhavale, "Advanced Image-Based Spam Detection and Filtering Techniques", IGI Global, Hershey, PA, USA, March 2017.
4. Shigno Lian, "Multimedia Content and Encryption: Techniques and Applications", 2017 by Auerbach Publication ISBN 9781420065275

Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/IBM sources.

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 & Cloud offerings,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 Pethuru Raj 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.

CE 70E Machine Learning in Python

Course Objectives:
This course examines the tools and techniques required for learning machine learning algorithms. This course will provide an introduction to the subject and its various applications. Student will learn to implement ML algorithms in python for solving various problems.
Prerequisites: basics of probability & statistics is required.
Syllabus:
UNIT I Basic programming in Python, Introduction: Basic definitions, types of learning, hypothesis space and inductive bias, evaluation, cross-validation.
UNIT II Linear regression, Decision trees, overfitting.
UNIT III Instance based learning, Feature reduction, Collaborative Filtering based recommendation.
UNIT IV Probability and Bayes learning.
UNIT V Logistic Regression, Support Vector Machine, Kernel function and Kernel SVM.
UNIT VI Neural network: Perceptron, multilayer network, backpropagation, introduction to deep neural network.
UNIT VII Clustering: k-means, Gaussian mixture model.

Text/Reference Books:
1. Geron Aurelien, “Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems”, OReilly, 2017.
2. Jerome H. Friedman, Robert Tibshirani, and Trevor Hastie, “The Elements of Statistical Learning”, Springer, 2001.
3. Sebastian Raschka, “Python Machine Learning”, Packt, 1st Edition, 2015

CE 70F Cloud Computing

Course Objectives:
This course will introduce various aspects of cloud computing, including fundamentals, management issues, security challenges and future research trends. This will help students and researchers to use and explore the cloud computing platforms.
Prerequisites: Basics of computer architecture and Organisation is required.
Syllabus:
UNIT I : Introduction to Cloud Computing, Cloud Computing Architecture
UNIT II: Service Management in Cloud Computing, Data Management in Cloud Computing
UNIT III : Resource Management in Cloud, Cloud Security
UNIT IV : Open Source and Commercial Clouds, Cloud SimulatorWeek 8 : Research trend in Cloud Computing, Fog Computing
Text/Reference Books:
1. Cloud Computing from Beginning to End by Ray J Rafaels
2. Cloud Computing: Concepts, Technology & Architecture by Zaigham Mahmood, Ricardo Puttini, Thomas Erl.
3. OpenStack Cloud Computing Cookbook by Kevin Jackson.

CE 700 Quantum Computing

About this Course

"Quantum Computing" is among those terms that are widely discussed but often poorly understood. The reasons of this state of affairs may be numerous, but possibly the most significant among them is that it is a relatively new scientific area, and it's clear interpretations are not yet widely spread. The main obstacle here is the word "quantum", which refers to quantum mechanics - one of the most counter-intuitive ways to describe our world. But fear not! This is not a course on quantum mechanics. We will gently touch it in the beginning and then leave it apart, concentrating on the mathematical model of quantum computer, generously developed for us by physicists. This doesn't mean that the whole course is mathematics either (however there will be enough of it). We will build a simple working quantum computer with our bare hands, and we will consider some algorithms, designed for bigger quantum computers which are not yet developed. The course material is designed for those computer scientists, engineers and programmers who believe, that there's something else than just HLL programming, that will move our computing power further into infinity.

Prerequisites are complex numbers and linear algebra

Course Contents:

7. **Unit I**: Introduction,Information and Computations, Characteristics of Computational Systems, Computability and Algorithms, Computational Complexity, Quantum Computing parameters and units, The Multiverse Interpretation of Quantum Mechanics
8. **Unit II:** Mathematical Model of Quantum Computing, Qubit, Qubit Measurement, Systems with Multiple Qubits, Measuring the Multiple Qubits Systems, Quantum System Evolution & Computations
9. **Unit III:** Quantum Computer and Quantum Algorithms,Deutsch's Problem, Quantum Computer Prototype, Suitable Algorithms
10. **Unit IV:** Shor's Algorithm, Factoring and the RSA, Factoring and Period Finding, Quantum Fourier Transform
11. **Unit V:** Grover's Algorithm. A Quantum Computer Application Boundaries, Grover's Algorithm, Challenges
12. **Unit VI:** Quantum environments, Search Spaces, Search Optimisation, Storage Optimisation, Quantum Resources, Future, Challenges

Text Book:

3. Nielsen, Michael A.; Chuang, Isaac L. (June 2012). Quantum Computation and Quantum Information (10th anniversary ed.). Cambridge: Cambridge University Press. ISBN 9780511992773. OCLC 700706156.

4. **References:** Research Papers as discussed in the class room.

CE 70G Blockchain Technology

Objective: Blockchain is an emerging technology platform for developing decentralized applications and data storage, The basic tenet of this platform is that it allows one to create a distributed and replicated ledger of events, transactions, and data generated through various IT processes with strong cryptographic guarantees of tamper resistance, immutability, and verifiability. The technology itself holds much more promise in various areas such as time stamping, logging of critical events in a system, recording of transactions, trustworthy e-governance etc. Many researchers are working on many such use cases such as decentralized public key infrastructure, self-sovereign identity management, registry maintenance, health record management, decentralized authentication, decentralized DNS, etc. Considering the need to disseminate the emerging concepts for students, we proposed a new course on blockchain technology, includes the fundamental design and architectural primitives of Blockchain, the system and the security aspects, along with various use cases from different application domains.

Pre-requisite: Expertise in Programming, Basic Knowledge of Computer Security, Cryptography, Networking.

Syllabus:

Unit1: Basic Cryptographic primitives used in Blockchain – Secure, Collison-resistant hash functions, digital signature, public key cryptosystems, zero-knowledge proof systems

Unit2: Basic Distributed System concepts – distributed consensus and atomic broadcast, Byzantine fault-tolerant consensus methods.

Unit3: Basic Blockchain – concepts to Bitcoin and contemporary proof-of-work based consensus mechanisms, operations of Bitcoin blockchain, crypto-currency as application of blockchain technology

Unit4: Hyperledger fabric platform- Decomposing the consensus process , Hyperledger fabric components, Chaincode Design and Implementation Hyperledger Fabric

Unit5: Beyond Cryptocurrency – applications of blockchain in cyber security, integrity of information, E-Governance and other contract enforcement mechanisms

Unit6: Security and Research Aspects

Text/Reference Books:

3. “S. Shukla, M. Dhawan, S. Sharma, S. Venkatesan, ‘Blockchain Technology: Cryptocurrency and Applications’, Oxford University Press, 2019.
4. Josh Thompson, ‘Blockchain: The Blockchain for Beginnings, Guild to Blockchain Technology and Blockchain Programming’, Create Space Independent Publishing Platform, 2017.

CE70H Cyber Security & Cryptography for Embedded Systems

Objective: Developed the knowledge of security concepts, cyber attacks and technologies to develop secure embedded systems.
Prerequisites: Basic understanding of Number Theory, Fundamentals of Operating Systems and Knowledge of programming language.

The course contains following topics:

Introduction to Security, Introduction to Embedded Security. Vulnerability types, Taxonomy of Attacks, Defense Mechanisms, Mathematics of Cryptography, Basics of symmetric versus asymmetric key encryption. Early ciphers - Substitution, permutation and product ciphers. Block versus stream ciphers. Basics of entropy and perfect secrecy, Mathematical foundations of the discrete logarithm problem, Diffie-Hellman Key Exchange, Mathematical foundations of RSA, Encryption using Elliptic curve The cryptographic hash – properties, Data Integrity, The cryptographic hash - construction, the Birthday paradox, Message Authentication, digital signature. Side Channels attacks on Embedded Systems, Embedded Cryptography, A5 Encryption for GSM, Hardware based Security. Transport layer security (TLS/SSL), FPGA based encryption and Decryption.
Text Books:

7. "Hardware Security: Design, Threats and Safeguards" by Debdeep Mukhopadhyay and Rajat Subhra Chakrabarty, CRC Press,2015.
8. "Cryptography & Network Security" by William Stallings4th Edition, 2006, Pearson Education Asia.
9. "Cryptography and Network Security" by Behrouz A. Forouzan, Mc Graw Hill.
10. "Cryptography & Network Security" by Kahate A, Tata Mc Graw Hill, 2004.
11. Morrie Gasser: Building a Secure Computer System
12. Michael Ligh, Steven Adair, Malware Analysts's cookbook, Wiley publishing

SEMESTER II ELECTIVE COURSES: FROM OTHER DEPARTMENTS

AM623 Machine Learning

Syllabus:
Introduction - Well-posed learning problems, Designing a learning system, Perspectives andissues 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
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

Evaluation Hypotheses – Motivation, Estimation hypothesis accuracy, Basics of samplingtheory, A general approach for deriving confidence intervals, Difference in error of two hypotheses, Comparing learning algorithms

Bayesian learning – Introduction, Bayes theorem, Bayes theorem and concept learning,Maximum likelihood and least squared error hypotheses, Maximum likelihood hypotheses forpredicting probabilities, Minimum description length principle, Bayes optimal classifier, Gibsalgorithm, Naïve Bayes classifier, An example learning to classify text, Bayesian belief networks The EM algorithm

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

Genetic Algorithms – Motivation, Genetic Algorithms, An illustrative Example, HypothesisSpace Search, Genetic Programming, Models of Evolution and Learning, Parallelizing Genetic Algorithms

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

Analytical Learning - Introduction, Learning with Perfect Domain Theories: Prolog-EBGRemarks on Explanation-Based Learning, Explanation-Based Learning of Search Control Knowledge

Combining Inductive and Analytical Learning – Motivation, Inductive-Analytical Approaches to Learning, Using Prior Knowledge to Initialize the Hypothesis, Using PriorKnowledge to Alter the Search Objective, Using Prior Knowledge to Augment Search Operators,

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 WHsieh, Cambridge Univ Press.
4. Richard o. Duda, Peter E. Hart and David G. Stork, pattern classification, John Wiley &SonsInc., 2001.
5. Chris Bishop, Neural Networks for Pattern Recognition, Oxford University Press, 1995

AM625 Digital Image Processing

Syllabus:

Digital Image Fundamentals: Introduction – Origin –Steps in Digital Image Processing – Components; Elements of Visual Perception – Light and Electromagnetic Spectrum – ImageSensing 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 – EdgeLinking 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.

Text / References:

1. Digital Image Processing, 3rd Ed., 2007, R. C. Gonzalez, Richard E. Woods, Prentice Hall.
2. Digital Image Processing Using MATLAB, 2nd Ed., 2009, R. C. Gonzalez, Richard E.Woods, Steven L. Eddins, Gatesmark Publishing.
3. Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press.
4. Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India.
5. Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley.
6. Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker

ME626 Introduction to Robotics

Syllabus:

Unit I: Robot definition, Robotics and programmable automation Historical background, laws ofRobotics. Robotics systems and Robot anatomy, specification of Robots.Robotgeometricalconfiguration.

Unit II: Performance Definition - Accuracy / Repeatability / Precision with respect to Position &Path, payload, speed, acceleration, cycle time - Challenges, Applications and uses of Mobile andother robots: wheeled, tracked, legged, aerial, underwater robots, surgical robots, rehabilitationrobots, humanoid robots, Nano Robots.

Unit III: Classification of end effectors, Types of Grippers Hooks, scoops and other devices,Gripper force analysis and design of Drive system for gripper – communication of robots

UnitIV: Euler angles for specifying orientation, Euler angles for roll-yaw-roll geometry, Gripperpositioning by Euler angles for roll-yaw-roll geometry - Euler angles for roll - pitch – yawgeometry, Cylindrical Robot coordinates polar Robot coordinates, calculation of cylindrical,polar coordinates, Some applications.

Practice:

1. Firebird Robot Platform Experiments,
2. Languages, Simulation Softwares for Robotics,
3. Case studies etc.

Text/References:

1. Francis N. Nagy, AndrasSiegler, *Engineering foundation of Robotics*, Prentice Hall Inc.,1980.
2. Richard D. Klafter, Thomas. A, ChriElewski, Michael Negin, *Robotics Engineering anIntegrated Approach*, Prentice Hall of India Pvt. Ltd., 1989.
3. P.A. Janaki Raman, *Robotics and Image Processing an Introduction*, Tata Mc GrawHillPublishing company Ltd., 1995.
4. Mikell P. Grooyer, Mitchell weiss, Roger N. Nagel, Nicholas G. Odrey, *Industrial Robotics,Technology programming and Applications*, Mc Graw Hill International Edition, 1986.
5. S.R. Deb, *Robotics Technology and flexible automation*, Tata Mc Graw Hill publishingcompany Ltd., 1994.
6. Carl D. Crane and Joseph Duffy, *Kinematic Analysis of Robot manipulation*, CambridgeUniversity press, 1998.

ME628 Robot Kinematics and Dynamics

Syllabus:

Unit I: Introduction, position and orientation of objects, objects coordinate frame Rotationmatrix, Euler angles Roll, pitch and yaw angles coordinate Transformations, Joint variables andposition of end effectors.

Unit II: Dot and cross products, coordinate frames, Rotations, Homogeneous coordinates,linkcoordinates D-H Representation, The ARM equation. Direct kinematic analysis for Four axis,SCARA Robot and six axis Articulated Robots.

Unit III: The inverse kinematics problem, General properties of solutions. Tool configuration,Inverse kinematics of four axis SCARA robot and six axis Articulated robot.

Unit IV: Workspace Analysis, work envelope of a Four axis SCARA robot and five axisarticulated robot workspace fixtures, the pick and place operations, continuous path motion,Interpolated motion, straight line motion.

Unit V: Introduction, lagrange's equation kinetic and potential energy. Link inertia Tensor, linkJacobian Manipulator inertia tensor. Gravity, Generalized forces, Lagrange-Euler Dynamicmodel, Dynamic model of a Two-axis planar robot Newton Euler formulation, Lagrange –Eulerformulation, problems.

Practice:

1. Robot Analyzer Platform Experiments,
2. Simulation Softwares for Robotics,
3. Case studies etc.

Text/References:

1. Robert J. Schilling, *Fundamentals of Robotics Analysis and Control*, Prentice Hall ofIndiaPvt. Ltd., 2000

2. Richard D. Klafter, Thomas. A, Chmielewski, Michael Negin, *Robotics Engineering anIntegrated Approach*, Prentice Hall of India Pvt. Ltd., 1989
3. P.A. Janaki Raman, *Robotics and Image Processing an Introduction*, Tata Mc GrawHillPublishing company Ltd., 1995
4. Francis N-Nagy AndrasSiegler, *Engineering foundation of Robotics*, Prentice Hall Inc.,1987
5. Bernard Hodges, *Industrial Robotics*, Jaico Publishing house, 2nd Edition, 1993.
6. Tsuneo Yohikwa, *Foundations of Robotics Analysis and Control*, Prentice Hall of IndiaPvt. Ltd., 2001.
7. John J. Craig, *Introduction to Robotics Mechanics and Control*, Second Edition, AddisonWesly Longman Inc. International Student edition, 1999
8. Bijay K. Ghosh, Ning Xi, T.J. Tarn, *Control in Robtics and Automation Sensor – Basedintegration*, Academic Press, 1999

Department of Applied Matheamtics

M. Tech in Modelling and Simulation

Brief Introduction of Department

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.

Department of Applied Mathematics offers a two year Multidisciplinary M. Tech. (Modelling & Simulation) programme, and also offers a Doctoral Degree programme in the areas of Applied Mathematics. **This programme was provisionally accredited by NBA.**

The aim of the Department was 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 Department is five and one visiting faculty. The Department is also actively engaged in handling the projects from various agencies. Since then the Department members have 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. Recently the Department 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.

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 practicals. 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
- Finite Element Analysis in Fluid Flow through Porous Media
- Computational Fluid Dynamics
- Partial Differential Equations & its Applications
- Numerical Methods for PDEs
    - Finite Elements Method
    - Boundary Element Method

- Domain Decomposition Method

- Boundary Layer Theory
- Numerical Parallel Algorithms and Parallel Computing.
- Bio-Mechanics
- Cryptography
- Image Processing

Vision of the Department

- ✓ To provide high quality education, research and training in Applied Mathematics and in the Multidisciplinary area: “Modelling and Simulation” for solving the complex problems.

Mission of the Department

- ✓ To build strong teaching and research environment for basic and applied research with thrust to defence related problems.
- ✓ To encourage and help the students community to develop mathematical and statistical models and also exploit available tools for solving real life and defence related problems.
- ✓ To become a premier department in the country in the area of “Modelling and Simulation” and applications of mathematics.
- ✓ To provide high quality education, research and customised training in the area of “Modelling and Simulation” for

  DRDO Scientists, Service Officers, DPSU and other civilian community.

Programme Educational Objectives

- ✓ The department of Applied Mathematics is committed to impart knowledge related to Modelling & Simulation and applied mathematical techniques to students and service officers to obtain realistic and reasonable solutions for real world and defence related problems to meet the challenges of current and future requirements of nation.
- ✓ Being an interdisciplinary programme, such knowledge can help to solve the problem holistically and to achieve successful career and professional accomplishment.
- ✓ To inculcate positive attitude, professional ethics, effective communication and interpersonal skills which would facilitate them to succeed in the chosen profession exhibiting creativity and innovation through research and development both as team member and as well as leader.

Programme Outcomes (POs)

- ✓ The department imparts higher education and training in the field of modelling and simulation meeting the defence, industries and academic requirement of the country.
- ✓ Various courses offered under his programme help to develop various mathematical models cutting across the boundaries and to understand simulation techniques.
- ✓ After providing the appropriate training in computation and simulation methods and imparting knowledge on contemporary issues, students are well equipped to tackle challenges in the related field.
- ✓ This is a unique capability which helps the students to establish themselves as a successful professional.
- ✓ An ability to function on multidisciplinary teams involving interpersonal skills.
- ✓ An ability to identify, formulate and solve engineering problems of multidisciplinary nature

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Eligibility for admission to M.Tech programme:

M.Sc. in Mathematics / Physics / Statistics / O.R. / Computer science (Provided mathematics is one of the subject at the graduate level), Bachelors Degree in Engineering / Technology of a recognized Institute / University. Proficiency in computer programming is essential.

Organization of M.Tech programme:

This programme is of four-semester duration. In first and second semester have six courses along with practical component of each course. The respective course instructor will give assignemts / 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 stuructures (C / C++) / MATLAB / MATHEMATICA / Simula8 / Maplesim / SPSS / R / Extend Sim. . .etc., All these softwares are licensed version and available in the department.

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. 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 where as 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 fourthe 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	Advanced Numerical Methods	3	1	4
2.	AM 602	Mathematical Modelling & System Analysis	3	1	4
3.	AM 603	Advanced Optimization Techniques	3	1	4
4.	AM 604	Advanced Statistical Techniques	3	1	4
5.	AM 605	Computer Graphics	3	1	4
6.	AM 606	Mathematical Methods	3	1	4
		Total	**18**	**6**	**24**

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 Department(AM)]	3	1	4
4.		Elective II [From Department(AM)]	3	1	4
5.		Elective III	3	1	4
6.		Elective IV	3	1	4
		Total	**18**	**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/ week

Note: During summer vacation (4 Weeks), Summer Internship / Industirial Tour will be accepted for all students relavant to the dissertation work especially modeling and Simualtion

List of Electives are given Below:

Sl. No.	Course Code	Course
Elective I, II		
	AM 623	Machine Learning
	AM 624	Tensor Analysis and Engineering Applications
	AM 625	Digital Image Processing
	AM 626	Computational Heat and Mass Transfer
	AM 627	Introduction to Non Newtonian Fluids
	AM 628	Computational Number Theory and Cryptography
	AM 629	Calculus of Variations and Integral Equations
	AM 630	Domain Decomposition Methods
	AM 631	Multigrid Methods
	AM 632	Ballistics
	AM 633	Bio-Mechanics

AM 601 Advanced Numerical Methods

Solution of Ordinary Differential Equations: Taylor series method – Euler and Modified Euler methods – Runge kutta methods– Multistep methods – Milne‟s method – Adams Moulton method.

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.

Numerical Solution of Partial Differential Equations- Finite Difference Methods (FDM) : (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 Finite Differences

Finite difference approximations for partial derivatives and finite difference schemes:

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 / References:

1. Numerical Solutions of Differential Equations, 2nd Ed., 1984, M. K. Jain, Wiley Eastern.
2. Numerical Solution of Partial Differential Equations, 3rd Ed., 1986, G.D. Smith, Oxford Univ. Press.
3. Computational Methods for Partial Differential Equations, 2007, M. K. Jain, S. R. K. Iyengar, New Age International.
4. Applied Numerical Analysis, 7th Ed., 2003, Curtis F. Gerald, Patrick O. Wheatley, Pearson Education.
5. Numerical Methods Using MATLAB, 4th Ed., 2004, John H. Mathews, Kurtis D. Fink, Pearson Education.
6. An Introduction to Computational Fluid Dynamics - The Finite Volume Method, 2nd Ed., 2007, H. K. Versteeg, W. Malalasekera, Pearson Education.

AM 602 Mathematical Modelling and System Analysis

Mathematical Modelling: Introduction to modelling and simulation, Classification of systems into continuous and discrete, Structural characterization of mathematical model and validation techniques.

Modelling Techniques: Dimensional analysis: Concept behind dimensional approach, Buckingham Pi theorem, Models using dimensional approach.

Continuous approach: Models based on physical laws.

Discrete Approach: Models based on discrete approach. Prey - Predator models.

Combat Modelling: Modelling the Lanchester laws with System Dynamics.

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.

Text Books / References

1. Modelling Mathematical Methods & Scientific Computations, 1995, Nicola Bellomo & Luigi Preziosi, CRC Press.
2. Systems Modelling and Analysis, 2003, I.J. Nagrath, M. Gopal, Tata McGraw Hill, New Delhi.
3. Introduction to Mathematical Systems Theory - A behavioural approach, 2nd Ed., 2008, Jan Willen Polderman, Jan C. Willems, Springer.
4. Introduction to System Dynamics, 1967, J.L. Shearer, A.T. Murphy, H.H. Richardson, Addison& Wesley.
5. Introduction to System Analysis, 1985, T.H. Glisson, McGraw Hill.

AM – 603 Advanced Optimization Techniques

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: Nelder Mead's Simplex search method, Gradient of a function, Steepest descent method, Newton's method, Conjugate Gradient methods for handling constraints.

Genetic algorithm (GA) : Differences and similarities between conventional and evolutionary algorithms, working principle, reproduction, crossover, mutation, termination criteria, different reproduction and crossover operators, GA for constrained optimization, draw backs of GA

Genetic Programming (GP): Principles of genetic programming, terminal sets, functional sets, differences between GA & GP, random population generation, solving differential equations using GP.

CPM/PERT: Simulation of CPM/PERT network, Analysis of an activity network, Simulation of inventory system and manufacturing system

Text Books / References:

1. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
2. Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
3. Engineering Optimization: Theory and Practice, 4th Ed., 2009, S.S. Rao, Wieley Eastern Ltd.
4. Optimization: Theory and Practice, 2004, MC Joshi, KM Moudgalya, Narosa.
5. Introduction to Optimization, 1988, Beale, John Wiley.
6. Optimal design – Jasbir Arora, Mc Graw Hill (International) Publishers
7. Optimization for Engineering Design – Kalyanmoy Deb, PHI Publishers
8. Genetic algorithms in Search, Optimization, and Machine learning – D.E.Goldberg, Addison Wesley Publishers
9. Genetic Programming- Koza
10. A Field Guide to Genetic Programming, Riccardo Poli, William B. Langdon, Nicholas F. McPhee
11. Genetic Programming Theory and Practice by Rick Riolo, Bill Worzel, Kluwer Academic Publishers
12. Genetic Programming: An Introduction, Wolfgang Banzhaf, Peter Nordin, Robert E. Keller, Frank D. Francone, Morgan Kaufmann Publishers
13. Multi objective Genetic algorithms - Kalyanmoy Deb, PHI Publisher

14. Numerical Methods and Optimization, Hari Arora, S.K. Kataria & Sons
15. Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer

AM 604 Advanced Statistical Techniques

Probability and Probability Distributions: Basic concepts of Probability , Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, Weibull etc.).

Inferential Statistics: Theory of Estimation, Sampling Distribution, Tests of Hypothesis (one sample t, two sample t etc.), Chi Square Test.

Introduction to Statistical modelling.

Regression modeling for Normal response and quantitative explanatory: 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 Design and Analysis of Experiments: Need for conducting Experiments, Applications of experiments, Basic Principles of Experiments, Road Map to conduct efficient experiments Terminologies associated with experiments.

Text/References

1. Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd.
2. Design and Analysis of Experiments, 8th Ed., 2012, Douglas C. Montgomery, Wiley.
3. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
4. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
5. All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer.
6. Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press.
7. Schaum's outlines Probability and statistics, 4th Ed., 2013, Murray R. Speigel, John Schiller, R Alu Srinivasan, Tata McGraw Hill.

AM 605 Computer Graphics

Introduction: Application areas of Computer Graphics, overview of graphics systems, video-display devices, raster-scan systems, random scan systems, graphics monitors and work stations and input devices

Output primitives: Points and lines, line drawing algorithms, mid-point circle and ellipse algorithms. Filled area primitives: Scan line polygon fill algorithm, boundary-fill and flood-fill algorithms.

2-D Geometrical transforms: Translation, scaling, rotation, reflection and shear transformations, matrix representations and homogeneous coordinates, composite transforms, transformations between coordinate systems.

2-D Viewing: The viewing pipeline, viewing coordinate reference frame, window to view-port coordinate transformation, viewing functions, Cohen-Sutherland and Cyrus-beck line clipping algorithms, Sutherland –Hodgman polygon clipping algorithm.

3-D Object representation: Polygon surfaces, quadric surfaces, spline representation, Hermite curve, Bezier curve and B-spline curves, Bezier and B-spline surfaces. Basic illumination models, polygon rendering methods.

3-D Geometric transformations: Translation, rotation, scaling, reflection and shear transformations, composite transformations, 3-D viewing: Viewing pipeline, viewing coordinates, view volume and general projection transforms and clipping.

Visible surface detection methods: Classification, back-face detection, depth-buffer, scan-line, depth sorting, BSP-tree methods, area sub-division and octree methods

Computer animation: Design of animation sequence, general computer animation functions, raster animation, computer animation languages, key frame systems, motion specifications

Text / References:

1. Computer Graphics, Donald Hearn and M. Pauline Baker, Pearson education, C version.
2. Computer Graphics Principles & practice, second edition in C, Foley, VanDam, Feiner and Hughes, Pearson Education.
3. Computer Graphics Second edition, Zhigand xiang, Roy Plastock, Schaum's outlines, Tata Mc Graw hill edition.
4. Procedural elements for Computer Graphics, David F Rogers, Tata Mc Graw hill, 2nd edition.
5. Principles of Interactive Computer Graphics, Neuman and Sproul, TMH.
6. Principles of Computer Graphics, Shalini, Govil-Pai, Springer.
7. Computer Graphics, with OpenGL Hearn and Baker, - Pearson
8. Computer Graphics, Sinha & Udai, - TMH

AM 606 Mathematical Methods

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. **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.

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.

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 – 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.

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.

AM 607 Mathematics for Engineers

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

Texts / References:

13. Advanced Engineering Mathematics, 11th Ed, 2010, Erwin Kreyszig, Wiley Eastern.
14. Linear Algebra and its Applications, 4th Ed., 2008, Gilbert Strang, Academic Press.
15. Numerical Methods for Scientists and Engineers, Joe D. Hoffman, Marcel Dekker Inc.
16. Numerical Methods for Engineers, Sixth Edition, Steven Chapra and Raymond Canale, McGraw-Hill Education
17. Elements of Numerical Analysis, 2nd Edition, Radhey S. Gupta**,** Cambridge University Press
18. Numerical Solutions of Partial Differential Equations: An Introduction, 2nd Ed., 2005, K. W. Morton, D. F. Mayers, Cambridge University Press.
19. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
20. Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
21. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
22. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
23. Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko, 3rd Ed., Vol. 7, 2006, Springer Verlag, New York.
24. .S. Gupta.. Calculus of Variation, Prentice Hall of India Pvt. Ltd.

AM 621 Advanced Modelling Techniques

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/References

1. Fuzzy Logic with Engineering Applications, 2009, Timothy J Ross, Wiley.
2. Neural Computing: An Introduction, 2010, R. Beale, T. Jackson, Adam Hilger, CRC Press.
3. Neural fuzzy systems: A Neurofuzzy Synergism to Intelligent Systems, 1996, Chin- Teng Lin and C.S.G. Lee, Prentice Hall International, INC.
4. Encounter With Chaos, 1992, Denny Gulick , McGraw Hill Inc.

AM 622 Simulation of Linear and Nonlinear Systems

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/References

1. An Introduction to Mathematical Control Theory, 1990, S. Barnett and R. G. Cameron, Oxford University Press.
2. Nonlinear Systems, 3rd Ed., 2003, H.K. Khalil, Prentice Hall.
3. Applied Nonlinear Control, 1991, J.J.E. Slotine, W. Li, Prentice Hall
4. Simulation Modeling & Analysis, 2008, Law A.M., Tata McGraw Hill.
5. System Modelling and Computer Simulation, 1996, Kheir N.A, Marcell Dekker.
6. Discrete-Event System Simulation, 5th Ed., 2009, Jerry Banks, John Carson, Barry L. Nelson, David Nicol, Prentice Hall
7. Operations Research: An Introduction, 2002, Taha H.A, Prentice Hall.

AM 623 Machine Learning

Introduction - 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

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

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

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

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

Genetic Algorithms – Motivation, Genetic Algorithms, An illustrative Example, Hypothesis Space Search, Genetic Programming, Models of Evolution and Learning, Parallelizing Genetic Algorithms

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

Analytical Learning - Introduction, Learning with Perfect Domain Theories: Prolog-EBG Remarks on Explanation-Based Learning, Explanation-Based Learning of Search Control Knowledge

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,

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

AM 624 Tensor Analysis and Engineering Applications

Definition and algebra of tensors. Summation convention – Contravariant and covaraiant vectors – Contraction of tensors – Inner product – Quotient law – Metric tensor – Chrirstoffel symbols – Covariant differentiation – Gradient, divergence and curl. Dyadic representation in Cartesian and general components. Calculus of tensor fields in curvilinear coordinates. Derivation and application of the basic equations of heat conduction, rigid body mechanics, elasticity, fluid mechanics & electromagnetism in tensor form.

Text / References:

1. Tensor Calculus - Barry Spain ., Radha Publishing House.
2. Mathematical Methods in Physics & Engg.,- John W.Dettman., Mc-Grawhill.
3. Tensor Calculus – U.C.De, Absos Ali Shaikh & Joydeep Sengupta., Narosa Publications.
4. Tensor Analysis with Application in Mechanics – Leonid.P.Levedev, Michael.J.Cloud Victoria eremeyev; World Scientific Publication.
5. Applications of Tensor Analysis – A.J.MeConnell, Dover Publications.
6. Tensor Analysis with Applications – Jafer Ahsan, Annamaya Publications.

AM 625 Digital Images Processing

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.

Text / References

1. Digital Image Processing, 3rd Ed., 2007, R. C. Gonzalez, Richard E. Woods, Prentice Hall.
2. Digital Image Processing Using MATLAB, 2nd Ed., 2009, R. C. Gonzalez, Richard E. Woods, Steven L. Eddins, Gatesmark Publishing.
3. Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press.
4. Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India.
5. Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley.
6. Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker.

AM 626 Computational Heat and Mass Transfer

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.

Convective Heat Transfer:

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.

Convective Mass Transfer

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 correlation’s for mass transfer. Simultaneous heat and mass transfer - analogy between heat, mass and momentum transfer

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.

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.

Text / References

1. Computational Fluid Dynamics-Basics with applications, 1st Ed., 1995, John D. Anderson: McGraw-Hill Science.
2. An Introduction to Fluid Dynamics, 2010, G. K. Batchelor, Cambridge University Press.
3. Computational Fluid Mechanics and Heat Transfer, 3rd Ed., 2011, Richard H. Pletcher, John C. Tannehill, Dale Anderson, Taylor & Francis.
4. Computational Fluid Dynamics: A Practical Approach, 1st Ed., 2008, Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu, Butterworth-Heinemann.
5. Computational Methods for Fluid Dynamics, 3rd Ed., 2013, J. H. Ferziger, M. Peric, Springer.
6. Convection in Porous Media, 4th Ed., 2013, Donald A. Nield, Adrian Bejan, Springer.
7. Convective Heat and Mass Transfer, 1st Ed., 2011, S. Mostafa Ghiaasiaan, Cambridge University Press.
8. Fundamentals of Heat & Mass Transfer by Thirumaleshwar, Pearson
9. Conduction Heat transfer, Poulikakos, Prentice Hall, 1994.
10. Analytical methods in Conduction Heat Transfer, G.E. Mayers, McGraw Hill, 1971.
11. Convective Heat and Mass Transfer, Kays W M and Crawford M E, McGraw Hill Int Edition, 3rd edition, 1993.
12. Introduction to Convective Mass Transfer, Spalding D B, McGraw Hill, 1963.

AM 627   Introduction to Non-Newtonian Fluids

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 / References

1. An Introduction to Fluid Dynamics, 1976, R.K.Rathy, Oxford & IBH Publishing.
2. Theory of Fluids with Microstructure – An Introduction, 1984, Vijay Kumar Stokes, Springer – Verlag
3. Micropolar Fluids Theory and Applications, 1999, Grzegorz Lukaszewicz, Birkhauser Boston.
4. Fluid Dynamics, 3rd Ed., 2004, William F. Hughes, John A. Brighton, Tata McGraw- Hill.

AM 628 Computational Number Theory and Cryptography

Introduction: Attacks, Services and Mechanisms, Security attacks, Security services, A Model for Internetwork security. Classical Techniques: Conventional Encryption model, Steganography, Conventional Encryption Principles, Conventional encryption algorithms, cipher block modes of operation, location of encryption devices.

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.

Factorization and Primality Testing: Complexity of Number Theoretic Algorithms, Fermat's Factorization, Kraitchik's Improvement, Pollard Rho Algorithm, Legendre and Jacobi Symbols, Computing Legendre symbols, Primitive Roots, Pseudo Primality Testing, Miller-Rabin Algorithm**,** Quadratic Reciprocity Law

Finite fields: Groups, Fields, Finite Fields, Arithmetic in Finite Field, Finding Multiplicative Inverses in finite fields, Binary Fields and their application in Cryptosystems, Primitive roots.

Cryptography: Introduction to Cryptosystems, Classical Ciphers, Cryptanalysis of Classical ciphers, LFSR based stream ciphers. Shannon's Theory**,** Public Key Cryptography, RSA Cryptosystem, Diffie-Helman Key Exchange, Rabin Cryptosystem, Knapsack Ciphers, Digital Signature, Secret Sharing, ElGamal Cryptosystem, Elliptic Curve Cryptography.

Elliptic Curve Cryptography: Introduction to Elliptic Curves, Geometry of Elliptic curves over Reals, Weierstrass Normal form, Point at infinity, Elliptic Curves over Finite fields, Group structure, Discrete Log problem for Elliptic curves, Factorization using Elliptic Curve, Advantage of Elliptic Curve Cryptography over other Public Key Cryptosystems.

Text / References

1. N. Koblitz, A Course in Number Theory and Cryptography, Springer 2006.
2. I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to theory of numbers, John Wiley & Sons, Inc 2006.
3. L. C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.
4. J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.
5. D. Hankerson, A. Menezes and S. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag, 2004.
6. J. Pipher, J. Hoffstein and J. H. Silverman , An Introduction to Mathematical Cryptography, Springer-Verlag, 2008.
7. G.A. Jones and J.M. Jones, Elementary Number Theory, Springer-Verlag, 1998.
8. R.A. Mollin, An Introduction to Cryptography, Chapman & Hall, 2001.

9. Song Y. Yan: Number Theory for Computing, Springer-Verlag, Second Edition,2002.
10. T. H. Cormen, C. E. Leiserson, and R. L. Rivest: Introduction to Algorithms, Second Edition, Prentice Hall of India, 1994.
11. K. Rosen: Elementary Theory of Numbers, Fifth Edition, Addison Wesley, 2004.
12. D. M. Bressoud: Factorization and Primality Testing, Springer-Verlag, 1989.

AM 629 Calculus of Variations and Integral Equations

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.

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.

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.

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.

Text / References

1. A.J. Jerri. Introduction to Integral Equations with Applications. Wiley-Interscience.
2. R.P. Kanwal. Linear Integral Equations: Theory and Techniques. New York: Academic Press.

3. J.M. Gelfand and S.V. Fomin. Calculus of Variations. Englewood Cliffs: Prentice-Hall, 1963.
4. Weinstock . Calculus of Variations. McGraw-Hall.
5. Abdul-Majid Wazwaz. A First Course in Integral Equations. World Scientific Pub.
6. P. David and S.G. David. Stirling Integral Equations. Cambridge University Press.

AM 630 Domain Decomposition Methods

The mathematical Foundation of Domain decomposition Methods. Discretised equations and Domain Decomposition Methods. Schur Complement and Iterative Sub-structuring Algorithms. Iterative Domain Decomposition Methods. Time-dependent problems. Multilevel and local grid refinement methods.

Text / References

1. Domain Decomposition Methods for Partial Differential Equations, 1999, Alfio Quarteroni and Alberto Valli, Clarendon Press, Oxford.
2. The Finite Element Method for Elliptic Problem, 1989, P. G. Ciarlet, North-Holland Publishing Company, Newyork.
3. Domain Decomposition Methods Algorithms and Theory, 2004, A. Toselli and O. Widlund, Springer-Verlag.
4. Domain Decomposition Methods for the Numerical Solution of Partial Differential Equations, 2008, Tarek P.A. Mathew, Springer-Verlag Berlin Heidelberg.

AM 631 Multigrid Methods

Basic concepts, local and global processing, discretization, 1D model problem and its direct and iterative solution, convergence analysis, 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, nonlinear and anisotropic problems, advanced techniques, algebraic approach, applications.

Text / References:

1. B. Smith, P. Bjorstad, W. Gropp*, Domain Decomposition: Parallel Multilevel Methods for Elliptic Partial Differential Equations, C*ambridge, 1996.
2. E. Henson, and S. F. McCormick: A Multigrid Tutorial, 2nd ed., SIAM, 2000.
3. U. Trottenberg, C. W. Oosterlee, and A. Schueller: Multigrid, Academic Press, 2001.

4. W. Hackbusch and U. Trottenberg eds.: Multigrid Methods, Springer-Verlag, Berlin, 1982.
5. P. Wesseling: An Introduction to Multigrid Methods, Wiley, Chichester, 1992.
6. W. Hackbusch: Multi-grid Methods and Applications, Springer, Berlin 1985.
7. Brandt: Multi-level Adaptive Solutions to Boundary-Value Problems, Math. Comput, Vol. 31, 333-390, 1977.

AM 632 Ballistics

Explosives: Explosive compounds and explosive mixtures-classification of explosives: Measurement of various explosive parameters

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.

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.

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.

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.

Design and Defeat of Armour: Introduction –Mechanical property requirements-Armour material Characteristics –Armour structure-stress-strain relationship-Waves in rods-Defeat of armour-Failure

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.

Text / References:

1. The Books of Ballistics and Gunnery, 1987, War Office, UK.
2. Modern Exterior Ballistics, 1999, Robert McCoy-Schiffer publishing Ltd.
3. Interior Ballistics, 1951, HMSO publication
4. Terminal Ballistics- A Text Book and atlas of gunshot wounds, Malcom J Dodd, CRC press, Taylor & Francis publications
5. Firearms in criminal investigation and trials, Dr. BR Sharma, 3rd Edition, Universal Law publishing Co. Pvt Ltd.
6. Gunshot wounds- practical aspects of Firearms. Ballistics and Forensic Techniques, Vincent JM DiMaio, Elsevier Science publishing Co. Inc
7. Wound Ballistics and the Scientific Background, Karl G Sellier & Beat P Kneubuehl Elseviour Science publishing Co. Inc.

AM 633 Bio-Mechanics

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 / References:

1. Biomechanics, Springer-verlag: Y.C.Fung
2. Bio-fluid Dynamics Taylor and Francis: Clement Kluinstreuer
3. Frontier in Mathematical Biology: S.A.Levin
4. Biomathematics: Ricciardi

M. Tech in Data Science

Introduction: 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.

Department of Applied Mathematics offers a two year Interdisciplinary M. Tech. (Modelling & Simulation) programme, and also offers a Doctoral Degree programme in the areas of Applied Mathematics.

The Department faculty members have 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.

This MTech. (Data Science) 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, game theory (IME, Economics), programming, algorithms, operating systems, databases, signal processing, machine learning and data mining techniques of data science (CS, EE). Information Theory (information, entropy, conditional information, coding), Multi-resolution (multirate) signal processing (wavelets, pyramids), 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 practicals. 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.

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 Data Science	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 B. Tech / BE degree in CSE / IT / ECE / ME / AE. OR MSc / MS degree in CS / IT / Mathematics / Physics / Electronics Provided 1) Mathematics is one of the subject at the graduate level and 2) Knowledge in computer programming is desirable

CSE - Computer Science Engineering

IT - Information Technology

AE - Aerospace Engineering

ECE - Electronics & Communication Engineering

ME - Mechanical Engineering

Semester I:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T /P	
1.	AM 603D	Computer Oriented Optimization Methods	3	1	4
2.	AM 604D	Statistical Computing for Data Science	3	1	4
3.	AM 606D	Scientific Computing	3	1	4
4.	AM 607D	Data Structures and Algorithms with C	3	1	4
5.	CE 615A	Intelligent Algorithms	3	1	4
6.	CE 696A	Artificial Intelligence and DSS	3	1	4
		TOTAL	1 8	6	24

Semester II:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 623D	Machine Learning	3	1	4
2.	AM 624D	Data Science: Tools and Techniques	3	1	4
3.	CE 694	Big Data Analysis and Algorithms	3	1	4
4.		Elective I (Department Electives)	3	1	4
5.		Elective II (Open Elective)	3	1	4
6.		Elective III (Open Elective)	3	1	4
		TOTAL	18	6	24

Semester III:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 651D	M. Tech Dissertation - 1	28**		14
		TOTAL	28		14

Semester IV:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 652D	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 609D	**Data Science: Industrial Perspectives#**
	AM 625D	Image and Video Analytics
	AM 627D	Information Theory and Coding
	AM 628D	Computational Number Theory and Cryptography
	CE 605	Applied Artificial Intelligent Systems
	CE 607	Decision Support Systems
	CE 610	Information Retrieval Systems
	CE 631	Deep Learning
	CE 632	Computer Vision
	CE 688	Game Theory
	CE 690	Parallel & Distributed Systems
	CE 691	Secure Wireless Sensor Networks
	CE 699	Internet of things
	EE 610D	Multiresolution Signal Processing
	AP 618	Advanced Sensors

- ✓ **# This is an audit course which is mandatory for both the semesters of this programme students.**
- ✓ **<u>Evaluation Process:</u> This is a seminar course where specialists will give talk(s) on various verticals like: biology, healthcare, retail governance, physical sciences, e-commerce, climate, supply chains and financial services, manufacturing, hospitality**

etc. This seminar series will provide the industry or domain specific context for advanced analytics. Summary report of each presentation of the talk given by the expert will be submitted by each student. In addition to this, at the end of the presentation of the expert talk, an exam will be conducted for 10 marks of each talk and a question paper will be set by the expert who has given the talk given to the students. Students will also explore the journal papers, do literature Survey related to this course and give at least one presentations in a month. A total of minimum of 5 presentations by expert talk and each student by 5 talks will be evaluated. A total of 100 marks evaluation will be done to assess the student in this course.

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 603D	**Computer Oriented Optimization Techniques**	**CORE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
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. Nelder Mead's Simplex search method.	
Constrained optimization: Constrained optimization with equality and inequality constraints. Kelley's convex cutting plane algorithm - Gradient projection method - Penalty Function methods. Constrained optimization: Lagrangian method - Sufficiency conditions - Kuhn-Tucker optimality conditions- Rate of convergence - Engineering applications Quadratic programming problems-Convex programming problems.	
Unconstrained optimization: One dimensional minimization - Elimination methods: Fibonacci & Golden section search - Gradient methods - Steepest descent method	

Genetic algorithm (GA) : Differences and similarities between conventional and evolutionary algorithms, working principle, reproduction, crossover, mutation, termination criteria, different reproduction and crossover operators, GA for constrained optimization, draw backs of GA	
Genetic Programming (GP): Principles of genetic programming, terminal sets, functional sets, differences between GA & GP, random population generation, solving differential equations using GP.	

Texts / References Books

1. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
2. Engineering Optimization: Theory and Practice, 4th Ed., 2009, S.S. Rao, Wieley Eastern Ltd.
3. Optimization: Theory and Practice, 2004, MC Joshi, KM Moudgalya, Narosa.
4. Introduction to Optimization, 1988, Beale, John Wiley.
5. Optimization for Engineering Design – Kalyanmoy Deb, PHI Publishers
6. Genetic algorithms in Search, Optimization, and Machine learning – D.E.Goldberg, Addison Wesley Publishers
7. Genetic programming: on the programming of computers by means of natural selection- John R. Koza, MIT Press, 1992.
8. Genetic Programming Theory and Practice by Rick Riolo, Bill Worzel, Kluwer Academic Publishers
9. Genetic Programming: An Introduction, Wolfgang Banzhaf, Peter Nordin, Robert E. Keller, Frank D. Francone, Morgan Kaufmann Publishers
10. Multi objective Genetic algorithms - Kalyanmoy Deb, PHI Publisher
11. Numerical Methods and Optimization, Hari Arora, S.K. Kataria& Sons
12. Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer
13. David G Luenberger, .Linear and Non Linear Programming., 2nd Ed, Addison-Wesley.
    Bazarra M.S., Sherali H.D. & Shetty C.M., Nonlinear Programming Theory and Algorithms, John Wiley, New York, 1979.

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 604D	**Statistical Computing for Data Science**	**CORE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	No of hours
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. Curve Fitting and Principles of Least Squares-Regression and correlation.	
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.	
Tabular data- Power and the computation of sample size- Advanced data handling Multiple regression- Linear models- Logistic regression- Rates and Poisson regression Nonlinear curve fitting	
Density Estimation- Recursive Partitioning- Smoothers and Generalised Additive Models - Survivals Analysis- Analysing Longitudinal Data- Simultaneous Inference and Multiple Comparisons- Meta-Analysis- Principal Component Analysis- Multidimensional Scaling Cluster Analysis	
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.	

Texts / References Books

1. **Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd.**
2. **Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.**
3. **An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.**
4. **All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer.**
5. **Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press.**
6. **Schaum's outlines Probability and statistics, 4th Ed., 2013, Murray R. Speigel, John Schiller, R Alu Srinivasan, Tata McGraw Hill**
7. **Richard Cotton, "Learning R", O'Reilly, 2013.**
8. **Dalgaard, Peter, "Introductory statistics with R", Springer Science & Business Media, 2008.**

9. **Brain S. Everitt, “A Handbook of Statistical Analysis Using R”, Second Edition LLC, 2014.**
10. **Samir Madhavan, “Mastering Python for Data Science”, Packt, 2015.**
11. **Sheldon M. Ross,”Introduction to Probability and Statistics for Engineers and Scientists”, 4th edition, Academic Press; 2009.**
12. **Paul Teetor, “R Cookbook, O’Reilly, 2011.**
    Mark Lutz ,”Learning Python”, O’Reilly,5th Edition,2013

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 606D	**Scientific Computing**	**CORE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Definition and sources of errors, solutions of nonlinear equations; Bisection method, Newton's method and its variants, fixed point iterations, convergence analysis; Newton's method for non-linear systems; Finite differences, polynomial interpolation; Numerical integration - Trapezoidal and Simpson's rules, Gaussian quadrature; Initial value problems - Taylor series method, Euler and modified Euler methods, Runge-Kutta methods.	
Linear systems – All variants of Gaussian elimination and LU factorization, Cholesky factorization. Linear least-squares problem - Normal equations, rotators and reflectors, QR factorization via rotators, reflectors and Gram Schmidt orthonormalisation, QR method for linear least-squares problems, rank deficient least-squares problems.	
Singular value decomposition (SVD) – numerical rank determination via SVD, solution of least squares problems, Moore- Penrose inverse, low rank approximations via SVD, Principal Component Analysis, applications to data mining and image recognition.	
Eigenvalue Decomposition - Power, inverse power and Rayleigh quotient iterations, Schur's decomposition, unitary similarity transformation of Hermitian matrices to tridiagonal form, QR algorithm, implementation of explicit QR algorithm for Hermitian matrices	

Texts / References Books

1. **L. N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, Phildelphia, 1997.**
2. **D. S. Watkins, Fundamentals of Matrix Computation, 2nd Edition, Wiley, 2002.**
3. **L. Elden Matrix Methods in Data Mining and Pattern Recognition, SIAM, Philadelphia, 2007**

4. **D. Kincaid and W. Cheney, Numerical Mathematics and Computing, 7th Edn., Cengage, 2013.**
5. **K. E. Atkinson, Introduction to Numerical Analysis, 2nd Edn., John Wiley, 1989.**
6. **L. N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, 1997.**
7. **D. S. Watkins, Fundamentals of Matrix Computation, 2nd Edn., Wiley, 2002.**
8. **D. Kincaid and W. Cheney, Numerical Analysis: Mathematics of Scientific Computing, 3rd Edn., AMS, 2002.**
   K. E. Atkinson, Introduction to Numerical Analysis, 2nd Edn., John Wiley, 1989.

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 607D	**Data Structures and Algorithms with C**	**CORE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
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 theb 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	

Texts / References Books

1. **Mullis Cooper: Spirit of C: Jacob Publications**
2. **Yashwant Kanetkar: Let us C: BPB**
3. **Gotterfied B.: Programming in C: Tata McGraw Hill**
4. **Jean Paul Tremblay & Paul G. Sorenson: An Introduction to Data Structures with Applications: Tata McGraw Hill.**
   Robert L. Kruse: Data Structures & Program Design: PHI

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 609D	**Data Science: Industrial Perspectives**	**Audit - Compulsory**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING / AUTUMN	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
This is a seminar course where specialists will give talk(s) on various verticals like: biology, health, governance, physical sciences, e-commerce, climate, supply chains and finance etc. This seminar series will provide the industry or domain specific context for advanced analytics. This will include the following topics: ➢ Industry/domain overview description, history, challenges faced, key players, industry trends. ➢ Key business processes (marketing, financial, sales, logistics, order fulfilment, procurement, executive reporting, customer facing). ➢ Key data elements for each major business process and systems of record. Critical metrics (KPI) for each business process and the definitions. Sources/location of the data, typical errors in data. ➢ Benchmarking information sources.	

➢ Signal and noise in system information relevance. ➢ Classes of users and associated metrics/information needed/questions asked or would like to ask.. Potential for new apps. ➢ Historical access to information and impacts. ➢ Impact of social media, text analysis, web and other sources of information. Timeliness of data/information. ➢ Predictive Vs historical analysis (customer segmentation, churn etc).	

Subject domains / industry

- Politics/elections required reading http://fivethirtyeight.com/ Nate Silvers book (signal and the noise), invite party strategists from major parties. Crowd sourced analytics (www.kaggle.com).
- Healthcare invite CFO/CMO from AIIMS, Apollo and/or other large hospitals to discuss metrics for hospital operation including financial, operational and medical procedures efficacy.
- Supply chain management invite VP/Operations/Logistics from auto companies, Flipkart/Amazon to discuss supply chain analytics and issues.
- Weather/climate change National weather bureau chief.
- Agriculture Industry think tanks re crop yields, weather patterns, evolving trends.
- Corporate - HR, Finance, Sales, Marketing, Web marketing, IT.
- Customer services/ support.
- Website analytics - Google.
- Financial Services Chief Marketing Officers/CEO to discuss customer analytics, services, service quality, innovation, profitability.
- Energy prospecting ONGC, Chevron, BP.
- Security communications, RAW, National Security agencies.
- Entertainment - movie/show launches.
- Retail Hindustan Lever, Proctor & Gamble, Godrej.
- Telecom Airtel, BSNL, Vodafone

Education Teach for India, UNICEF, Gates Foundation.

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 623D	**Machine Learning**	**CORE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
AUTUMN	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	No of hours
Introduction - Definitions – Theoretical- Definitions – Applied Practice- 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	
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	
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, Gibbs algorithm, Naïve Bayes classifier, An example learning to classify text, Bayesian belief networks The EM algorithm.	
Graphical and sequential models- Bayesian networks- conditional independence Markov random fields-inference in graphical models- Belief propagation- Markov models- Hidden Markov models- decoding states from observations- learning HMM parameters.	
Computational learning theory – Introduction, Probability of 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 (Passive vs Active learning, V-C dimension). Clustering Methods-Partitioned based Clustering - K-means- K-medoids; Hierarchical Clustering - Agglomerative- Divisive- Distance measures; Density based Clustering - DBScan; Spectral clustering.	
Types of Machine Learning –Supervised –Unsupervised – Reinforcement- Decision Tree learning. **Neural networks**- the perceptron algorithm- multilayer perceptron's- back propagation nonlinear regression- multiclass discrimination- training procedures- localized network structure - dimensionality reduction interpretation.	

Texts / References Books

1. **Tom M. Mitchell, Machine Learning –- MGH**
2. **Stephen Marsland , Machine Learning: An Algorithmic Perspective, Taylor & Francis (CRC)**
3. **William W Hsieh, , Machine Learning Methods in the Environmental Sciences, Neural Networks, 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**
6. **Charles Dierbach, Introduction to computer science using Python a computational problem solving focus, John-Wiley & Sons, 2012.**
7. **T. Hastie ,R.Tibshirani and J.Friedman,"Elements of Statistical Learning",**

Springer, 2009.
8. **E. Alpaydin, "Machine Learning", MIT Press, 2010.**
9. **K. Murphy, "Machine Learning: A Probabilistic Perspective", MIT Press, 2012.**
10. **C. Bishop, "Pattern Recognition and Machine Learning, Springer", 2006.**
11. **Shai Shalev - Shwartz, Shai Ben-David, "Understanding Machine Learning: From Theory to Algorithms", Cambridge University Press, 2014.**
John Mueller and Luca Massaron, "Machine Learning For Dummies", John Wiley & Sons, 2016.

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 601	**Data Science: Tools and Techniques**	**CORE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
AUTUMN	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	No of hours
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 and Pandas: 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	
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 parameter, Function that return Multiple Values, Functions with Default arguments, Named arguments, Scope and Lifetime of Variables, Global specifier	
Data Visulization With MatplotLib: 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, Hands on 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, Support Vector Machine, Introducing Correlation Matrix	
Deep Learning: Deep Learning Introduction, Deep learning methods, Supervised Deep learning, Unsupervised deep learning	
Artificial Neural Networks(ANN): Introduction to ANN, Practical use cases of ANN, Understanding Neural Networks, Hidden Layers, Activation Functions-(Relu, Soft max), Feed forward and Backward Propagation, Introducing Keras and Tensor flow for Neural Network, Hands on Example on ANN to understand above concepts (defining the input layers, creating hidden layers, Activation function usage, Output Layer), Understanding the network training, Module loss, Validation loss calculation, Performance Improvement by introducing	

Dropout layer.	
CNN in Computer Vision application: Image Processing introduction, Types of Images, Importing and exporting images, Visualizing Images in Python, Image filtering, Data Augmentation, Hands-on Laboratory to understand CNN better"Tagging Images into different labels", Padding in CNN, Batch Normalization, Confusion Matrix, Mini project Building CNN model to recognize the handwritten digit, Saving the Models, Using Pre-trained Models, Recurrent Neural Networks.	

Texts / References Books

1. **Samir Madhavan, Mastering Python for Data Science, Packt Publishing, 2015**
2. **Sebastian Raschka Python Machine Learning, Packt Publishing, 2015**
3. **H. Bhasin, Python Basics, Mercury Learning And Information, 2019**
4. **Magnus Lie Hetland, Beginning Python, Apress, 2015**
5. **Nikhil Ketkar, Deep Learning withPython, Apress, 2017**
6. **Peter Norton, Alex Samuel, David Aitel, Eric Foster-Johnson, Leonard Richardson, Jason Diamond, Aleatha Parker, Michael Roberts Beginning Python, Wiley Publishing, 2005**
7. **Expert Python Programming: Best practices for designing, coding, and distributing your Python software Tarek Ziadé, Packt Publishing, 2008.**
8. **Programming Python, Mark Lutz, O'Reilly Media, 2010.**
9. **Programming in Python 3: A Complete Introduction to the Python Language, Mark Summerfield, Addison-Wesley, 2010**
10. **Practical programming: An introduction to computer science using Python, Jennifer Campbell, Paul Gries, Jason Montojo, Greg Wilson, Pragmatic Bookshelf, 2009.**
11. **Core Python Programming, 2nd Edition, Wesley Chun, Prentice Hall, 2006.**
12. **Core Python Applications Programming, Wesley J Chun, Prentice Hall, 2012**
13. **Programming Computer Vision with Python: Tools and algorithms for analyzing images, Jan Erik Solem, O'Reilly Media, 2012**
14. **Convolutional Neural Networks in Python, Lazy Programmer. Kindle Edition**
    Neural Network Projects with Python, James Loy, Packt Publishing

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Name of the Course</td><td rowspan="2">CORE / ELCTIVE</td><td colspan="4">CREDITS</td></tr>
<tr><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>AM 625D</td><td>Image and Video Analytics</td><td>ELECTIVE</td><td>3</td><td>0</td><td>1</td><td>4</td></tr>
</table>

<table>
<tr><td rowspan="2">Offered in (SPRING / AUTUMN)</td><td rowspan="2">Offered by (Name of Department/ Centre)</td><td colspan="5">Total Marks : 100</td></tr>
<tr><td>Quiz-1</td><td>Quiz-2</td><td>Quiz-3</td><td>Internal</td><td>External</td></tr>
<tr><td>AUTUMN</td><td>Applied Mathematics</td><td>10</td><td>10</td><td>10</td><td>20</td><td>50</td></tr>
</table>

Course Contents	**No of hours**
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	

Texts / References Books
1. Digital Image Processing, 3rd Ed., 2007, R. C. Gonzalez, Richard E. Woods, Prentice Hall.

2. **Digital Image Processing Using MATLAB, 2nd Ed., 2009, R. C. Gonzalez, Richard E. Woods, Steven L. Eddins, Gatesmark Publishing.**
3. **Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press.**
4. **Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India.**
5. **Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley.**
6. **Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker.**
7. **Rick Szelisk, "Computer Vision: Algorithms and Applications", Springer 2011.**
8. **Jean-Yves Dufour, "Intelligent Video Surveillance Systems", Wiley, 2013.**
9. **Caifeng Shan, Fatih Porikli, Tao Xiang, Shaogang Gong, "Video Analytics for Business Intelligence", Springer, 2012.**

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 627D	**Information Theory and Coding**	**ELECTIVE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	**No of hours**
Information Theory: Uncertainty, Information, Entropy, Discrete Memoryless Channel, Mutual Information, Channel Capacity, Shannon's Theorems, Gaussian Channel, Limits to Communication	
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	
Cyclic Codes: Polynomial Representation of Code words, Generator Polynomial, Systematic Codes, Generator Matrix, Syndrome Calculation and Error Detection, Decoding of Cyclic Codes	
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	
Decoding of Convolutional Codes: Maximum Likelihood Detection, The Viterbi Algorithm	
Automatic Repeat Request Strategies: Basic Techniques, Hybrid ARQ	
Introduction to Cryptography: History. Overview of cryptography, Simple classical cryptosystems, Cryptanalysis **Perfect Secrecy:** Information theoretic security**,** One time pad **Secret and Public Key Encryption**: Description of DES, Description of AES (advanced encryption standard), Trapdoor Function, The RSA Algorithm	

Texts / References Books
1. Jorge Castiñeira Moreira, Patrick Guy Farrell , Essentials of Error-Control Coding, **John Wiley, 2006. ISBN: 978-0-470-02920-6** **2. G. A. Jones and J. M. Jones, “Information and Coding Theory,” Springer, ISBN 1-85233-622-6, 3rd Edition.** **3. John F. Dooley, History of Cryptography and CryptanalysisCodes, Ciphers, and Their Algorithms, Springer, 2018, ISBN 978-3-319-90442-9** **4. Maria Welleda Baldoni, Ciro Ciliberto, Giulia Maria Piacentini Cattaneo, Number Theory, Elementary Cryptography and Codes, Springer, 2009, ISBN 978-3-540-69199-0** **5. Jorge Castiñeira Moreira, Patrick Guy Farrell, Essentials of Error-Control Coding, John Wiley & Sons Ltd, 2006, ISBN-13 978-0-470-02920-6** **6. Hideki Imai, Essentials of Error-Control Coding Techniques, Academic Press, Inc., 1990, ISBN 0-12-370720-X** **7. Dominic Welsh, Codes and Cryptography, Oxford Science Publications, 1988** **8. T. M. Cover, J. A, Thomas, “Elements of information theory,” WielyInterscience,2nd Edition, 2006** **9. R. W. Hamming, “Coding and information theory,” Prentice Hall Inc., 1980.** **10. Robert M. Gray, Entropy and Information Theory, 2ndEdition, Springer, 2011, ISBN 978-1-4419-7969-8**

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
AM 628D	**Computational Number Theory and Cryptography**	**ELECTIVE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
AUTUMN	**Applied Mathematics**	**10**	**10**	**10**	**20**	**50**

Course Contents	No of hours
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.	

Texts / References Books

13. **J. Katz and Y. Lindell, Introduction to Modern Cryptography, 2nd Edition, Chapman & Hall/CRC, 2008**
14. **Abhijit Das, Computational number theory, Chapman and Hall/CRC., 2018**
15. **N. Koblitz, A Course in Number Theory and Cryptography, Springer 2006.**
16. **I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to theory of numbers, John Wiley & Sons, Inc 2006.**
17. **L. C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.**
18. **J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.**
19. **D. Hankerson, A. Menezes and S. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag, 2004.**
20. **J. Pipher, J. Hoffstein and J. H. Silverman , An Introduction to Mathematical Cryptography, Springer-Verlag, 2008.**
21. **G.A. Jones and J.M. Jones, Elementary Number Theory, Springer-Verlag, 1998.**
22. **R.A. Mollin, An Introduction to Cryptography, Chapman & Hall, 2001.**
23. **Song Y. Yan: Number Theory for Computing, Springer-Verlag, Second Edition,2002.**
24. **T. H. Cormen, C. E. Leiserson, and R. L. Rivest: Introduction to Algorithms, Second Edition, Prentice Hall of India, 1994.**
25. **K. Rosen: Elementary Theory of Numbers, Fifth Edition, Addison Wesley, 2004.**
26. **D. M. Bressoud: Factorization and Primality Testing, Springer-Verlag, 1989.**
27. **V. Shoup, A computational introduction to number theory and algebra, Cambridge University Press**
28. **M. Mignotte, Mathematics for computer algebra, Springer-Verlag.**
29. **I. Niven, H. S. Zuckerman and H. L. Montgomery, An introduction to the theory of numbers, John Wiley**

30. J. von zur Gathen and J. Gerhard, Modern computer algebra, Cambridge University Press.
31. R. Lidl and H. Niederreiter, Introduction to finite fields and their applications, Cambridge University Press.
32. A. J. Menezes, Applications of finite fields, Kluwer Academic Publishers
33. J. H. Silverman and J. Tate, Rational points on elliptic curves, Springer International Edition.
34. D. R. Hankerson, A. J. Menezes and S. A. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag
35. A. Das and C. E. Veni Madhavan, Public-key cryptography: Theory and practice, Pearson Education Asia
H. Cohen, A course in computational algebraic number theory, Springer-Verlag

Course Code	Name of the Course	CORE / ELCTIVE	CREDITS			
			L	T	P	C
EE 610D	**MULTIRESOLUTIONAL SIGNAL PROCESSING**	**ELECTIVE**	**3**	**0**	**1**	**4**

Offered in (SPRING / AUTUMN)	Offered by (Name of Department/ Centre)	Total Marks : 100				
		Quiz-1	Quiz-2	Quiz-3	Internal	External
SPRING	**Electronics Engineering**	**10**	**10**	**10**	**20**	**70**

Course Contents	**No of hours**
Introduction to Multiresolution Analysis: Vector Spaces – Properties– Dot Product – Basis – Dimension, Orthogonality and Orthonormality – Relationship Between Vectors and Signals – Signal Spaces – Concept of Convergence – Hilbert Spaces for Energy Signals- Fourier Theory: Fourier series expansion, Fourier transform, Short time Fourier transform, Time-frequency analysis, Definition of Multi Resolution Analysis (MRA) – Haar Basis – instruction of General Orthonormal MRA – Wavelet Basis for MRA – Continuous Time MRA Interpretation for the DTWT – Discrete Time MRA – Basis Functions for the DTWT – PRQMF Filter Banks.	
Advanced DSP Techniques: Matrix factorizations and least squares filtering, optimal linear filter theory, classical and modern spectral estimation, adaptive filters, and optimal processing of spatial arrays, Multirate signal processing, Multirate digital signal processing, Decimation, interpolation, sampling rate conversion, filter design and implementation for multirate conversion, sampling rate conversion by an arbitrary factor, applications of multirate signal processing.	
Wavelet Transform Techniques: Definition and Properties – Concept of Scale and its Relation with Frequency – Continuous Wavelet Transform (CWT) – Scaling Function and Wavelet Functions (Daubechies Coiflet, Mexican Hat, Sinc, Gaussian, Bi Orthogonal)– Tiling of Time – Scale Plane for CWT. DISCRETE WAVELET TRANSFORM Filter Bank and Sub Band Coding Principles – Wavelet Filters – Inverse DWT Computation by Filter Banks – Basic Properties of Filter	

Coefficients – Choice of Wavelet Function Coefficients – Derivations of Daubechies Wavelets – Mallat's Algorithm for DWT – Multi Band Wavelet Transforms Lifting Scheme- Wavelet Transform Using Polyphase Matrix Factorization – Geometrical Foundations of Lifting Scheme –Lifting Scheme in Z –Domain	
Advanced Transform Techniques for MSP: Frequency for signal and image analysis, spatial frequency components, Signal/image restoration using the Fourier domain, Homomorphic filtering, Heisenberg plane, Huff transform, Examples of the Windowed FT, Gabor Transform in Heisenberg space, ACT, DCT, Hilbert transform, PC: from signals to images, Fuzzy logic for signal/image/video processing, applications of MSP in machine learning, Machine Learning for Sensors and Signal Data.	
MSP implementations in FPGA: Digital Signal Processing Designing for FPGA Architectures, filter designs, IP implementations, real-time MSP architecture implementations, high-speed signal recording, handling and processing, MAC engine implementations, speech, image and video processing, Implementations of DSP hardware technologies, DSP arithmetics, FIR and IIR digital filters, Multirate signal processing, Fourier transforms, and Adaptive filters, hybrid designs.	

Texts / References Books

1. **Moon & Stirling, Mathematical Methods and Algorithms for Signal Processing, Prentice Hall, 2000. ISBN 9780201361865 (required)**
2. **Adaptive Filter Theory by Simon Haykin, Prentice Hall, 2002 Neural and Adaptive Systems by Jose Principe et al, Joh Wiley & Sons, 2000.**
3. **Wavelets and Subband Coding by Martin Vetterli and JelenaKovacevic, Prentice Hall, 2007. Notes and papers**
4. **Discrete-Time Signal Processing by A. V. Oppenheim and R. W. Schafer, 3rd Edition, 2014.**
5. **Digital Signal Processing: A Computer-based Approach by S. K. Mitra, 4th Edition, 2013.**
6. **Multirate Systems and Filter Banks by P. P. Vaidyanathan, 1st Edition, 1993 (1st Pearson Impression in 2006).**
7. **http://firasaboulatif.free.fr/index_files/gaidaa%20book/Digital%20Signal%20Processing/Multirate%20Filtering.pdfv**
8. **http://www.doiserbia.nb.rs/img/doi/0353-3670/2007/0353-36700703437R.pdf**
9. **https://reality.ai/machine-learning-for-sensors-and-signal-data/ https://freevideolectures.com/course/3042/advanced-digital-signal-processing**

Department of Applied Physics

M. Tech. (Sensor Technology)

Brief Description: 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 microfluidics, nanotechnology, biotechnology and photonics have been responsible for this concomitant growth in the development of current sensors. An interdisciplinary approach which 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 selective. This domain has, hence, seen large number of Industries, Institutes and small entrepreneur companies coming up in recent times. The programme intends to educate and train bright fresh students in the field of sensor technology to carry out challenging responsibilities in their future career, 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.

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.
(iii)

Eligibility:

The candidate should possess Master degree or equivalent in Physics, Applied Physics, Electronic Science, Photonics **OR** B. E./ B. Tech/ BSc.(Engg.) or equivalent in Electronics Engg./ Electrical Engg./ Electrical & Electronics Engg./ Electronics & (Tele)Communication Engg./ Electrical Communication Engg./ Electronics & Instrumentation Engg./ Instrumentation Engg./ Optics & Optoelectronics.

Organization:

The M. Tech. programme is of four-semester duration. In each of the first two semesters there are six courses and practical each. There would be continuous evaluations through the semester 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 thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners. Course syllabus has been updated periodically to keep pace with the contemporary technological advancement.

Semester I

Sl No	Course Code	Course Name	Credits			Total Credits
			L	P	T	
1	AP 601	Principles of Sensing: Material Science and Physics I	3	0	1	4
2	AP 603	Sensor Data Acquisition and Signal Conditioning	3	0	1	4
3	AP 604	Fabrication Technology and Packaging of MEMS Systems	3	0	1	4
4	AP 614	Fibers Optic Sensors	3	0	1	4
5	AP 602	Sensor Technology Laboratory-I		4		4
6	AM 602	Mathematics for Engineers	3	0	1	4
		TOTAL	**18**	**5**	**1**	**24**

Semester II

Sl No	Course Code	Course Name	Credits			Total Credits
			L	P	T	
1	AP 606	Sensors Transducers and Actuators	3	0	1	4
2	AP 608	Machine learning techniques for sensor data analytics	3	0	1	4
3	AP 605	Principles of Sensing: Material Science and Physics II	3	0	1	4
4	AP 607	Sensor Technology Laboratory-II			8	4
5		Elective I	3	0	1	4
6		Elective – II	3	0	1	4
		TOTAL	**18**	**2**	**4**	**24**

Semester III:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AP 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.	AP 652	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**

List of Electives

Sr. No.	Course Code	Course
		Elective I & II
1	AP 609	Advanced Sensors
2	AP 610	Programming embedded system for sensors
3	AP 611	Remote sensing and sensors
4	AP 615	Sensors for Defence
5	AP 612	Nanotechnology for Advanced Sensors
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-I 3-1-100

1. **Introduction**: Sensor fundamentals, Application considerations, Definition of Sensors; sensors, signals and systems, Sensor classification
2. **Physical Aspects in Sensing**: Input output relationship, interfering and modifying inputs, compensation techniques, static and dynamic characteristics, impedance, reliability
3. **Material Aspects in Sensing:**, Structure, dynamics of solids and mechanics of solids:
   a. **Metals:** Properties of metals; structural, electrical, mechanical, thermal, Applications; thermal expansion devices, shape memory alloys, thermocouples, ohmic and schottky contacts, thermal conductivity, sensors based on these properties
   b. **Semiconductors:** Intrinsic and extrinsic semiconductors, direct-indirect band gap materials, metal semiconductor junctions, gas sensitive resistors, MOS sensors, peizoresistance, peizoresistive sensors
   c. **Dielectric Materials:** Polarization, internal fields, frequency response, piezoelectric, pyroelectric, ferroelectric materials
   d. **Magnetic and superconducting materials:** paramagnetic, ferromagnetic, antiferromagnetic, ferromagnetic materials, superconductors, applications of magnetic materials and sensors, SQUID
4. **Sensor Characterization:** Study of Static and Dynamic Characteristics, Sensor reliability, aging test, failure mechanisms and their evaluation and stability study.
5. **Measurement, Instrumentation and Calibration**: Introduction, classification of transducers, Errors in measurement, statistical analysis of random errors, calibration and standards, Noise

Texts/References

1. Sensors and signal conditioning by Ramon Pallas Arrny and John G Webster, John Wiley & sons (1991).
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, 2nd Edition 2013
5. Sensor Materials by P T Moseleyand A J Crocker
6. Material Science and Enginerring by V. Raghavan.

7. Fundamentals of Material Science and Enginerring by William D. Callister.
8. Principles of Materials Science & Engineering by W. F. Smith.

AP602 Sensor Technology Laboratory-I 3-1-100

1. Data acquisition using LAB view
2. Experiments using Automotive sensor (Oxygen sensor, coolant temperature sensor, level sensor, humidity sensor, sound sensor, tilt sensor, UV sensor, flame sensor, opto sensor, motion sensor, light intensity measurement sensor) Data processing and acquisition using Arduino and Labivew
3. Hall Effect
4. Michelson Interferrometer
5. Optical Fiber Sensors, source characterization
6. Mini projects
7. Soft Lithography
8. Study of Material Crystallinity using X-ray diffraction
9. Microscopic Study of materials

AP 603 Sensor Data Acquisition Systems 3-1-100

1. **Signal conditioning:** Types of signals and signal conditioning, classes of signal conditioning, field wiring and signal measurement, types of noises (different types) and basics of environmental aspects EMI/EMC, minimising noise, shielded and twisted-pair cable, Lock in amplifier, box car averaging, time resolved data analysis, pulse width modulation, data structure.
2. **Fundamentals of Data Acquisition:** Essentials of computer interfacing –configuration and structure -interface systems-interface bus.
3. **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/A Boards.
4. **Serial data communication:** RS232 and RS485 interface standards.
5. **Stand-alone Loggers/controllers:** Methods of operation, stand-alone loggers/controller hardware, communications hardware interface, stand-alone loggers/controller firmware and software design, Data acquisition using PCMCIA cards.
6. **IEEE 488 standard**: GPIB bus structure and handshaking, device communications, IEEE 488.2, Standard commands for programmable instruments (SCPI).
7. **Ethernet & LAN systems:** Physical layer, Ethernet design rules.
8. **Universal Serial Bus:** Overall structure, Physical layer, datalink layer, user layer.
9. **Virtual instrumentation:** Virtual instrument and traditional instrument, Hardware and software for virtual instrumentation, Virtual instrumentation for test, control, and design, Graphical system design, Graphical and textual programming, Data acquisition with PCI, PCI express and PXI bus interfaces
10. Various communication protocol MODBUS, CAN, HART,

Reference Books:

1. Ramon Pallas-Areny and John G Webster, Sensors and Signal Conditioning, Wiley India Pvt. Ltd., 2nd ed., 2012.
2. Maurizio Di Paolo Emilio, Data Acquisition systems- from fundamentals to Applied Design, Springer, 2013.
3. Robert H King, "Introduction to Data Acquisition with LabVIEW", McGraw Hill, 2nd ed., 2012.

4. John Park and Steve Mackay, Practical Data acquisition for Instrumentation and Control', Newness publishers, 2003.
5. Maurizio Di Paolo Emilio, Data Acquisition systems- from fundamentals to Applied Design, Springer, 2013.
6. Robert H King, “Introduction to Data Acquisition with LabVIEW”, McGraw Hill, 2nd ed., 2012.

AP604 Fabrication Technology and Packaging of MEMS Systems 3-1-100

1. **Evolution of Microsystems:** Benefits of micro systems, concept of micro machines/ micro systems. Scaling laws, nano machines, Silicon as a mechanical material.
2. **Materials Processing Methods:** Growth of Thin films, Chemical Vapour Deposition – Principles and systems, CVD growth of thin films, Molecular Beam Epitaxy, Liquid Phase Epitaxy, Vapour growth of Nitrides. Metal-organic CVD, PVD, PLD, sputter coating, spin coating, dip coating, fiber extrusion, electrospinning, Basic concepts of crystal growing, Solution growth, Melt growth, Flame fusion techniques and flux growth.
3. **Etching and Lithographic techniques:** Bulk etching and RIE, Top down approach to nanolithography-Immersion lithography- Optical lithography, UV photolithography- Phase lithography- Including Plasma X-ray sources- E-Beam Lithography- Focused Ion beam lithography, LIGA, Soft lithography for nanofilms and nanoscale patterning.
4. **MEMS actuators:** Electrostatic actuators, Thermal actuators, Piezoelectric Actuators, Magnetic Actuators
5. **Structural MEMS:** Static Bending of thin plates, mechanical vibration, thermomechanics, fracture mechanics, thin film mechanics, Mechanical Testing of MEMS and NEMS
6. **Packaging:** Foundation of MEMS packaging, Types of Packaging: metal, ceramic, thin film multilayer packaging, plastic packaging, Chip scale packaging, Ball grid array, Multichip packaging, COF/HDI technology, Packaging in high endurance applications
7. **Case Studies :** Thin films for microelectronics, optical coatings, photodetectors, smart sensors, Pressure, strain, acceleration and vibration sensors, and micro fluidics: chemical and bio medical sensors, Examples aeronautics (control surfaces) aerospace, automobiles engineering, tire pressure sensor, structural health monitoring, biomedical engineering and intelligent consumer product design, MEMS based Infrared sources: sources for sensor application
8. Nanoimprint technology, Dip pen lithography, Polymer MEMS.

References:

a. Physics of Semiconductor Devices by S.M. Sze, Wiley Publications (2006)
b. Mark J Jackson, Micro and Nano-manufacturing , Springer; First Edition, (2006) ISBN
2. Dieter K, Schroder, Semiconductor Material and Device Characterization, Wiley-IEEE Press, 3rd Edition, (2006) ISBN- 10:0471739065
3. L. B. Freund and S Suresh, Thin film materials: Stress, Defect formation and surface Evolution, Cambridge University Press, (2004) ISBN-10:0521822815
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)
6. Tai-Ran Hsu, ‘MEMS & Microsystem, Design and Manufacture’, McGraw Hill, 2002
7. Banks H.T. Smith R.C. and Wang Y.Smart, ‘Material Structures – Modeling, Estimation and Control’, John Wiley & Sons, New York, 1996.
8. Massood Tabib – Arar, ‘Microactuators – Electrical, Magnetic Thermal, Optical, Mechanical, Chemical and Smart structures’, Klumer Academic publishers, New York , 1997.
9. M.Eluenspoek, R.Wiegerink, “Mechanical Microsensors”, Springer, 2001.

10. Microelectronic processing, Stephan Campbey

AP 614 Fiber Optic Sensors

1. **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, Mechanical Property of Fiber and Fiber Optics Cables.
2. **Optical Fibers Characteristics:** Fiber Attenuation, Absorption losses, Scattering losses, Radiation losses, Bending losses, Measurement of losses, Dispersion in fibers, Effect of dispersion in communication link, Dispersion reduction and compensation techniques.
3. **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.
4. **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.
5. **Fiber Bragg Gratings:** Introduction, Methods for Fiber Bragg Grating Fabrication, Theory of Fiber Bragg Gratings, Types of Fiber Bragg Gratings, Measurement and Characterization of Gratings, FBGs in Fiber Lasers.
6. **Optical Fiber Sensor:** Introduction, Classification and Types of Optical Fiber Sensors, Wavelength Modulation based sensors: Temperature, Humidity, pH, Oxygen, Vibration & CO2, Interferometry based sensors; Acoustic, Gyroscope, Temperature, Polarimetric Sensor; Temperature, Strain, Current & Magnetic field sensor, Fiber Bragg Grating Sensors: Principle and Applications. Frequency modulation-based Sensor, Distributed Sensors.
7. Microspheres (WGM), evanescent modes in fiber optics, SPR mode
8. Fiber Optics and waveguides, concentrators, coatings for thermal absorption, electro-optic and acousto-optic modulators, interferometric fiber optic modulators.

Text/References

1. A. K. Ghatak and K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press (1998).
2. J. C. Palais, Fiber Optic Communications, Prentice-Hall Inc. 4^{th} Ed. (1998).
3. G. Kaiser, Optical Fiber communication, 4th Edition, Tata McGraw Hill, 2008.
4. S. K. Sarkar, Fiber optics in Telecommunications and Sensor Systems, S Chand & Co., New Delhi, 2002.
5. J. P. Dakin and B Culshaw, Optical Fiber Sensors, Vol. 1 & 2, Artech House, Boston and London, 1998.
6. R. Kashyap, Fiber Bragg Gratings, Academic Press, 1999
7. K.T.V. Grattan and B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, Chapman and Hall, 1998

AP 606 Sensors, Transducers & Actuators 3-1-100

1. **Properties and components of transducers:** Electric charges, fields and potentials, capacitance, induction resistance, Measurement of current, voltage, resistance, impedance, phase angle, frequency measurement, time interval measurement, resistive, inductive, Proximity and capacitive transducers

2. **Mechanical transducers:** Mechanical transducers for Temperature measurement, pressure measurement, force measurement, torque measurement, density measurement, liquid level measurement, viscosity measurement, flow measurement
3. **Thermal properties and transducers**: pyroelectric effect, Seebeck and Peltier Effect, thermal expansion, heat capacity, heat transfer
4. **Optical properties, components, sources and detectors:** types of sources : source-detector characterstic, Radiometry, Photometry, windows, mirrors, lenses, Fresnel lenses gas sensing– Basic Principle, Thermal detectors, Photo multipliers, photoconductive detectors, Photo diodes, Avalanche photodiodes, CCDs, Image Intensifiers, Solar Cells, photon counting techniques to count low photon flux, microphone, photoacoustic
5. **Chemical Properties for sensors:** Electrochemical properties: Debye-Huckel ion transport theory, basics of electrode potential, measurement of pH, potentiometric properties, amperometric properties, catalysis, Chemical spectrometry, Biosensors, SERS, Mass spectroscopy, Ion mobility sensor, Combustible gas detection, photoionization detectors for detecting VOC.
6. **Actuation and actuators: Active elements:** Piezoelectric, magnetostrictive, photoelectric, thermoelectric, actuator principles, actuators as system components, actuators in mechatronics and adaptronics, electrostatic/Electromagnetic actuators (types of motors) Intorduction and classificiation of motors, PZT actuators, Smart actuators, multilayer actuator.
7. **Split in two parts typwise**
8. Tactile sensors

References:

1. Foundations of MEMS, C. Liu, Prentice Hall, 2011, 2nd edition.
2. Microsystem Design, S. D. Senturia, Kluwer, 2001.
3. Micromachined Transducers Sourcebook," G.T.A. Kovacs, McGraw Hill, 1998.
4. Actuators basics and applications, H Janocha, Springer.
5. Sensors and Transducers, D Patranabis PHI Publications, 2nd edition (2013).

AP 607 Sensor Technology Laboratory-II 3-1-100

(Fabrication, Testing and characterization of sensors)

1. Experiments using Piezoelectric sensor
2. Experiments using Strain gauge sensor
3. Experiments using Bourdon Gauge sensor
4. Use of PLC Trainer & Application
5. Use of SCADA for supervisory control
6. Experiments using Wireless Sensor Network
7. Experiments using Flow measurement systems
8. Experiments using Temperature Sensor consisting of thermocouple, thermistor and RTD, Data processing and acquisition using Arduino and Labivew Dynamic characterstics of MS, simple mech. System
9. Experiments using Resistive, Inductive, capacitive measurement Data processing and acquisition using Arduino and Labivew

AP 608 Machine Learning Techniques for Sensor Data Analytics 3-1-100

1. Introduction: Role of Machine learning techniques in sensor data analytics, Learning from data, Machine learning examples, Simple model for Machine Learning, Types of learning,
2. Theory of generalization: Feasibility of learning, Hoeffding inequality, complexity of hypothesis set, growth function, VC dimension, Training versus testing

3. Supervised Learning: Perceptron, Linear classification, Linear regression, Logistic regression, Neural Network, Backpropagation algorithm, Support Vector Machines, Radial Basis Functions, K-nearest neighbor, Decision Trees, Bayesian Learning, Deep learning
4. Feature extraction and dimensionality reduction: Curse of dimensionality, Principal Component analysis, Linear discriminant analysis
5. Unsupervised Learning: Clustering, K-means clustering, Agglomerative hierarchial clustering
6. Machine Learning issues: Overfitting, Validation, Occam's razor, Sampling bias, Data Snooping
7. Examples of Machine learning algorithms using Python.
8. Image processing: basics

Reference:

i. Thomas A. Runkler, "Data Analytics: Models and Algorithms for Intelligent Data Analysis", Springer Vieweg, 2012.
ii. S. Haykin, "Neural Networks, A Comprehensive Foundation", Pearson Education Inc., 2004.
iii. Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification, 2nd Edition, 2001.
iv. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.
v. Y. S. Abu-Mostafa, M. Magdon-Ismail, and Hsuan-Tien Lin, Learning from data, AMLbook.com
vi. Y. S. Abu-Mostafa, Learning from data, Caltech lectures (online).
vii. S. Sarkar, Introduction to Machine Learning, NPTEL course, IIT Kharagpur (online).

AP 691 Principles of Sensing: Material Science and Physics -II 3-1-100

2. **Flow, Temperature and Acoustic sensors:** Flow sensors: pressure gradient technique, thermal transport, ultrasonic, electromagnetic and Laser anemometer. microflow sensor, coriolis mass flow and drag flow sensor. Temperature sensors thermoresistive, thermoelectric, semiconductor and optical. piezoelectric temperature sensor. Acoustic sensors- microphones-resistive, capacitive, piezoelectric, fiber optic
3. **Velocity and Acceleration sensors:** 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.
4. **Strain, Force, Torque and Pressure sensors:** Strain and stress, strain gages, strain gage beam force sensor, piezoelectric force sensor, load cell, torque sensor, units of pressure-diaphragm, bellows, thin plates, piezo-resistive and capacitive pressure sensor, optoelectronic pressure sensors, vacuum sensors- pirani gauge, ionization gage, gas drag gauge.
5. **Magnetic Sensors:** Inductive and magnetic sensor, LVDT, RVDT, eddy current, transverse inductive, Hall effect, magnetoresistive, magnetostrictive sensors
6. **Position, Direction, Displacement and Level sensors:** Potentiometric and capacitive sensors. Fiber optic liquid level sensing, Fabry Perot sensor, ultrasonic sensor, capacitive liquid level sensor.

Texts/References

1. Sensors and signal conditioning by Ramon Pallas Arrny and John G Webster, John Wiley & sons (1991).
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, 2nd Edition 2013
5. Sensor Materials by P T Moseleyand A J Crocker
6. Material Science and Enginerring by V. Raghavan.

7. Fundamentals of Material Science and Enginerring by William D. Callister.
8. Principles of Materials Science & Engineering by W. F. Smith.

AP 609 Advanced Sensors 3-1-100

1. **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.
2. **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, Modern Trends
3. **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 Commercial Biosensor
4. **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 gas treatment
5. Heptics sensors, Sensors in missiles, electronic nose, any other contemporary topic, lectures from various DRDO labs (will have proj. component)
6. **Radiation Sensors:** Electromagnetic radiation, gas detection using electromagnetic radiation, Nuclear particles, detection using nuclear particles
7. **Biological Sensors: Metamaterials,** characteristics of bio sensors, Antibody based sensors, enzyme based sensors, biological microresistor.
8. **Smart Sensors:** Shape memory alloys, Rheological materials, Polymers and composites
9. LIDAR, sensor for dynamic system digital image correlation
10. Applications of position sensitive detectors in defence

References:

1. Karl B. Schnelle, Jr., Charles A. Brown, “ Air Pollution Control technology Handbook”, 2nd Edition, CRC Press, 2015.
2. Nathanson Jerry, “ Basic Environmental Technology: Water Supply, Waste Management, and Pollution Control”, 5th Edition, Prentice Hall, 2009
3. Biomedical Engineering and Design Handbook, Volume 1: Volume I: Biomedical Engineering Fundamentals Myer Kutz, McGraw Hill Publisher, 2nd Edition 2009.
4. Medical Instrumentation; Application and Design; J. G. Webster, Editor, 4th Edition,2015, JohnWiley & Sons,Inc.;New York.
5. John Turner, Automotive Sensors, Momentum Press, 1st Edition, 2009.
6. Automotive Sensors, BOSCH, 2002
7. Techniques of Radiation Dosimetry by K. Mahesh 1985
8. Nuclear Radiation Detectors, S.S. Kapoor, V. S. Ramamurthy 1986
9. Handbook Of Chemical And Biological Sensors R.F Taylor, Jerome S. Schultz, 1996 by CRC Press

AP 615 Sensors for Defence 3-1-100

(Micro) µ radar for personnel use and for unmanned miniaturized vehicles, SAR, GPR principles.

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).
Health monitoring sensors (embedded, continuous or intelligent), Condition monitoring of equipment and munitions.
Drug and nutraceutical (nutrition) delivery sensors and systems.
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.
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), Star Sensors
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. (LRDE, CABS, ADE, DEBEL)

References

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 relevant field.
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, Chr Boller, and Geoffrey R. Tomlinson, eds. *Health monitoring of aerospace structures: smart sensor technologies and signal processing*. John Wiley & Sons, 2004.

AP 610 Programming embedded systems for sensors 1-2-100

Programmers model for computers: computer architectures

Progrmming: C and Assembly, Programming Style, Declarations and Expressions, Arrays, Qualifiers and Reading Numbers, Decision and Control Statements, Programming Process, More Control Statements, Variable Scope and Functions, C Preprocessor, Advanced Types, Simple Pointers, Debugging and Optimization, In-line Assembly, Handling bits & bytes, Handling I/O, Hardware and Software Interrupts, Timers

2. **C Programming Tool chain in Linux:** C preprocessor, Stages of Compilation, Introduction to GCC, Debugging with GDB, The Make utility, GNU Configure and Build System, GNU Binary utilities, Profiling, using gprof, Memory Leak Detection with valgrind - Introduction to GNU C Library

3. **Handling challenges specific to embedded systems:** Object oriented programming with C, Header files for Project and Port, Examples. Meeting Real time constraints, Creating hardware delays, Need for timeout mechanism, Creating loop timeouts, Creating hardware timeouts. Creating embedded operating system, Basis of a simple embedded OS, Introduction to sEOS, Using Timer 0 and Timer 1, Portability issue

4. **Time-Driven Multi-State Architecture And Hardware:** Multi-State systems and function sequences: Implementing multi-state (Timed) system, Implementing a Multi-state (Input/Timed)

system. Using the Serial Interface: RS232, The Basic RS-232 Protocol, Asynchronous data transmission and baud rates, Flow control, Software architecture, Using on-chip UART for RS-232 communication - Memory requirements, the serial menu architecture, Examples. Case study: Intruder alarm system 16 bit technology Raspberry PI, Arduino, etc

Embedded C lab

- Programming using Ports
- Delay generation using Timer
- Programming Interrupts
- Implementation of standard UART communication
- Creating Simple Embedded OS [sEOS]
- EOS based on Timers
- Time triggered architecture programming

Linux Lab

- Basic commands
- File Handling Using SHELL Scripting
- Print the Environmental variables in Linux using C
- Create process in Linux using C

AP 611 Remote sensing and sensors 1-2-100

1. Basics of remote sensing
2. **RF Sensors:** Microwave Antenna-Introduction, types of Antenna, fundamental parameters of antennas, radiation mechanism, Fresnel and Fraunhoffer regions. Antenna for communication and Antenna for sensing, radiometer and radar, synthetic aperture radar (SAR)
3. **Applications of Radar:** Automotive, remote sensing, agriculture, medicine, detection of buried objects, NDT, defense factors affecting the performance of RADAR, RADAR transmitters, Receivers, indignious RADARS in DRDO case study
4. **Radiometers:** Radiative transfer theory, SMMR, Types of radiometers - and Bolometers, Applications in automotive, agriculture, medicine, weather forecasting
5. **Microwave power Sensors:** Diode Sensors: Diode detector principles, dynamic range average power sensors, signal waveform effects on the measurement uncertainty of diode sensors. Thermocouple Sensors: Principles of Thermocouple sensor, power meters for thermocouple sensors
6. **RFID Sensors:** Introduction, Components of RFID systems, hardware and software components, RFID standards, RFID applications.
7. **THz Sensor:** THz Technology- An Overview, THZ Rays sensing and imaging

References:

i. Finkenzeuer Klous, “RFID Handbook”, 2nd edition, Chicesten, England, John Wiley and Sons, 2004.

b. Constantine A. Balanis, “Antenna Theory Analysis and Design”, John Wiely & Sons Third Edition,. 2005

c. B.Hoffman - Wellenhof, H.Lichtenegger and J.Collins, "GPS: Theory and Practice ", 5th revised edition, Springer, Wein, New York, 2001

d. Lillesand & Kiefer, ‘Remote Sensing and Image Interpretation’, John Wiley & Sons, 2007.

e. Terahertz Sensing Technology Volume 1: Electronic Devices and Advanced Systems Technology Edited by: Dwight L Woolard (US Army Research Laboratory, USA), William R Loerop (US Army Soldier Biological and Chemical Command, USA), Michael S Shur (Rensselaer Polytechnic Institute, USA)

AP 612 Nanotechnology for advanced sensing 3-1-100

1. **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,
2. **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
3. **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.
4. **Characterization and properties of nanomaterials**: Structural Characterization, X-ray diffraction (XRD), Small angle X-ray scattering **(SAXS)**, Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Scanning probe microscopy (SPM), Surface plasmon resonance, Quantum size effects, Surface scattering, Change of electronic structure, Quantum transport, Effect of microstructure, Ferroelectrics and dielectrics, Superparamagnetism.
5. **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: A representative example for the imitation of human senses by means of nanotechnology and nanosensors: electronic skin based on nanotechnology.

   Corresponding Lab Session:

   Lab demos in the form of synthesis, characterization of metal and oxide nanoparticles.

Text/References

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)

M. Tech in Lasers and Electro-optics

Brief Description: 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 programme 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:

(iv) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings and other departments

(v) Graduates in the relevant field of science/technology from recognized Universities across the country.

Eligibility:

The candidate should possess Master degree or equivalent in Physics, Applied Physics, Electronic Science, Photonics **OR** B. E./ B. Tech/ BSc.(Engg.) or equivalent in Electronics Engg./ Electrical Engg./ Electrical & Electronics Engg./ Electronics & (Tele)Communication Engg./ Electrical Communication Engg./ Electronics & Instrumentation Engg./ Instrumentation Engg./ Optics & Optoelectronics.

Organization: The M. Tech. programme is of four-semester duration. In each of the first two semesters there are five 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.

Semester I

Sl No	Course Code	Course Name	Credits			Total Credits
			L	**P (in Hr)**	**T**	
1	AM 607	Mathematics for Engineers	3	0	1	4
2	AP 631	Applied Optics	3	0	1	4
3	AP 632	Lasers & Optical Electronics	3	0	1	4
4	AP 643	Introduction to Fiber Optics	3	0	1	4
5	AP 633	Semiconductor Photonic devices	3	0	1	4
6	AP 635	Laser & Optical Communication Laboratory – I	0	8	0	4
		TOTAL	**15**	**4**	**5**	**24**

Semester II

Sl No	Course Code	Course Name	Credits			Total Credits
			L	**P (in Hr)**	**T**	
1	AP 636	Laser Systems and Applications	3	0	1	4
2	AP 637	High Power Lasers	3	0	1	4
3	AP 638	Laser & Optical Communication Laboratory – II	0	**8**	0	4
4		Elective – I	3	0	1	4
5		Elective – II	3	0	1	4
6		Elective – III	3	0	1	4
		TOTAL	**15**	**4**	**5**	**24**

Semester III:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AP 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.	AP 652	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**

List of Electives

Sr. No.	Course Code	Course
		Elective I,II & III
1	AP 639	Computational Photonics
2	AP 634	Integrated Optics and Silicon Photonics
3	AP 646	Free Space Optical Communication
4	AP 640	Nanophotonics
5	AP 648	Fourier Optics & Holography
6	AP 641	Non-linear and Quantum Optics
7	EE 612	High Power Microwave Systems and DEW

AP 631 Applied Optics

1. **Wave optics:** Basic postulates of wave optics, Monochromatic waves, plane waves, spherical waves, paraxial waves, Interference of waves, Multiwave interference, Polychromatic waves, Group velocity and Pulse Dispersion.
2. **Gaussian and special beams:** Complex amplitude of Gaussian beam, Parameters of Gaussian beam, transmission of Gaussian beams through optical components, Hermite-Gaussian beam.
3. **Fourier Optics:** Impulse response and transfer function of free space, Fourier transform using a lens, Fraunhofer and Fresnel diffraction, Off-axis and On-axis Fourier transform holography.
4. **Electromagnetic fields:** Wave equation, Plane waves, Reflection and Refraction of plane waves, Fresnel Formulae, Wave propagation in stratified medium
5. **Polarisation of light:** Electromagnetic theory of light, Dielectric media, Monochromatic EM waves, Absorption and dispersion, Polarisation of light, Jones Calculus, Poincare sphere.
6. **Basic optical components and Devices:** Polarisers, Quarter, Half, and Full waveplates, Beam splitters: polarizing and non-polarizing, wavelength filters, dichroic mirrors, Lenses.

Text

1. B E A Saleh and M C Teich, Fundamentals of Photonics, John Wiley and Sons, 2007.

References

1. A. Ghatak, Optics, TMH, 2005.
2. E. Hecht, Optics, Pearson Education India, 2012
3. M. Born and E Wolf, Principles of Optics, Cambridge University Press, 2002.
4. J. W. Goodman, Introduction to Fourier Optics, 3rd Ed. Viva Books Pvt. Ltd., New Delhi, 2007.
5. E. G. Steward, Fourier Optics: An Introduction, Halsted Press, New York, 1983.
6. Jack D. Gaskill, Linear Systems, Fourier Transforms and Optics, Wiley, New York, 1978.

AP632 Lasers & Optical Electronics

1. **Light-matter interaction:** Interaction of radiation with atomic systems, Einstein's coefficients, spontaneous emission, stimulated emission, Linewidth of the laser, line broadening
2. **Laser Amplifiers:** Laser Amplifier, Amplifier power source, Nonlinearity & gain saturation, Amplifier noise
3. **Resonator Optics:** Planar mirror & spherical mirror resonators; stability condition.
4. **Lasers:** 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.
5. **Anisotropic media:** Review of propagation of Electromagnetic waves in Uniaxial and biaxial crystals, the dielectric constant tensor and the 'index ellipsoid'.
6. **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.
7. **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 acousto-optic tunable filters.
8. **Magneto-optics:** Principles,Faraday effect,Gyrotropic permittivity, Kerr rotation and Kerr ellipticity, Applications.
9. **Photonic switching & computing:** Photonic switches: Electro-optic, Accousto-optic and Magneto-optic switches, all optical switches, Bi-stable optical devices, optical interconnections, optical computing.

Text

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.

AP633 Semiconductor Photonic Devices

1. **Review of Semiconductor Physics:** Energy Bands, Density of States, Fermi-level, PN Junction, Homo and Hetero Junction, Quantum Wells. Semiconductor Optoelectronic materials.
2. **Optical processes in semiconductors:** Electron-Hole formation and recombination, Absorption in semiconductor, Electric field effect in absorption, Absorption in QWs and Quantum confined Stark Effect, KK relations, Radiations in semiconductors, Deep level transitions, Auger Recombination, Luminescence from QW, Measurement of absorption and Luminescence.
3. **Light Emitting Diode:** The electroluminescence Process, LED materials, Device configuration and Efficiency, LED structures, LED performance characteristics, Frequency response and Modulation bandwidth. LEDs for display and Lighting.
4. **Semiconductor Laser:** Junction Laser Operating Principles, Threshold Current, Hetrojunction Laser, Distributed Feedback Lasers and Distributed Bragg Reflector, Coupled Cavity Lasers, 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.
5. **Modulation and Switching Devices:** Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator.
6. **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.

Text:

1. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).

Reference

1. G. Ghione, Semiconductor Devices for High-Speed Optoelectronics, Cambridge University Press (2009)
2. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communication, Oxford University Press (2007), 6th Ed., Ch.15-17.
3. G. Keiser, Optical Fiber Communications, McGraw-Hill Inc., 3rd Ed. (2000), Ch.4, 6.
4. J. Singh, Semiconductor Optoelectronics: Physics and Technology, McGraw-Hill Inc. (1995).
5. J. M. Senior, Optical Fiber Communication: Principles and Practice, Prentice Hall of India, 2nd Ed.(1994), Ch.6-8.
6. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17, and 18.

Video Reference:

NPTEL Video Lecture Course: "Semiconductor Optoelectronics" by Prof. M. R. Shenoy, IIT Delhi.

AP634 Integrated Optics and Silicon Photonics

1. **Formation and analysis of 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 LiNbO3, 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.
2. **Guided-wave interactions:** Coupled mode analysis of coupled waveguide structures., Examples of coupled mode analysis – the grating reflection filter, and the directional coupler.
3. **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 and acoustooptic waveguide devices. Directional couplers, optical switch; phase and amplitude modulators, Y-junction, power splitters, Arrayed waveguide devices. Tapered couplers, nonlinear effects in integrated optical waveguides.
4. **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.
5. **Photonic Devices:** Optical Phase Modulators and Variable Optical Attenuators, Mach–Zehnder Interferometer, Waveguide Bend, Waveguide-to-Waveguide Coupler, Arrayed Waveguide Grating (AWG), Waveguide Couplers for Small-dimension Waveguides, Advantage and Disadvantage of Silicon Photonics.
6. **Silicon Light-emitting Devices:** Erbium Doping, Low-dimensional Structures, Dislocation-engineered Emitters, Raman Excitation.

Text/References:

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.

AP 636 Laser Systems and Applications

1. **Design, Structure and Working of some Laser Systems:** He-Ne, CO_2, Nd:YAG, Excimer, Dye, Chemical Laser, Ti Sapphire Laser, **Safety aspects of laser handling & legislation**.
2. **Laser Metrology: Laser** for measurement of distance, length, velocity, acceleration; rotation sensing; RLG and FOG.
3. **Military Applications:** Low power laser applications including Laser Range finders-LRF(DPSSL, Eye Safe & High PRF) & Laser Target Designators; Laser based EOCM: Dazzlers, Laser Warning receivers, Infrared countermeasures, Laser DIRCM; Laser Guidance; Laser based navigation; Laser based imaging; Laser based remote sensing: Laser radar, laser radar seekers, laser bathemetry, obstacle avoidance, proximity sensors, Laser Fuze, detection of chemical, biological & explosive materials; identification of friend or foe (IFF); Multifunction laser systems.
4. **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.
5. **Bio-Medical Application of Lasers:** Lasers in diagnostics and treatment.
6. **Industrial Application of Laser:** Laser cutting, Laser welding, Laser drilling, Laser marking, , Photolithography, Laser based unmanned ground vehicles
7. **Holography:** Holographic interferometry and applications; Holography for non – destructive testing – Holographic components

Text/References:

1. Jean-Claude Diels, L. Arissian, Lasers: The Power and Precision of Light, John Wiley & Sons 2011.
2. William M. Steen, J. Mazumder Laser Material Processing, Springer, 2010.
3. K. Barat, Laser Safety Tools and Training, CRC Press 2009.
4. H. Weichel, Laser Beam Propagation in the Atmosphere, SPIE Press 1990.
5. J. F Ready, Industrial Applications of Lasers, 2nd Ed., Academic Press, 1997.
6. K. Nagothu, New Paradigms for Underwater Communication, ProQuest, 2009.
7. G. K Ackermann & J. Eichler, Holography: A Practical Approach, John Wiley & sons 2008.
8. W. Demtroder, Laser Spectroscopy: Experimental Techniques, Springer, 2008.
9. G. S Ahluwalia, W. Andrew, Cosmetics Applications of Laser & Light-Based Systems, 2009.
10. G. J. Muller, Applied Laser Medicine, Hans-Peter Berlien. Springer, 2003.
11. Webb C. E. and Colin, Handbook of Laser Technology and Applications: Volume 1& 2, Institute of Physics Publishing, 2000.
12. Monte Ross, Ed. Laser Applications, Vol 1.5, New York, Academic Press 1971.
13. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, Wiley Interscience 2007.

AP 637 High Power Lasers

1. **Introduction to Directed Energy Applications**: Historical development & military utility; Types of DEWs (Laser based & Microwave based), Elements of a Laser DEW system, Technology Development: History and Status, Types of DEW Systems (Laser based, Microwave based etc), Potential applications of HPL & HPM based DEWs, Benefits of laser, laser technology for Novel systems, laser system requirements for Military applications; Technology Advances: Relevance to India; Opportunities and Priorities for India, national/international scenario of HPL technology.
2. **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.
3. **Fiber Laser**: Introduction, Materials, Fiber design, Fiber laser components, fiber laser Systems: optical fiber amplifier, High Power cw Fiber Laser Systems, High Energy ns Fiber Laser Systems, Mode-Locked fs Fiber Lasers, Single Frequency Fiber Lasers, Beam Combining, Nonlinear Fiber Optics: Frequency Conversion/Supercontinuum Generation.
4. **Beam Director Technology:** Design considerations for beam director, threat alerting system, target acquisition & tracking system, laser beam pointing, target sightline stabilization, system processor & boresight functions, HPL beam control, battle damage assessment
5. **Atmospheric effects on Laser DEW performance & compensation mechanism**: Effects of atmosphere on HPL beam propagation: absorption, scattering & turbulence effects, thermal blooming effects, measurement of atmospheric turbulence parameter(C_n^2),laser transmission model, beam propagation through wakes & plumes, Turbulence mitigation: Adaptive optics
6. **International laser programmes**: ABL, ATL, SBL, Nautilus; Airborne Laser Technology-Impact on missile defence, advanced tactical laser-regional security implications, HPL-DEW for missile defence
7. **Safety aspects of laser & legislation**: Introduction: 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 .

Text/References:

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

AP639 Computational Photonics

1. **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, optically active and magneto-optic waveguides.
2. **Beam Propagation Method:** Theory and working of beam propagation method, Tutorials on MMI couplers, optical gratings, co-directional couplers or polarization converters.
3. **FDTD Method:** Theory and working of FDTD method, Tutorials on photonics band gap simulation: 2D and 3D of different crystal lattices.
4. **Fiber Optics:** Simulation and modeling of single mode and multimode optical fiber using mode solver, FBG and Chirped FBG synthesis, photonic crystal fiber simulation
5. **Nanodesign:** Mask designing for nanofabrication of different device geometry.

Software Tool: Suitable Commercial software tools would be used.

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 640 Nanophotonics

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 Mirrrors
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.
6. **Simulations of photonic crystal.**

Text/References:

1. C. Caloz, T. Itoh, Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, John Wiley and Sons, 2006
2. W. Cai and V. Shalaev, Optical Metamaterials, Fundamentals and Applications, Springer, 2010.
3. S. A. Ramakrishna and T. M. Grzegorczyk, Physics and Applications of Negative refractive index materials, SPIE and CRC Press, 2009.
4. Sir J. B. Pendry, Fundementals and Applications of negative refraction in Metamaterials, Princeton University Press, 2007.
3. J. D. Joannopoulos, S. G. Johnson, J. N. Winn, and R. D. Meade, Photonic Crystal: Molding Light Flow of Light, Princeton University Press, 2008.
4. G. T. Reed and A. P. Knights, Silicon Photonics: An Introduction, JohnWiley and Sons Ltd, 2004.

AP 641 Nonlinear and Quantum Optics

1. **Nonlinear optics basics:** Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients.
2. **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 non-linear optical devices. Sum and difference frequency generation, Optical parametric amplification (OPA) and oscillation (OPO), Analysis of OPA and OPO; practical device configurations and applications..
3. **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.
4. **Ultrafast Optics:** Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Nonlinear Schrödinger equation, Supercontinuum generation.
5. **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.

Text/References

1. A. Yariv and P. Yeh, Optical waves in crystals: propagation and control of laser radiation, Wiley, New York, 2002.
2. G P Agrwal
3. Peter E. Powers, Fundamentals of Nonlinear Optics, CRC Press, 2011.
4. A. Yariv, Quantum Electronics, John Wiley, 1989.
5. Y. R. Shen, The Principles of Non-linear Optics, John Wiley & Sons, 2003
6. R. W. Boyd, Nonlinear Optics, Academic Press, 2008.
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).
12. H.M. Moya-Cessa and F. Soto-Eguibar, Introduction to Quantum Optics (Rinton Press 2011).

AP 648 Optical Signal Processing

1. Two dimensional signals and systems: Fourier analysis in two dimensions, spatial frequency, two dimensional sampling theory
2. Scalar Diffraction theory: Huygen-Fresnel Diffraction theory, Angular Spectrum theory, Fresnel and Fraunhofer diffraction, Examples
3. Coherent & Incoherent imaging systems: Phase transformation and Fourier transforming properties of a thin lens, Image formation in a coherent imaging system, Frequency response of coherent and incoherent imaging systems, Phase contrast microscopy- Principals and Applications.
4. Holography: Recording and reconstruction of wavefronts, Gabor hologram, Leith-Upatneiks hologram, Fresnel holograms, Fraunhofer holograms, Image holograms, Fourier holograms, Transmission and reflection holograms, holographic stereograms, Rainbow holograms, Multiplex holograms, Embossed holograms, thick holograms, holographic recording materials, Computer generated holograms, Digital holography, holography with spatially incoherent light, Spectral holography
5. Applications of Holography: Microscopy, Holographic Interferometry, Holographic storage, other applications.

References:

1. J. W. Goodman, Introduction to Fourier Optics, Third ed. Viva books Pvt. Ltd., 2007.
2. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc. New York, 1991.
2. R. J. Collier, C. B. Burckhardt, and L. H. Lin, Optical Holography, Academic Press, New York, 1971.
3. P. Hariharan, Optical holography: Principles, Techniques and Applications, Cambridge University Press, Cambridge, UK, Second Ed., 1999.
4. G. Saxby, Practical Holography, Institute of Physics Publishing, Bristol, U.K., Third Edition, 2003.
5. H. M. Smith, Principles of Holography, John Wiley & Sons, New York, Second ED., 1975.
6. L. P. Yaroslavski and N. S. Merzlyakov, Methods of Digital Holography, Consultants Bureau, Plenum Publishing Company, New York, 1980.

AP 635 Laser & Optical Communication Laboratory 1

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. Detection of polarisation states using polarisation components like polarizers, waveplates etc.
5. Analysis of various light source spectra using OSA.
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.
7. Macro and Microbending loss in optical fibers and its application
8. Measurement of Photodiode characteristics
9. Study of Fraunhofer diffraction pattern of a rectangular and circular aperture.
10. Fiber optic link design
11. Measurement of attenuation and dispersion in optical fibers
12. Fiber to Fiber splicing and splicing loss measurement.
13. Setting up of Mach-Zender interferometer
14. Measurement of Photoluminiscence of an active materials using PL measurement setup.
15. Design of driver circuit for LED and Laser diode
16. Characterisation of Erbium Doped Fiber Amplifier
17. Pulse width measurement of different laser using autocorellator.
18. Holography
19. One Mini project (**compulsory for all**)

Note: Every student should perform a minimum of 15 experiments from the above list.

AP 638 Lasers & Optical Communication 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. Study of Faraday effect
12. Design of a fiber optic sensor
13. Line coding and decoding, voice coding
14. Measurement of insertion loss of an isolator, coupler and multiplexer
15. Beat length measurement in bi-refringent fibers.
16. Laser Raman Spectroscopy Experiments
17. M^2 measurement of different lasers
18. Mini project (**compulsory for all**)

Note: Every student should perform a minimum of 15 experiments from the above list.

M. Tech. in Optoelectronics and Communication Systems (Optical Communication and Photonics)

Brief Description: The rapid growth of networks and the internet over the past decade has been enabled by advances in photonics technology. Optical communication networks provide the high capacity ubiquitous connectivity that forms the backbone of global internet. Today, optics has become the way by which most of the information is communicated around the globe and is the only technology that is capable of meeting the exponentially growing demand for communicating information. The programme intends to impart training to selected candidates in the field of Optical Communication and Photonicsthat would enable them to meet the challenges in this rapidly developing field.

Stakeholders:

(vi) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings and other departments

(vii) Graduates in the relevant field of science/engineeringfrom recognized Universities/Institutes across the country.

Eligibility:

The candidate should possess Master degree or equivalent in Physics, Applied Physics, Electronic Science, Photonics **OR** B. E./ B. Tech/ BSc.(Engg.) or equivalent in Electronics Engg./ Electrical Engg./ Electrical & Electronics Engg./ Electronics & (Tele)Communication Engg./ Electrical Communication Engg./ Electronics & Instrumentation Engg./ Instrumentation Engg./ Optics & Optoelectronics.

Organization: The M. Tech. programme is of four-semester duration. In each of the first two semesters there are five courses and practical. 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 thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners. Course syllabus has been updated periodically to keep pace with the contemporary technological advancement.

Semester I

S. No	Course Code	Course Name	Credits			*Total Credits
			L	P (in Hr)	T	
1	AP 631	Applied Optics	3	0	1	4
2	AP 632	Laser & Optical Electronics	3	0	1	4
3	AP 643	Introduction to Fiber Optics	3	0	1	4
4	AP 635	Laser & Optical Communication Laboratory – I	0	8	0	4
5	AP 633	Semiconductor Photonic devices	3	0	1	4
6	AM 607	Mathematics for Engineers	3	0	1	4
		TOTAL	15	4	5	24

Semester II

S. No	Course Code	Course Name	Credits			*Total Credits
			L	P (in Hr)	T	
1	AP 644	Broadband Communication Systems	3	0	1	4
2	AP 645	Digital & Optical Communication Systems	3	0	1	4
3	AP 638	Laser & Optical Communication Laboratory – II	0	8	0	4
4	AP 647	Optical Networks	3	0	1	4
5		Elective – I	3	0	1	4
6		Elective-II	3	0	1	4
		TOTAL	15	4	5	24

Semester III:

Sl. No.	Course Code	Course Name	Credits		*Total Credits
			L	T / P	
1.	AP 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.	AP 652	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**

List of Electives

Sr. No.	Course Code	Course
Elective I& II		
1	AP 646	Free Space Optical Communication
2	AP 641	Non-linear and Quantum Optics
3	AP 640	Nanophotonics
4	AP 648	Fourier Optics & Holography
5	EE 608	Advanced Wirless Communication
6	EE 631	Satelite Communication
7	EE 632	Advanced Communication Systems
8	EE 633	Underwater Communications

AP 643 Introduction to Fiber Optics

1. **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, Mechanical Property of Fiber and Fiber Optics Cables.
2. **Optical Fibers Characteristics:** Fiber Attenuation, Absorption losses, Scattering losses, Radiation losses, Bending losses, Measurement of losses, Dispersion in fibers, Effect of dispersion in communication link, Dispersion reduction and compensation techniques.
3. **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.
4. **Optical Receivers:** Basic Concepts, Common Photodetectors, Receiver Design, Receiver Noise, Coherent Detection, Receiver Sensitivity, Sensitivity Degradation, Receiver bandwidth and Performance
5. **Fiber Amplifier:**Optical Amplification in rare-earth dopedfibers, Types of Fiber Amplifiers, EDFA, Amplifier Noise, Optical SNR, System Application, Raman Amplifiers, Wideband Optical Amplifier.
6. **Fiber Bragg Gratings:** Introduction, Methods for Fiber Bragg Grating Fabrication, Theory of Fiber Bragg Gratings, Types of Fiber Bragg Gratings, Measurement and Characterization of Gratings, FBGs in Fiber Lasers.
7. **Optical Fiber Sensor:** Introduction, Classification and Types of Optical Fiber Sensors, Sensor Modulation techniques, Fiber Bragg Grating Sensors: Principle and Applications.
8. **Overview of Optical Fiber Communication:** Light wave 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. **OptisystemTuotorials**

a) Calculate the attenuation-limited fiber length based on the power budget equation. Simulate the resulting system and verify that it meets performance objectives.

b) Calculate the dispersion-limited fiber length for a fiber optic transport system that employs standard single-mode fiber and a directly-modulated single-mode laser diode transmitter. Simulate the resulting system and verify that it meets performance objective.
c) Design and simulate a fiber optic system using dispersion-compensating fiber to reduce chromatic dispersion.

Text Book:

1. A. K. Ghatak and K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press (1998).
2. G. Kaiser, Optical Fiber communication, 4th Edition, Tata McGraw Hill, 2008.

References

1. J. C. Palais, Fiber Optic Communications, Prentice-Hall Inc. 4th Ed. (1998).
2. S.K.Sarkar, Fiber optics in Telecommunications and Sensor Systems, S Chand & Co., New Delhi, 2002.
3. J. P. Dakin and B Culshaw, Optical Fiber Sensors, Vol. 1 & 2, Artech House, Boston and London, 1998.
4. R.Kashyap,Fiber Bragg Gratings, Academic Press, 1999
5. K.T.V. Grattan and B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, Chapman and Hall, 1998

AP 644 Broadband Communication Systems

1. **Introduction:**Broadband Network Architectures, Future of broadband communications
2. **Basic Broadband Technologies:** Internet Protocol Suite, IPv6, Basics of Intranet & Extranet technologies, X.25 Technology, Frame Relay, Frame Relay Standards, Types of VPN and General Architecture, Fiber Channel Technology & topologies,
3. **xDSL:** IDSL, HDSL (SDSL, ADSL, RADSL, CDSL, and VDSL), xDSL, xDSL Coding Technologies, Provisioning of xDSL.
4. **Cellular Communication:** Analog Cellular Communications, The Cell site, The Mobile Telephone Switching Office (MTSO), Cell site Configurations, Tiered sites, Reuse of Frequencies, Allocation of Frequencies
5. **Global Services Mobile Communications (GSM), Wireless Data Communication (Mobile IP) and GPRS:** Analog to Digital Movement, GSM Architecture, Mobile Equipment (MS), BTS, BSC, BSS, MSC, VLR, IP Routing, Applications That Demand Mobile IP, Variations in Data Communications (Wireless), Possible Drawbacks with Wireless, Wireless Data Technology Options, The GSM Phase II Overlay Network, Circuit−Switched or Packet−Switched Traffic, GPRS Radio Technologies, PDP Contexts, GSM and NA−TDMA Evolution, Applications for GPRS
6. **Third−Generation (3G) Wireless Systems and VoIP:** EDGE, WCDMA, Applications of the Wireless Internet, Multimode Second Generation/UMTS Terminals, VoIP, QoS, Application of VoIP (H.323 Protocol Suites, Delay and Jitter on VoIP Networks, Protocol Stack.

7. **4G & 5G:**Introduction to 4G Standards, Introduction to 4G Architecture, components & basic internet & communication call flows. Introduction to 5G standards, basic 5G architectures, 5G services, Recent trends and applications in 5G, Massive Multiple- Input Multiple- Output (MIMO) Wireless Systems.

References:

1. **Cajetan M. Akujuobi, Matthew N.O. Sadiku, Introduction to Broadband Communication Systems, ,Chapman and Hall/CRC , 2007.**
2. Robert C. Newman, Broadband Communications Prentice Hall, NJ, USA, 2001.
3. Rajiv Ramaswami, Kumar N. Sivarajan and G. H. Sasaki, “Optical Networks: A Practical Perspective”, Elsevier, Third Edition, 2010.
4. P.E. Green, Jr., “Fiber Optic Networks”, Prentice Hall, NJ, 1993.
5. C. Siva Ram Moorthy and Mohan Gurusamy, “WDM Optical Networks: Concept,Design and Algorithms”, Prentice Hall of India, Ist Edition, 2002.
6. Biswanath Mukherjee, “Optical WDM Networks”, Springer, 2006.
7. B Sklar, “Digital Communications: Fundamentals and Applications” PH, 2001
8. Kuhn Paul J., Ulrich,Roya, “Broadband Communications” 1998.
9. SofoklisKyriazakos, River Publishers, 4G Mobile and Wireless Communications Technologies.
10. Jonathan Rodriguez, Wiley Publications, Fundamentals of 5G Mobile Networks

AP 645 Digital and Optical Communication Systems

1. **Elements of Digital Communication systems**: Model of Digital Communication Systems, Digital Representation of Analog Signal, Bandwidth-S/N tradeoff, Hartley Shannon Law, Sampling Theorem, Pulse Code Modulation, PCM Generation and Reconstruction, Quantization noise, Non uniform Quantization and Companding, DPCM, Adaptive DPCM, DM and Adaptive DM. Noise in PCM and DM,, Information Capacity, Bits, Bit Rate, Baud rate & M-ary Encoding.
2. **Digital Modulation techniques:** Introduction, Pulse amplitude modulation (binary and M-ary, QAM), Pulse position modulation (binary and M-ary), Carrier modulation (M-ary ASK, PSK, FSK, DPSK), Continuous phase modulation (QPSK and variants, MSK, GMSK), Trellis Code Modulation, Probability of Error & Bit Error Rate, Error Performance.
3. **Lightwave Systems:** System Architectures, Design Guidelines, Long-Haul Systems, Sources of Power Penalty, Forward Error Correction, Computer-Aided Design
4. **Multichannel Systems:** WDM Lightwave Systems, WDM Components, System Performance Issues, Optical Time-Division Multiplexing, Subcarrier Multiplexing, Code-Division Multiplexing
5. **Loss Management:** Compensation of Fiber Losses, Erbium-Doped Fiber Amplifiers, Raman Amplifiers, Optical Signal-To-Noise Ratio, Electrical Signal-To-Noise Ratio, Receiver Sensitivity and Q Factor, Role of Dispersive and Nonlinear Effects, Periodically Amplified Lightwave Systems
6. **Dispersion Management:** Dispersion Problem in SMF, Dispersion-Compensating Fibers, Fiber Bragg Gratings, Dispersion-Equalizing Filters, Optical Phase Conjugation, Channels at High Bit Rates, Electronic Dispersion Compensation.

7. **Nonlinear effects in Optical Fibers:** Stimulated Raman scattering, Stimulated Brillouin scattering, Self-phase modulation, Cross Phase modulation, Four-wave mixing. Solitons communication systems.
8. **Tutorials:Modelling of Fiber Optics Communication system**
   a. Simulate the broadening of a Gaussian pulse propagating through an optical fiber. Compare the results predicted by the linear system model of an optical fiber with the results of simulation.
   b. Determine the sensitivity of a PIN photodiode based optical receiver by determining the minimum received power necessary to achieve a given Q factor. Compare the results of simulation with the results of an analytic approach.
   c. Loss managements and Use of EDFA
   d. Design and modeling of Multi amplifier system and Effect on OSNR

Text Books:

1. **G. P. Agarwal, Fiber-Optic Communication Systems, 4th Ed., Wiley, 2010.**
2. **Advanced Electronic Communications Systems, by Wayne Tomasi, 6 Edition Pearson Education.**

References

1. Principles of communication systems - Herbert Taub. Donald L Schiling, Goutam Sana, 3rd Edition,McGraw-Hill, 2008.
2. Digital and Analog Communicator Systems - Sam Shanmugam, John Wiley, 2005.
3. G. Keiser, Optical fiber communication systems, McGraw-Hill, New York, 2000.
4. Franz & Jain, Optical communication, Systems and components, Narosa Publications, New Delhi, 2000.
5. G. P. Agarwal, Non-linear Fiber Optics, Third Ed., Academic Press, New York, 2001.

AP646 Free Space Optical Communication

1. **Introduction FSOC/OWC**: Various modes of wired & wireless communication, Wireless access schemes, Historical perspective OWC, current scenario and challenges, Basic Link configuration of FSOC, various application areas of FSOC
2. **Laser sources & Receivers for free space communications:** Atmospheric low loss windows, optical sources and detectors for these windows, Characteristics of source and detectors.
3. **Channel Modeling -Indoor channel:** Various link configurations, propagation models for LOS, nLOS, Diffuse configurations, Artificial light interference effects in indoor channel.
4. **Channel Modeling -Outdoor channel:** Atmospheric channel loss, Absorption and scattering characteristics of atmosphere Fog & Visibility effects, Beam divergence, Optical & Window loss, Geometrical Loss, pointing loss, Various models of FSO in atmospheric channels, Power calculations,
5. **Atmospheric turbulence effects:** Atmospheric composition and structure, Significance and Measurement of $Cn^{2,}$ Atmospheric Attenuation, Various atmospheric turbulence models, Basic beam propagation types, Effects of atmospheric turbulence on laser beam propagation, Realization of atmospheric effects on OWC test beds

6. **Modulation Techniques:** Importance of modulationin FSO, various modulation formats, selection criteria for modulation, basic modulation schemes OOK,PPM, PIM, DH-PIM, BPSK etc. error propagation in Gaussian channels in each modulation formats
7. **FSO link Performance under atmospheric turbulence:** performance of FSO link in various modulation formats, comparison across the modulation formats, turbulence induced penalty in FSO link
8. **Mitigation techniques:** introduction, aperture averaging, various diversity techniques, spatial diversity, time diversity coding techniques, adaptive optics and other techniques
9. **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.
10. **Introduction to Satellite free Space Communication and under water communication, visible light communication**

Tutorials: Relevant tutorial will be conducted using optisystem and matlab

Text/References

1. Morris Katzman, "Laser Satellite Communications", Prentice Hall Inc, New York, 1991.
2. J. Franz and V.K.Jain, "Optical Communication Systems", Narosa Publication, New Delhi, 1994.
3. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K.Jha

AP647 Optical Networks

1. **Introduction:** Telecommunications Network Architecture, Services,Circuit Switching and Packet Switching, Optical Networks, The Optical Layer, Transparency and All-Optical Networks, Optical Packet Switching, Transmission Basics, Network Evolution.
2. **Client Layers of the Optical Layer:** SONET/SDH, Optical Transport Network, Generic Framing Procedure, Ethernet, IP, Multiprotocol Label Switching, Resilient Packet Ring, Storage-Area Networks
3. **WDM Network elements:** Optical Line Terminals, Optical Line Amplifiers, Optical Add/Drop Multiplexers, Optical Crossconnects
4. **Control and Management:** Network Management Functions, Optical Layer Services and Interfacing, LayerswithintheOpticalLayer, Multivendor Interoperability, Performance and Fault Management, Configuration Management, Optical Safety
5. **Network Survivability:** Basic Concepts, Protection in SONET/SDH, Protection in the Client Layer, Why Optical Layer Protection, Optical Layer Protection Schemes, Interworking between Layers.
6. **WDM Network Design:** Cost Trade-Offs: A Detailed Ring Network Example, LTD and RWA Problems, DimensioningWavelength-RoutingNetworks, Statistical Dimensioning Models, MaximumLoadDimensioningModels.
7. **Photonic Packet Switching:** Optical Time Division Multiplexing, Synchronization, Header Processing, Buffering, Burst Switching, Testbeds.
8. **FTTx:**Introduction to FTTX, Fiber to the Home Architectures, FTTH in MDUs (Multiple Dwelling Units), FTTH PON Types, FTTH PON(Passive Optical Network), Triple Play Systems (BPON,GPON,EPON,RFOG) WDM and PON Other Uses For PONs, FTTX hardware and components (Cables, Splitters, Cabinets, Subscriber components).

9. **FTTx Installation, Testing and Management:** Outdoor cable installation, Duct, aerial, direct burial, Micro-duct solutions, Drop cable installation, Fiber terminations on with pigtail, Splicing and joint closing, Testing FTTH (Key factors affecting network, Testing during construction, Testing for commissioning).

Practical Exposure (Optional)

1. Practical View samples Set up FTTX link
2. Splicing and joint closing,
3. Installation of indoor hardware rack and wall mounting
4. Fiber arrangement and trucking
5. Connector installations
6. OTDR Testing, Troubleshooting
7. Multicore cable termination

Text/References

1. Rajiv Ramaswami, Kumar N. Sivarajan and G. H. Sasaki, “Optical Networks: A Practical Perspective”, Elsevier, Third Edition, 2010.
2. P.E. Green, Jr., “Fiber Optic Networks”, Prentice Hall, NJ, 1993.
3. C. Siva Ram Moorthy and Mohan Gurusamy, “WDM Optical Networks: Concept,Design and Algorithms”, Prentice Hall of India, IstEdition, 2002.
4. Biswanath Mukherjee, “Optical WDM Networks”, Springer, 2006.
5. Gerd Keiser , Wiley-IEEE “FTTx Concepts and Applications”
6. James Farmer, Brian Lane, Kevin Bourg, Weyl Wang, “FTTx Networks” 1st Edition November 2016.

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 tunnelling. 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.

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/engineering from recognized Universities/Institutes across the country.

Eligibility: The candidate should possess Master degree or equivalent in Physics, Applied Physics, Electronic Science, Photonics OR B. E./ B. Tech/ BSc.(Engg.) or equivalent in Electronics Engg./ Electrical Engg./ Electrical & Electronics Engg./ Electronics & (Tele)Communication Engg./ Electrical Communication Engg./ Electronics & Instrumentation Engg./ Instrumentation Engg./ Optics & Optoelectronics.

Organization: The M. Tech. Programme is of four-semester duration. In each of the first two semesters, there are five courses and practical. 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 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 Name	Credits			Total Credits
			L	P (in Hr)	T	
1	AP 640	Classical linear and non-linear optics and elements of quantum optics	4	0	0	4
2	AP 650	Quantum Mechanics	4	0	0	4
3	AP 653/ CE 700A	Quantum Computation and Information Processing	4	0	0	4
4	AP 654	Classical & Quantum information theory	4	0	0	4

5	EE 624	Digital System Design Using FPGA	3	2	0	4
6	AP 655	Quantum Technology Laboretory-1	0	8	0	4
		TOTAL	**20**	**8**	**0**	**24**

AP 640 Classical Linear and non-linear optics and elements of quantum Optics

1. **Ray optics and Maxwell' 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 Equationelectric constant and refractive index. Vector and Scalar Potentials andGauge invariance. Polarisers, Quarter, Half, and Full waveplates, Beam splitters: polarizing and non-polarizing, wavelength filters, dichroic mirrors, Lenses (**concurrentLab Experiments**).

2. **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.

3. **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.
4. **Vector and vortex beams**- Orbital angular momentum of light beams and OAM states.
5. **Elements of Non-linear optics.** Second order nonlinear susceptibility: Phase matching, Second Harmonic Generation, Sum and difference frequency generation. Parametric up and down conversion. Third order nonlinearity, saturable absorption.
6. **Lasers:**Basic laser theory. Laser oscillators and amplifiers. Generation on nanosecond and femtosecond pulses. Group velocity and Pulse Dispersion. Diode laser, DPSS lasers, Distributed Fibre Laser and VECSELS.
7. **Wave guides and Optical Fibers**: Light Propagation in Optical Fibers, Optical fiber Modes and Configurations, Mode Theory for Circular waveguides, Single Mode, Multi-mode andPolarization Maintaining Fibers.Fiber Attenuation, Absorption losses, Scattering losses, Radiation losses, Bending losses, Measurement of losses, Dispersion in fibers, Effect of dispersion in communication link, Dispersion reduction and compensation techniques.
8. **Fourier Optics**: Impulse response and transfer function of free space, Fourier transform using a lens, Fraunhofer and Fresnel diffraction, Off-axis and On-axis Fourier transform holography.
9. **Quantization of the electromagnetic field**
   Field quantization. Coherent states and squeezed states.Beam Spliiter representation in terms of field operators. Correlation functions and photon statistics. Phase space representation and Wigner function.

References

1. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
2. A. K. Ghatak and K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press (1998).

3. G. Kaiser, Optical Fiber communication, 4th Edition, Tata McGraw Hill, 2008.
4. B E A Saleh and M C Teich, Fundamentals of Photonics, John Wiley and Sons, 2007.

5. A. Ghatak, Optics, TMH, 2005. 2. E. Hecht, Optics, Pearson Education India, 2012

6. Mandl and Wolf,

AP 650 Quantum Mechanics

1.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 Tunnelling. Position and momentum eigenstates.

2.Linear algebra and complex vectors spaces

. Hilbert space. State vectors. Basis sets and the Gram-Schmidt orthogonalization. Unitary operators, operator adjointsand 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 andObservables in quantum mechanics.

3.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.

4.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.

5. Composite systems

Tensor product spaces. Bipartite and multipartite states. Partial trace of composite states. Schmidt decomposition. Entangled and separable systems.

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 CODE: AP 653 /CE 700A

COURSE TITLE: Quantum Computation and Information Processing

COURSE CREDIT: 04 (L-03h; P-02h or Demo:02h)

Evaluation Pattern: Monthly test: 03 of 10 Marks each; Final Evaluation: 50 Marks; Term-Work:10 Marks

About the Course: *Quantum Computation and Information* is the future of computing; which will enrich Artificial Intelligence and help to build Secure Cyber World. Quantum Computers offer exponential speedup over any classical computer and has the potential to revolutionise the methods of building Computer Networks. This course will make the students understand the fundamental principles of *Quantum Computation and Information* Processing.

Course Objectives: This course work will meet the following learning objectives-

1) Provide insight into the conceptual similarities and differences between classical & Quantum computing
2) Enable learning on how to take the first step in understanding how a quantum bit can be physically implemented
3) Learn to understand & appreciate the key challenges in realising quantum hardware and technology
4) Understand the fundamentals of qubits, quantum gates and measurements,
5) Learn how properties of quantum information can be applied to construct some of the most well-known quantum algorithms and processing the information.

Prerequisites: Probability and Statistics, Linear Algebra, Turing Machines, Basics of Classical Computations, Basics of Classic Algorithms; Basics of Machine Learning

Unit-I

Differences between Quantum and Classical Computation; Assess the applications of quantum computation; Information Explosion; Speed-ups and Scale-ups in quantum and classical environments; Quantum Supremacy

Unit-II

Engineering requirements for quantum vs classical algorithm implementation; Determine technical requirements for quantum computers to run realistically large quantum algorithms; Mathematical and Computational Perspectives; Revise the concepts of Matrices, Vectors, Probability, Linear Algebra, Approximation theory, Quantum Probability; Understand the mathematical description of quantum states and basic quantum operations

Unit-III

Qubits and Bloch Sphere; Quantum Circuits; Adiabatic Quantum Computing; Quantum parallelism; Discern potential performance gains of quantum vs. classical algorithms: Shor Algorithm, Grover Algorithm; Complexity Classes

Unit-IV

Understand engineering challenges currently faced by developers of quantum computers; Uncertainties; Error Corrections; Simulators; Various Quantum Computing Models; Discern the scientific limits of quantum algorithms for domain-specific-needs and optimization.

Unit-V

Entropy and Entanglement, No Cloning Theorem, Teleportation, Quantum Computing Simulators/Environments; Quantum Information Theory; Quantum Random walks, Quantum Internet & Protocols

Text Book

1. Eleanor Rieffel and Wolfgang Polak, *QUANTUM COMPUTING - A Gentle Introduction*, The MIT Press Cambridge, Massachusetts London, England, 2011; Total Pages 385

References

2. Nielsen, Michael A.; Chuang, Isaac L. (June 2012). Quantum Computation and Quantum Information (10th anniversary ed.). Cambridge: Cambridge University Press. ISBN 9780511992773. OCLC 700706156.
3. Relevant to the semester and the unit-wise discussions, the reference research papers & the courseware links will be shared.

AP 654 Classical and Quantum Information theory

1.Classical Information theory

Convex functions and Jensen's inequality. Shannnon Entropy, mutual entropy and mutual information. Joint and conditional entropy. Data compression and codes. Kolmogorov complexity. Classical channels and Shannon coding theorems. Entropic inequalities.

2.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.

3.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.

4.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.

5.Quantumentropy.

Properties of Entropy. Conditional entropy. Quantum mutual information. Additivity subaddtivity and strong subadditivity. The Holevo bound. A comparison between classical and quantum information theory.

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 Name: DIGITAL SYSTEM DESIGN USING FPGAs
Course Code: EE624

UNIT I INTRODUCTION TO DIGITAL DESIGN: 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 - Introduction to HDL - Behavioral modeling - Data flow modeling - Structural modeling
- Basic language elements – Entity – Architecture - Configurations - Subprograms & operator overloading -
Packages and libraries – Test Bench - Advanced Features - Model simulation - Realization of combinational and
sequential circuits using HDL – Registers – Flip flops - counters – Shift registers –Multiplexers - sequential machine
–Multiplier – Divider, Introduction to Synthesis and Synthesis Issues.

UNIT III TESTING, FAULT MODELLING AND TEST GENERATION - Introduction to testing – Faults in
Digital Circuits – Modelling 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 FPGA - FPGAs - Logic blocks, Routing architecture, Design flow technology - mapping for FPGAs,
Xilinx FPGA Architecture, Xilinx XC4000 - ALTERA's FLEX 8000, Design flow for FPGA Design, Case studies:
Virtex II Pro.

UNIT V FPGA IP Design: Introduction to IP Design, Design of Data path components, Control path components.
Design of a simple RISC CPU. Debugging using Embedded Logic Analyzers.

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

381

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:

AP 655 Quantum Technology Laboratory-I

1. Study of Optical lences and lens systems.
2. Study of Polarizer, Polarizing and Non-polarising BS, QW, HW, FW Plates
3. Polarisation properties of laser with and without QW, HW and FW Plates
4. Fourier Optics
5. Mach-Zehnder interferometer.
6. Young's double-slit experimental setup
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. Measurement of attenuation and dispersion in optical fibers
9. Beam Divergence & M^2 Measurement.
10. The Basic Design Flow of DSP Implementation in FPGA.
    i) To understand use of Xilinx System Generator.
    ii) To understand Xilinx Synthesis Technology or XST.
    iii) Familiarization of Simulink, Signal Processing Toolbox, Signal Processing Block-set.
11. Implementation of Dual Port RAMS Addressable Shift Register, FIFO And ROM in FPGA.
    i) Familiarization with Memory Blocks implementation in FPGA.
    ii) To Understand FGPGA Hardware.
    iii) Familiarization of XUP board (Vertex-5).
12. Implementation of M Code Adder in FPGA
    i) This exercise provides an introduction to the integration of M Code into a System Generator System.
    ii) To understand functionality of a basic 2-input adder is interpreted from the M-code.
13. Generation of Simulink System Period
    i) To understand Simulink system periods, and confirm the meaning of this parameter from the simulation results.

Department of Technology Management

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
		Total	**18**	**6**	**24**

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 – I	3	1	4
6		Elective – II	3	1	4
		Total	**18**	**6**	**24**

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

Semester III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	TM651	M.Tech. Dissertation Phase I			14
		Total			**14**

Semester IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	TM652	M.Tech. Dissertation Phase II			14
		Total			**14**

LIST OF ELECTIVES

Sl. No.	Course Code	Course Name
Elective I, II		
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
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		

SEMESTER 1 : INTRODUCTION TO TECHNOLOGY MANAGEMENT (TM601)

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.

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.

<u>SEMESTER 1 : R & D MANAGEMENT (TM 602)</u>

Unit I : Introduction to R&D function, R&D – Reactive and Passive Partner to Responsive Collaborator, Driving the Economy through R&D activities, The Strategic Aspects of R&D Management, Project Planning and Budgeting, Road mapping, Project Selection, Project Evaluation.

Unit II : Human Resource Management in R&D, Attraction and Retention of Talent in R&D, Creativity in R&D Organizations, Interpersonal Relationships, Teams and Team building.

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

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

SEMESTER 1 : PROJECT MANAGEMENT (TM 603)

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.

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.

SEMESTER 1 : STRATEGIC MANAGEMENT FOR TECHNOLOGY (TM604)

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-Demonetization, 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

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

SEMESTER 1: MANAGEMENT OF INNOVATION AND INTELLECTUAL PROPERTY (TM605)

Unit I: *Organizational and technological innovation* : role of organizational design and processes, strategic role of intellectual property protection in technological innovations case studies, role of open source, 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, Open innovation in tech management

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.

SEMESTER 1: HUMAN RESOURCE MANAGEMENT FOR TECHNOLOGY INTENSIVE ORGANISATIONS (TM 615)

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)

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

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)

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)

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, 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.

Unit III: *Optimization Experiments*: Response Surface Methodology, Responses Surface Model Fitting, Mixture Experiments, Variability and Quality: Characterizing Variability in Data, Shewhart Control Charts, Off-Line Quality Control and Robust Design,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)

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, 4th edition, Prentice-Hall Inc., New Jersey, (1994)

ELECTIVES FROM DEPARTMENT

MANAGEMENT OF MANUFACTURING AND INTEGRATION (TM 607)

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)

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.

Unit III: IT support systems for Knowledge management, Ontology, case studies and applications of knowledge management, using data from patents, technology, measurement of innovation and in corporate organizations, learning in the context of open innovation and open source.

Text Books:

1. Harvard Business Review on Knowledge Management by Peter Ferdinand Drucker, David Garvin, Dorothy Leonard, Susan Straus, John Seely Brown
2. 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

SYSTEMS ENGINEERING FOR MANAGERS (TM 609)

Unit I : SYSTEMS ENGINEERING AND THE WORLD OF MODERN SYSTEMS

- What Is Systems Engineering?
- Origins of Systems Engineering
- The Power of Systems Engineering
- Examples of Systems Requiring Systems Engineering

Unit 2 : STRUCTURE OF COMPLEX SYSTEMS

- System Building Blocks and Interfaces
- Hierarchy of Complex Systems
- System Building Blocks
- The System Environment
- Interfaces and Interactions
- Complexity in Modern Systems
- Examples of Complex Systems

Unit 3: THE SYSTEM DEVELOPMENT PROCESS

- Systems Engineering through the System Life Cycle
- System Life Cycle
- Evolutionary Characteristics of the Development Process
- The Systems Engineering Method
- Testing throughout System Development
- Development process examples

Unit 4: SYSTEMS ENGINEERING MANAGEMENT

- Managing System Development and Risks
- WBS
- SEMP
- 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

<u>SOFTWARE PROJECTS MANAGEMENT (TM611)</u>

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 (5^{th} 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)

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.

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 I. Younker, Value Engineering: Analysis And Methodology,
2. J. Paul Guyer, Value Engineering (Engineering Sound Bites) Kindle Edition

DESIGN MANAGEMENT (TM 614)

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)

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)

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)

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 (5th 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)

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.

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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.	EE605	Navigation System Concepts	3	1	4
6.	AM607	Mathematics for Engineers	3	1	4
		Total	18	6	24

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	EE608	Modern Wireless communications	3	1	4
4	EE609	Antenna Systems	3	1	4
5		Elective-I	3	1	4
6		Elective-II	3	1	4
		Total	18	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.	EE605	Navigation System Concepts	3	1	4
6.	AM607	Mathematics for Engineers	3	1	4
		Total	18	6	24

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	EE609	Antenna Systems	3	1	4
4	EE607	Detection and Estimation Theory	3	1	4
5		Elective-I	3	1	4
6		Elective-II	3	1	4
		Total	18	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.	EE605	Navigation System Concepts	3	1	4
6.	AM607	Mathematics for Engineers	3	1	4
		Total	18	6	24

Semester II

Sl No	Course Code	Course Title	Contact Hours/ Week		Credits
			L	T/P	
1	EE609	Antenna Systems	3	1	4
2	EE612	High Power Microwaves Systems	3	1	4
3	EE613	Electronic Warfare	3	1	4
4	EE614	EMI/EMCDesign	3	1	4
5		Elective-I	3	1	4
6		Elective-II	3	1	4
		Total	18	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 (Navigation 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.	EE605	Navigation System Concepts	3	1	4
6.	AM607	Mathematics for Engineers	3	1	4
		Total	18	6	24

Semester II

Sl. No	Course Code	Course Title	Contact hours/ Week		Credits
			L	T/P	
1	EE615	GNSS Receiver Design and Applications	3	1	4
2	EE616	Multi Sensor Integrated Navigation	3	1	4
3	EE617	Inertial Navigation Systems	3	1	4
4	EE618	Indoor Navigation	3	1	4
5		Elective-I	3	1	4
6		Elective-II	3	1	4
		Total	18	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 (Wireless Networks and Applications)

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.	CE663	Applied Cryptography	3	1	4
5.	CE660	Advanced Computer Networks	3	1	4
6.	AM607	Mathematics for Engineers	3	1	4
		Total	18	6	24

Semester II

Sl. No	Course Code	Course Title	Contact hours/ Week		Credits
			L	T/P	
1	CE 691	Secured Wireless Sensor Networks	3	1	4
2	EE619	Software Defined Radio	3	1	4
3	EE608	Modern Wireless communications	3	1	4
4	EE609	Antenna Systems	3	1	4
5		Elective-I	3	1	4
6		Elective-II	3	1	4
		Total	18	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	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.	EE638	Analog and Mixed mode VLSI Design	3	1	4
5.	EE624	Digital System Design using FPGA	3	1	4
6.	AM607	Mathematics for Engineers	3	1	4
		Total	18	6	24

Semester II (@DIAT, Pune)

Sl. No.	Course Code	Course	Contact hours/week		Credits
			L	T/P	
1.	EE625	High Performance DSP using FPGA	3	1	4
2.	EE620	SoC and Embedded Systems	3	1	4
3.	EE648	VLSI Fabrication Technology	3	1	4
4.	EE619	Software Defined Radio	3	1	4
5.		Elective-I	3	1	4
6.		Elective-II	3	1	4
		Total	18	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].

List of Electives

Sl. No.	Course Code	Course Title	Contact hours/week		Credits
			L	T/P	
1.	EE626	Compressed Sensing & Sparse Signal Processing	3	1	4
2.	EE627	Signal Theory, Linear Algebra & Transform Techniques	3	1	4
3.	EE628	Advanced Electronics Systems	3	1	4
4.	EE629	Sonar Signal Processing	3	1	4
5.	EE630	Sonar System Engineering	3	1	4
6.	EE631	Satellite Communication	3	1	4
7.	EE632	Advanced Communication Systems	3	1	4
8.	EE633	Underwater Communications	3	1	4
9.	EE634	Monolithic Microwave Integrated Circuit	3	1	4
10.	EE635	Inertial Sensors and Systems	3	1	4
11.	EE636	Navigation & Avionic Systems	3	1	4
12.	EE637	ASIC Verification using System Verilog	3	1	4
13.	EE638	Analog and Mixed mode VLSI Design	3	1	4
14.	EE639	Computer Aided Design for VLSI Circuits	3	1	4
15.	EE640	FPGA Architecture and Applications	3	1	4
16.	EE641	VLSI Signal Processing	3	1	4
17.	EE642	SoC Design and Verification	3	1	4
18.	EE643	Digital Interface Design	3	1	4
19.	EE644	MIMO Communications	3	1	4
20.	EE645	Advanced Digital Signal Processing	3	1	4
21.	EE646	Advanced Simulation Techniques	3	1	4
22.	EE647	RF Photonics	3	1	4
23.	EE648	VLSI Fabrication Technology	3	1	4
24.	EE649	Introduction to Electronics Systems	3	1	4
25.	EE623	Semiconductor Devices	3	1	4

Detailed Contents

Course Name: MICROWAVE ENGINEERING
Course Code: EE601

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, dBμ.

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 determine the standing wave ratio and Reflection coefficient
4.	Functions of multi-hole directional coupler by measuring the following parameter a) Main line and Auxiliary line SWR b) Coupling factor and directivity c) Study of magic tee d) Study of circulator / Isolator **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

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, 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 • Period gram power spectral estimation technique • PSD through correlogram technique • Spectrogram analysis
4.	Model based power spectral estimation techniques 1. AR Model , MA Model, ARMA Model 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 a) FIR & IIR Filters
7.	High Resolution pseudo-spectral estimation technique via a) MUSIC & ESPRIT
8.	Design of Quadrature Mirror Filters (QMF)

Course Name: WIRELESS AND MOBILE COMMUNICATIONS
Course Code: EE603

UNIT-I: WIRELESS COMMUNICATIONS AND DIVERSITY: Fast Fading Wireless Channel Modeling, Rayleigh/Ricean Fading Channels, BER Performance in Fading Channels, Diversity modeling for Wireless Communications, BER Performance Improvement with diversity, Types of Diversity – Frequency, Time, Space

UNIT-II: BROADBAND WIRELESS CHANNEL MODELING: WSSUS Channel Modeling, RMS Delay Spread, Doppler Fading, Jakes Model, Autocorrelation, Jakes Spectrum, Impact of Doppler Fading

UNIT-III: CELLULAR COMMUNICATIONS: Introduction to Cellular Communications, Frequency reuse, Multiple Access Technologies, Cellular Processes - Call Setup, Handover etc., Teletraffic Theory

UNIT-IV: CDMA: Introduction to CDMA, Walsh codes, Variable tree OVSF, PN Sequences, Multipath diversity, RAKE Receiver, CDMA Receiver Synchronization

UNIT-V: OFDM: Introduction to OFDM, Multicarrier Modulation and Cyclic Prefix, Channel model and SNR performance, OFDM Issues – PAPR, Frequency and Timing Offset Issues

UNIT-VI: MIMO: Introduction to MIMO, MIMO Channel Capacity, SVD and Eigen modes of the MIMO Channel, MIMO Spatial Multiplexing – BLAST, MIMO Diversity – Alamouti, OSTBC, MRT, MIMO - OFDM

UNIT-VII: UWB (Ultra wide Band): UWB Definition and Features, UWB Wireless Channels, UWB Data Modulation, Uniform Pulse Train, Bit- Error Rate Performance of UWB

UNIT-VIII: 3G AND 4G WIRELESS STANDARDS: GSM, GPRS, WCDMA, LTE, WiMAX

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. Mobile Wireless Communications – Mischa Schwartz – Cambridge University Press.

LIST OF EXPERIMENTS:

Sr. No.	**Experiments**
1.	Error Vector Magnitude Measurement for GSM Signal **Objective** 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**

	i) To measure the channel power of a CDMA modulated RF signal using an oscilloscope and the VSA software ii) To perform an in-band limit test or spectrum emission mask test on a CDMA modulated spectrum
3.	Spectrum Analysis of GSM Signal **Objectives** i) To measure the spurious and harmonics of the GSM and CDMA modulated RF signal using an oscilloscope and the VSA software 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** i) To measure the occupied bandwidth of a GSM and CDMA modulated RF signal using an oscilloscope and the VSA software ii) To determine the parameter that changes the occupied bandwidth
5.	Adjacent Channel Power Ratio Measurement for GSM and CDMA Signals **Objective** 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 **Objective** 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

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 P_d, Probability of False Alarm P_{FA} and Relation between P_d, P_{fa} and SNR–statistical phenomenon of Noise. Target characteristics– RCS, RCS fluctuation, Swirling Models, SNR deviation for fluctuating targets,

UNIT-V: CLUTTER – Ground/Surface, Sea lutter, 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.

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

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

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
4. **Inertial Navigation:** Inertial-Frame Navigation Equations, Earth-Frame Navigation Equations, Local-Navigation-Frame Navigation Equations, Navigation Equations Precision, Initialization and Alignment, INS Error Propagation, Platform INS, Horizontal-Plane Inertial Navigation.
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.HofmannWollenhof, 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	Singlesatellite-waveform	• Simulatesinglesatellitewith C/A codeforGPS, IRNSS,GLONASS, Galileo,Beidou,SBAS(shouldincludeGAGAN)and QZSS • Specifythefrequencychannel, dynamic
2	Multi-satellitewavefo rm	• Simulatemulti-satellitesignals • ConstellationfromGPS,GLONASS,QZSS,Galileo,Beidou
3	GPS,GLONASS, Galileo,Beidou,SBA SandQZSS real-time signal generation	• Simulateupto 15line-of-sightsatellitesforeach constellation:GPS L1C/A, GLONASS L1C/A,or Beidou B1,Gailleo,SBAZ,QZSS • Providereal-timecontrolforindividualsatellites,including satelliteon/off,absoluteorrelative satellitepower,adding multipath,andapplying a pseudo-rangeerror.
4	Scenariogenerationa nd editing	• Createcustomscenarioswithyourchoiceof location, date,time, andduration foreitherstaticandmoving receivers
5	Satellitebaseda ugmentationsys tem(SBAS)	• SBASmessage editorto configure the SBAS messageforPRNMask,FastCorrection,FastCorrectionDegra dation Data Factor,NetworkTime,GP Mask,LongTermCorrection and IonosphereCorrection
6	Real-timeCWinterfe rence	• ShouldsupportaddingmultipleCWinterferencesignal to real-timeGNSSsignals withinGPS,GLONASS orBeidou bands.

7	Real-time display	• Displaythe locationof each satellite insky-view to getreal-timeupdate ofthesatelliteasits azimuth/elevation changesintime. • Bar viewof real-timesatellitepowerforallvisibilesatellites. • Real-timereceivertrajectoryview todisplaythe historytrajectoryofthe playing scenariowithdetailed informationonUTC,longitude,latitude,altitude,headingandvel ocity.

Course Name: STATISTICAL SIGNAL PROCESSING
Course Code: EE606

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, 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: RECURSIVE LEAST-SQUARES ALGORITHMS FOR ARRAY SIGNAL PROCESSING.

QR Decomposition for Least-Squares Estimation. Gram-Schmidt Orthogonalization for Least-Squares Estimation. Givens Algorithm for Time-Recursive Least-Squares Estimation. Recursive Least-Squares Estimation Based on the Householder Transformation. Order-Recursive Least-Squares Estimation Algorithms. Summary and References. Problems.

UNIT VI: POWER SPECTRUM ESTIMATION.

Estimation of Spectra from Finite-Duration Observations of Signals. Nonparametric Methods for Power Spectrum Estimation. Parametric Methods for Power Spectrum Estimation. Minimum-Variance Spectral Estimation. Eigenanalysis Algorithms for Spectrum Estimation. Summary and References. Problems.

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.

REFERENCE BOOKS:

Optimum signal processing: An introduction - Sophocles.J.Orfamadis, 2 ed., 1988, McGraw-Hill, Newyork

1 Adaptive signal processing-Theory and Applications, S.Thomas Alexander, 1986, Springer –Verlag.

2 Signal analysis – Candy, Mc Graw Hill Int. Student Edition

3 James V. Candy, Signal Processing : A Modern Approach, McGraw-Hill, International Edition, 1988.

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	Simulation of Adaptive BFSK, BPSK, ASK modulators and demodulators.
2.	Simulation of delay estimation
3.	Simulation of Adaptive Beam forming, concept of IQ channels and Adaptive filter
4.	Simulation of MUSIC algorithm

Course Name: DETECTION AND ESTIMATION THEORY
Course Code: EE607

UNIT-I: REVIEW OF VECTOR SPACES: Vectors and matrices: notation and properties, orthogonality and linear independence, bases, distance properties, matrix operations, eigen values and eigenvectors.

UNIT-II: PROPERTIES OF SYMMETRIC MATRICES: Diagonalization of symmetric matrices, symmetric positive definite and semi definite matrices, principal component analysis (PCA), 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, Bayes' criterion of signal detection, 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.

UNIT-VII: SPECIALIZED TOPICS IN ESTIMATION: Spectral estimation methods as MUSIC, ESPIRIT, DOA Estimation.

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 1. Constant amplitude Signal in AWGN 2. Time varying Known Signals in AWGN 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

Unit-1: Wireless Communications and Diversity:
Multipath Propagation, Wireless Channel Modeling – Passband/ Baseband, Fading Nature of the Wireless Channel, Rayleigh Fading Wireless Channel, Probability Density Function of Amplitude and Phase, Bit Error Rate (BER) Performance in AWGN Communication Channel - Analysis, BER Performance in Fading Wireless Channel – Analysis, Deep Fade Phenomenon in Wireless Channels, Diversity in Wireless Systems Multiple Antenna Wireless Systems, System Model, Optimal Receiver Combining – MRC Derivation, SNR Performance, BER Performance with Diversity – Analysis, Diversity Order, Types of Diversity: Antenna, Frequency, Time; Antenna Spacing Requirement, Deep Fade Analysis with Diversity,

UNIT-2: Wireless Channel Modeling:

RMS Delay Spread, Max Delay Spread, Inter Symbol Interference, Coherence Bandwidth – Flat versus Frequency Selective Fading, Mobility - Doppler Shift and Channel Modeling, Jakes Model, Autocorrelation Function, Jakes Spectrum,

UNIT-3: CDMA Technology:
Introduction to CDMA - Walsh codes, Orthogonality, PN Sequences, Generation using LFSR, Properties of PN Sequences, Advantages of CDMA – Jammer Rejection, Graceful Degradation, Universal Frequency Reuse, Multipath diversity, RAKE Receiver, CDMA for Multi-User Systems with Interference,

UNIT-4: OFDM:
Introduction to Multicarrier Modulation (MCM) and OFDM, Sampling MCM Signal, IFFT Generation and Cyclic Prefix, OFDM System Model, IFFT/ FFT Transceiver Model, OFDM - SNR and BER performance, Multi-user OFDM, OFDMA Systems for UL and DL, SC-FDMA

UNIT-5: Multiple Input Multiple Output (MIMO) Technology:
Introduction to 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, Optimal Waterfilling Power Allocation, MIMO Diversity – Alamouti, Orthogonal Space-Time Block Codes (OSTBC), MIMO Beamforming – Maximum Ratio Transmission (MRT), MIMO-OFDM System Model and Analysis, Multi-user MIMO – Block Diagonalization, Successive Optimization

UNIT-6: Wireless Standards:
Introduction to LTE, LTE-A Standards and Technology Specs,

UNIT-7: 5G Technology:
Introduction to 5G Wireless Technologies – Massive MIMO, mmWave, NOMA, FBMC and Full Duplex

TEXT BOOKS:

1. Andrea Goldsmith, Wireless Communication, Cambridge University Press
2. Tse, David and Viswanath, Pramod, Fundamentals of Wireless Communication, Cambridge University Press (2006).
3. Aditya Jagannatham, Principles of Modern Wireless Communication Systems, McGraw Hill, (2016)

REFERENCE BOOKS:

1. Theodore Rappaport, —Wireless Communications, principles and Practices, 2nd Edition, Pearson.163
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, *Proceedings of the IEEE,* 2014.

Course Name: ANTENNA SYSTEMS
Course Code: EE609

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 -Schelkunoffand 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 -BrooknerTheorm, 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, ,JanetRF 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 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, radiation pattern, E-palne and H-plane etc.)
3.	Radiation pattern measurement using DAMS controller and their connectivity to the antenna positioner inside the anechoic chamber and to the VNA.
4.	Measure and understood the antenna software which support to VNA, Antenna positioned and DAMS 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

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.

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

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: OPTIMUM BEAMFORMING AND DIRECTION OF ARRIVAL ESTIMATION
Time delay beamforming, frequency domain beamforming, optimum beamformers: MVDR, MPDR, MMSE, Max SNR, LCMV, LCMP, GSC, mismatched beamformer, eigenvector beamformer, beamspace beamformer, broadband beamformer, adaptive beamformers: LMS and RLS. DoA estimation: ML, MAP, MUSIC, ESPRIT, for uncorrelated, correlated and coherent signals.

UNIT – IV: SPACE-TIME ADAPTIVE PROCESSING (STAP)
Introduction to STAP, and STAP techniques.

UNIT-V: COMPRESSED SENSING AND SPARSE SIGNAL PROCESSING
Introduction to CS, sparse representations: motivations and basic formulations, uniqueness of sparserepresentation. Measurement matrices: null space property, Restricted Isometry Property (RIP), JohnsonLindenstrauss Lemma, Random Matrices and RIP. Reconstruction algorithms: convex optimisation 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/Simulink, Lab view and its tool boxes to simulate spatially coherent signals in the presence of spatially and temporally correlated/uncorrelated noise (Simulation of Received Array Data Vector)
2	Target Signal & Ambient Noise Simulation (Scalar & Vector Sensor Array Data Vector Simulation): Generation of Multiple spatial targets in presence of Strong interferences and Additive Correlated/Uncorrelated, White/Colored Ambient Noise
3	Development of following Direction Of Arrival (DoA) estimation techniques 1. Convential Beam former Via Delay & Sum technique (Wideband Spatial Filter) 2. Convential 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:- MVDR, MPDR ,MUSIC, ESPRIT, Subspace Intersection Method (SIM), Generalized Side lobe Cancellation (GSC) Beam former
5	Performance comparison of Conventional (Lab3) and High resolution Adaptive beam formers (Lab4) in the presence of strong interferences and Spatially Correlated Noise
6	Real time demonstration – Direction of Arrival estimation of an acoustic source using 8 element microphone array hardware.

Course Name: HIGH POWER MICROWAVE SYSTEMS
Course Code: EE612

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 Edl Schamiloglu ,High Power Microwave, CRC Press.
2. A. V. Gaponov-Grekhov, ,Victor L. GranatsteinApplications 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, ,A.D.R. PhelpsGeneration and Application of High Power Microwaves, CRC Press.

Course Name: ELECTRONIC WARFARE
Course Code: EE613

UNIT-I: INTRODUCTION TO ELECTRONIC WARFARE: Electronic Defence, Electronic Combat (ESM-ECM-ECCM), Radar Basics (Radar Technology Evolution, Radar Range Equation, RCS Reduction, Counter-Low Observable), SIGNIT, Intercept System Characteristics and Functions, Frequency Coverage, Analysis Bandwidth, Wideband Radar Signal Trends, Dynamic Range, Dynamic Range Requirements, Sensitivity, Noise Figure Measurement, Y-Factor Measurement, Some Sensitivity Measures, Output SNR and Receiver Applications, Threshold Detection, Sensitivity and the Received Pulse Density, The Ultimate Limits to ELINT Parameter Measurements, Probability of Intercept.

UNIT-II: ELECTRONIC SUPPORT MEASURES: Typical ESM Systems, ESM Sensitivity, ESM 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, Infrared Countermeasures (IRCM), Off-Board ECM Systems, Communications Countermeasures (COM-ECM), Electro-Optic Counter Measure (Eocm) Systems¸ Airborne Tactical Jamming System, Shipboard Self-Defense System, EA/Susceptibility against Weapon Systems.

UNIT-IV: ELECTRONIC COUNTER-COUNTERMEASURES: Search Radar Counter-Countermeasures, Tracking Radar Counter-Countermeasures, Infrared Counter-Countermeasures, Communications Counter-Countermeasures.

UNIT-V: NEW ELECTRONIC DEFENSE TECHNIQUES: New Electronic Defense Techniques and Technologies trend, Shared Apertures/MRFS, Anti Anti-Radiation Missile Techniques, Anti-Stealth Techniques, RF Direct Energy Weapons, Design and Evaluation Criteria: Design Criteria, Evaluation Criteria for the Choice of a System, Operational Effectiveness, Electronic Defense and Conventional Defense, Electronic Warfare Digitization.

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 technique using Watson-Watt Technique
4.	Location Estimation technique using GPS Receivers
5.	Simulation of Wideband and Narrow band Receivers

Course Name: EMI/EMC DESIGN
Course Code: EE614

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, Radiated. Common Mode and Ground Loop Coupling Radiated Differential Mode Coupling, Near Field Cable to Cable Coupling, Power Mains and Power Supply Coupling.

UNIT-II: EMI SPECIFICATIONS AND STANDARDS: Units of specifications, Civilian standards (CISPER, FCC, EN, IEC), Military standards -MIL-STD-461E, MIL-STD-1385, RADHAZ, HERO, NEMP.

UNIT-III: EMI TESTS AND MEASUREMENTS: 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.

UNIT-IV: EMI CONTROL TECHNIQUES: Shielding, Filtering, Grounding, Bounding, Isolation Transformer, Transient Suppressors, Cable Routing, Signal Control, Component Selection and Mounting.

UNIT-V: EMC DESIGN OF ELECTRONIC SYSTEMS: EMC requirements for Electronic Systems, System Design for EMC, PCB Traces Cross Talk, Impedance Control, Power Distribution Decoupling, Zoning, Motherboard Designs and Propagation Delay Performance Models.

UNIT-VI: ELECTROMAGNETIC RADIATION HAZARDS: Biological Effects of EMR, Thermal and Non-Thermal, Comet Assay, Electrophoresis, Prediction and Analysis of EMR Hazards, Mitigation Techniques.

UNIT-VII: EMC MANAGEMENT CONCEPTS [E(MC)^2]: Electromagnetic Environmental Effects (E3) Management, Spectrum Supportability (SS), E3 and SS policies- plans- and programs at the executive and working levels(program/project management), Spectrum Management, 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 (source- http://www.emcmanagement.com/)

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,***2nd Ed.***, 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.
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).
5. Electromagnetic compatibility management guide for platforms, systems and equipment, Standard Handbook, 1981 - Science - 125 pages, Pennsylvania State University.

LIST OF EXPERIMENTS:

Sr. No.	Experiments
	FieldFox and Spectrum Analyser
1.	Digital Pulse Spectra and Rise Time Measurement **Objective** i) To investigate the relationship between the rise/fall time of a digital signal and its frequency spectrum
2.	Controlling Crosstalk: Frequency-Domain Perspective **Objectives** i) To measure crosstalk in the frequency domain ii) To investigate the factors affecting the crosstalk level
3.	Controlling Crosstalk: Time-Domain Perspective **Objectives** i) To measure crosstalk in the time domain ii) To investigate the factors affecting the crosstalk level
4.	Controlling Common Impedance Coupling **Objectives** i) To illustrate the effect of power supply noise on sensitive circuits ii) To illustrate the usage of decoupling capacitors and printed circuit board (PCB) layout in reducing power supply noise
5.	Controlling Radiated Emission from Cable and PCB **Objectives** i) To observe the frequency spectrum of the near-field electromagnetic (EM) radiation from cables and printed circuit board (PCB) traces using a near-field probe and spectrum analyzer ii) To learn some simple methods to reduce unwanted radiation using ferrite beads, grounding, and differential signaling
6.	Transfer Impedance Measurement **Objectives** i) To measure the transfer impedance of a coaxial cable as a function of frequency ii) To understand the importance of transfer impedance as a gauge of the shielding capability of a cable
7.	Measure the EMI using EMI test receiver, LISN, EMI software's etc
8.	Measurement of frequency ranges of various EMI/EMC antennas and there various test range comparison to MIL-STD-461F
9.	Different probes of EMI/EMC used to measure the EMI (for H-field, E-field), which is present in the various electronic circuits and their frequency of operations.
10.	To measure and verify the EMI present in the RADAR circuits/KITS

Course Name: GNSS RECEIVER DESIGN AND APPLICATIONS
Course Code: EE615

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

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

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: concept 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, gen-nav

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

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 CityGML, 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, FastSLAM, 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 Multisensor 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, new York, 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

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.

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”, Hüseyin Arslan, 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

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 micro processor,micro controller,DSP processors,Tesla parallel computing hardwares .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, inter connections
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:

5. ARM System-on-Chip Architecture (2nd Edition) Steve Furber.
6. Real-time digital signal processing: Based on the TMS320C6000, Nasser Kehtarnavaz .
7. Advanced FPGA Design: Architecture, Implementation, and Optimization, Steve Kilts, IEEE press Wiley 2007.

REFERENCE BOOKS:

4. http://www.xilinx.com/publications/xcellonline: Xcell Journal.
5. DSP Architecture, Programming and Application- B Venkataramani, M Bhaskar.
6. 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

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, Magnetoresistive 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

UNIT I 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 II MIXERS:
Balancing Mixer - Qualitative Description of the Gilbert 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 Switching 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 III 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 IV UB SYSTEMS:
Data converters in communications, Power amplifiers, Adaptive Filters, Equalizers.
Transceivers- system level considerations, Receiver design, transmitter design, and synthesizer design.

UNIT V 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 and Power Amplifier using ADS Software.
5	Simulation of Mixer using ADS Software.

Course Name: SEMICONDUCTOR DEVICES
Course Code: EE623

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, carrierlifetime, 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, I-Vcharacteristic, steadystate and transient conditions, capacitance model, reverse-bias breakdown,metal-semiconductor 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, C-Vcharacteristics – low and high frequency; the MOSFET – fabrication, operation, gradual channel approximation,simple charge control model (SCCM), I-V characteristic, second ordereffects – 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, highfrequency response, back gating effect, HEMTs – fabrication, modulation (delta) doping, analysis ofIII-V heterojunctions, charge control, I-V characteristics, SPICE model.

UNIT IV: **BJTs and HBTs;**

Fabrication, basic operation, minority carrier distributions and terminalcurrents, I-V characteristic, switching, second-order effects – base narrowing, avalanche multiplication, highinjection, emitter crowding, Kirk effect, etc.; breakdown, high-frequency response, Gummel-Poon model, SPICEmodel; HBTs: - fabrication, basic operation, technological aspects, I-V characteristics, SPICE model.

Unit V: Roadmap for Next GenerationField 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. Large signal and small signal modeling of PN Junctions
2	Schottky diode implementation in SPICE2
3	MOS Capacitor modeling in SPICE 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

UNIT IDigital 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 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.

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 VContemporary 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.

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 1. To understand use of Xilinx ISE 2. To understand Xilinx Synthesis Technology or XST. 3. Familiarization of Xilinx Vivado Design Tools.
02.	Familiarization of FPGA Boards 1. Xilinx FPGA Boards (Virtex 6,Kintex7) 2.Implementation of Full adder, ALU , Memory and FIFO on FPGA
03.	Fault Detection Logic Implementation on FPGA 1. Stuck at Fault 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

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 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.

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 MicroBlaze 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. 1. To understand use of Xilinx System Generator. 2. To understand Xilinx Synthesis Technology or XST. 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. 1. Familiarization with Memory Blocks implementation in FPGA. 2. To Understand FGPGA Hardware. 3. Familiarization of XUP board (Vertex-5).
03.	Implementation of M Code Adder in FPGA 1. This exercise provides an introduction to the integration of M Code into a System Generator System. 2. To understand functionality of a basic 2-input adder is interpreted from the M-code.
04.	Generation of Simulink System Period 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

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. a. Basic Pursuit b. Matching Pursuit, c. Orthogonal Matching Pursuit, d. Subspace Pursuit, e. Compressive Sampling Matching Pursuit.

Course Name: SIGNAL THEORY, LINER ALGEBRA & TRANSFORM TECHNIQUES
Course Code: EE627

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: a) Transform Techniques b) Z Transform c) Fourier Transform 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

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; Borivoje Nikoli´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. Aim: 1.To understand the Various modeling such as a)data flow modeling b)behavioural modeling C)Structural modeling of VHDL. 2.Writing the test bench to create various stimulus for the DUT.
02	Implement the Booth Multiplier using structural modeling in FPGA. Aim: 1. To understand the Structural modeling of VHDL. 2.To understand the wordlength effects. 3.To understand the use of Xilinx ISE 16.1. 4.Hands on experience in SPARTAN 3E FPGA kits.
03	Implement a Traffic Light controller using Mealy Machine in FPGA. Aim: 1. To understand the Mealy State machine. 2. To understand the use of Xilinx ISE 16.1. 3.Hands on experience in SPARTAN 3E FPGA kits
04	Implement a Sequence Detector using Moore machine in FPGA. Aim: 1. To understand the Moore State machine. 2. To understand the use of Xilinx ISE 16.1. 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 and logical operations. Aim: 1. To understand the mixed modeling styles of VHDL. 2. To understand the use of Xilinx ISE 16.1. 3. Hands on experience in SPARTAN 3E FPGA kits.

Course Name: SONAR SIGNAL PROCESSING
Course Code: EE 629

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 1. Conventional Beam former Via Delay & Sum technique (Wideband Spatial Filter) 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 Passive Sonar performance with & without STAP.

Course Name: SONAR SYSTEM ENGINEERING
Course Code: EE630

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, Delay-and-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

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.Suyder Hond 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

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

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, ZhaohuiWang, "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, ZhaohuiWang, "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

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 Transformers
2.	S-parameter analysis of : a) Power dividers b) Branch line couplers c) Rat race
3.	Filter design: Lumped to Micro strip Line transformation a) Low pass filter b) High Pass Filter c) Band Pass Filters d) Band Stop Filter
4.	Amplifier Design and Stability Analysis (Simulation using ADS/Matlab) a) Region of operation analysis b) Gain analysis c) Stability analysis using Smith Chart 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

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, Somnath Puri 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

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, Walfred Fried,"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 a. Amplitude Modulation, Frequency Modulation, Phase Modulation. b. Amplitude Shift keying, Frequency Shift Keying, Phase Shift keying.
6.	Study of Sampling and Reconstruction of signals
7.	Study of signal sampling and Reconstruction Techniques

Course Name: ASIC VERIFICATION USING SYSTEM VERILOG
Course Code: EE637

Maximum Marks – 100; Credits - 3

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” Meyyappan Ramanathan

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. 2. Write an example to demonstrate the static array, multi-dimensional static array, dynamic array, associative array and queue type array. 3. Write an example to demonstrate a simple interface.
2	1. Write an example to demonstrate class constructor, inheritance, encapsulation, and polymorphism. 2. Write an example to demonstrate randomization, rand casec, rand sequence, rand sequence abort. 3. Write an example to demonstrate DPI (Direct Programming Interface), both sv to c and c to sv. 4. Write an example to demonstrate semaphore, mailbox, virtual interface
3	1. Create SV based test environment for 1-bit adder. 2. Create class based test environment for 1-bit adder
4	1. Create a class based test environment for RAM memory given. 2. Create a class based test environment for FIFO memory given.
5	1. Create coverage and assertions for decade counter. 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

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 follower-Common 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 ADC-Pipeline 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. Vineetha P.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, Anantha Chadrakasan, 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

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", Addison-Weseley 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 1. Inverter 2.NAND GATE 3.Full adder 4.4 bit adder 5.4 bit counter
2	Modeling and Simulation of ALU using Verilog. 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 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

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

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 1) FIR 2)IIR
2	RTL Modelling and testing of 8 point FFT algorithm. 1) Serial architecture implementation 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

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 SystemOnAChip 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 Rajsuman, 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 a) Memory b) Clock Divider and Address Counter c) n-Bit Binary Counter and RTL Verification
2	Basic Verification environment for FIFO/UART
3	Verification Planning for FIFO/UART a) Development of the test cases as per the verification plan 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*

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 convetors 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 CompactRIO 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 a) LCD b) ADC
2	Motor Control and interface using PSoC
3	Case Study- underwater Glider and line follower Robot.

Course Name –*MIMO COMMUNICATIONS*
Course Code- *EE 644*

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*

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 – VijayK.Madisetti and Douglas B. Williams
4. DSP – A Practical Approach – Emmanuel C. I feacher, 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 –*ADVANCED SIMULATION TECHNIQUES*

Course Code- *EE 646*

UNIT-I: INTRODUCTION TO PROGRAMMING IN MATLAB

Introduction, writing program, running, and debugging. Programming: conditional statement, looping statement, inbuilt functions, plotting, retrieving and storing data.

UNIT-II: INTRODUCTION TO SIMULINK

Introduction, using SIMULINK for modelling, inbuilt functional blocks, building own blocks.

UNIT-III: SIMULATION OF COMMUNICATION TECHNIQUES

Analog Communication: AM, FM, PM, Digital Communication: ASK, PSK, FSK, QPSK, and QAM, OFDM modelling, MIMO Modelling.

UNIT-IV: SIMULATION OF SIGNAL PROCESSING TECHNIQUES

Signal generation, rate conversion, spectrum estimation, filter design, convolution, correlation, FFT, case study of SP application.

UNIT-V: SIMULATION OF ARRAY SIGNAL PROCESSING TECHNIQUES

Spatial signal generation, uniform linear array, uniform planar array, conventional beam forming, adaptive beam forming, DoA estimation.

UNIT-VI: SIMULATION OF RADAR SIGNAL PROCESSING TECHNIQUES

Radar waveform generation, pulse compression, MTI, pulse integration, CFAR, doppler estimation, angle estimation.

UNIT-VII: SIMULATION OF IMAGE PROCESSING TECHNIQUES

Image representation, reading image, feature extraction, image manipulation, storing image.

REFERENCE BOOKS:

1. Digital Signal Processing: A Computer Based approach - S.K. Mitra, 3rd Ed., Tata McGraw Hill.
2. Digital Signal Processing: Principles, Algorithms & Applications - J. G. Proakis & D. G. Manolakis, 4th Ed.,PHI.
3. Discrete Time Signal Processing - Alan V Oppenheim & Ronald W Schaffer, PHI.
4. An Introduction to Digital Signal Processing: A Focus on Implementation - Stanley H. Mneney, University of KwaZulu-Natal, Durban, South Africa.

Course Name: RF PHOTONICS

Course Code: EE647

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, Opticallycontrolledphasedarrayantennas.

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 digitalisations, optical vector mixing, RF down conversion, Photonic-assisted microwavechannelization (SDM,WDM, TDM), far-field/near-field AoA measurement, UltraWidebandfreespacebeamforming, 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, PhaseNoise, SpectrumAnalysis, InstantaneousFrequency, IF based microwave/optical power monitoring, Multiple-Frequency Measurement Based on Frequencyto-Time Mapping, DopplerFrequencyShiftEstimation, measurements of other signalparameters (Time–frequency analysis, Compressive sensing for a spectrallysparse signal), Software-defined solutions for photonicmicrowave 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-ConnectedDistributedRadarSystem, Distributed MIMO chaotic radar based on WDM technology, MicrowavePassiveDirectionFinding, 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

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 epitaxialgrowth, 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 ofMicroelectronic 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, SpectroscopicEllipsometry Measurement,.

Course Name: Introduction to Electronics systems
Course Code: EE649

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.

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

Department of Applied Chemistry

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. & M.Sc 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 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 Materials Science and Chemical Technology

(CHEMICAL SCIENCE AND TECHNOLOGY)

Semester I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	AC-601	Chemistry for Chemical Technology	3	1	4
2	AC-602	Polymer Science & Technology	3	1	4
3	AC-603	Thermodynamics and Combustion Process	3	1	4
4	AC-604	Chemical Process Design	3	1	4
5	AC-605	Advanced Analytical Techniques	3	1	4
6	AM-607	Mathematics for Engineers	3	1	4
		Total	**18**	**6**	**24**

Semester II

Sl. No.	Course Code	Course	Contact hours/week		Credits
			L	T/P	
1	AC-606	Chemical Reaction Engineering	3	1	4
2	AC-607	Nano-chemical technology	3	1	4
3		Elective – I [From Dept. of Applied Chemistry]	3	1	4
4		Elective – II [From Dept. of Applied Chemistry]	3	1	4
5		Elective – III	4	-	4
6		Elective – IV	4	-	4
		Total	**20**	**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	AC-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	AC-652	M.Tech. Dissertation Phase II	28		14
		Total	**28**		**14**

List of Electives/ Self Study

Sl. No.	Course Code	Course Name
1	AC-608	Safety, Health and Hazard management
2	AC-609	NBC Warfare (Concepts & remediation)
3	AC-610	Advances in Chemical Technology
4	AC-611	Environmental Science & Technology
5	AC-612	Technology of paints, pigments and varnishes
6	AC-613	Explosives and Pyrotechniques
7	AC-614	Rocket and Gun Propellants
9	AC-615	Surfactant Technology
10	AC-616	Catalytic Processes
11	ME-654	Advanced Heat And Mass Transfer
Courses offered in Applied Chemistry or other Departments		

AC-601 : CHEMISTRY FOR CHEMICAL TECHNOLOGY

Unit 1: Introduction to Chemical Technology: Bulk Chemicals, Fine Chemicals, etc.
Unit 2: **Chemistry of air sensitive compounds & chalcogens:** Electron deficient compounds, 18 e rules, S, Se, Te and their organic/inorganic compound e.g. alkyl/metal chalcogenides.
Unit 3: Chemistry of energetic compounds: Synthetic methods of advanced energetic compounds & their properties.
Unit 4: Biochemical Processes: Fermentation processes
Unit 5: Specialty Chemicals: Hydrazines, nitrogen rich compounds, bulk solvents, etc.
Bulk Chemicals:
Unit 6: Medicinal Chemistry: Introduction, Drug Chemistry, Bio-molecules, Antimicrobial properties
Unit 7: Technology of Dyes: Introduction, Types of Dyes, Application, Toxicity and Treatment, Speciality dyes.
Unit 8: Chemistry of Natural Products & Industrial Applications: Types of Natural products, Extraction, Analysis, Industrial applications.

TUTORIALS/ PRACTICALS/ SEMINARS:

- Detection of toxic elements in waste effluents by use of ion chromatography and absorption spectroscopy
- Synthesis of Energetic chemicals

TEXT/REFERENCES:-

1. *Inorganic Chemistry: Principles of Structure and Reactivity, J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi, Pearson Education, (2006).*
2. *Organic Synthesis, 3rd Edition, M.B. Smith, Academic Press, (2006).*
3. *The Organic Chemistry of Drug Design and Drug Action, R. B. Silverman, Elsevier, 2004*
4. *Chemical and Biochemical Reactors and Process Control, J. Metcalfe Coulson, John Francis Richardson, D. G. Peacock, Butterworth Hieneman, 2007*
5. *Speciality Chemicals: Innovations in Industrial Synthesis and Applications, B. Pearson, Elsevier Science Publisher, 1991*.

AC-602: POLYMER SCIENCE & TECHNOLOGY

Unit 1: Introduction to polymer chemistry: Definition, classification and characteristic, Condensation and addition polymers, Rubber, Elastomer & Properties of Polymers (Thermal, Electrical etc.)
Unit 2: Advanced Polymers: Conducting Polymers, Photoactive Polymers, Thermoplastic and Thermosetting polymers
Characterization of polymers:
Unit 3: Polymer blends: Polymer networks, gels, processing and application of blends,
Unit 4: Functional polymers: Composite formulation, electronics application, textiles, foul release, impact, adhesion, sealing, energy storage, energy devices, microwave / EMI shielding etc.

Unit 5: Polymers for defence applications: Kevlar, HTPB, EPDM etc.
Unit 6: Bio, Biodegradable and Biomedical polymers: Natural and synthetic biodegradable polymers, catalytic biodegradation, chitosan and polylactic acid based copolymers
Unit 7: Polymers for commercial applications: Acrylics, nylon, polycarbonate, polyamides, polyesters, nano-composites
Unit 8: Degradation Techniques & degradation of polymers
Unit 9: Polymer based devices

TUTORIALS/ PRACTICALS/ SEMINARS:

- Thermogravimetric analyses of polymers (degradation)
- Polymers film casting and its analysis by IR and UV-Visible spectroscopy

TEXT/REFERENCES:-

1. *Polymer Science & Technology (2nd Ed) by Joel R. Fried, Prentice Hall, 2014*
2. *Thermal Analysis of Polymers, fundamentals & application by Joseph D.Menczel& R. Porne Prime, Wiley, 2009.*
3. *Industrial Polymers, Specialities Polymers and their applications, Manas Chanda, Salil K. Roy, Series Editor: Donald E. Hudgin,CRC Press.*
4. *Polymer Chemistry & Physics of Modern Materials by JMG Cowie, CRC Press.*
5. *Text Book of Polymer Science by Billmeyer, John Wiley & Sons, 1984.*
6. *Introductory Polymer Chemistry, Gauri S. Misra New Age International Ltd., 1993.*
7. *Polymer by Vasant R. Gowariker, N. V. Viswanathan, JayadevSreedhar, New Age International (P) Ltd., New Delhi.*
8. *Principles of Polymerization, George Odion.*
9. *Polymers , Reynolds & Scothum*

<u>AC-603: THERMODYNAMICS & COMBUSTION PROCESS</u>

Unit 1: Introduction to Thermodynamics: Laws of thermodynamics , Cornot cycle.
Unit 2: Basics of Combustion
Unit 3:General equations of equilibrium: Vapor - liquid equilibrium in miscible Binary and multicomponent systems, methods for equilibria in complex multireacton systems, Homogeneous Closed Systems, Homogeneous Open Systems, Equilibrium in a Heterogeneous Closed System,
Unit 4: Thermodynamics of solutions: Gibbs-Duhem equation, The Phase Rule, The Chemical Potential, Activity and Activity Coefficient, Calculations of flash point, isobaric X-Y diagrams, Modified Raoults Law Group contribution methods for activity coefficients.
Unit 5: Azeotropy: Vapor-liquid equilibria in systems with partially miscible liquid phase. Liquid - liquid equilibria.
Unit 6: Combustion: An introduction, thermodynamics of combustion chemistry, combustion chemistry modeling combustion instability, flame, Combustion of solid rocket propellants, liquid propellants

Unit 7: Chain reaction or specific reactions: Hydrogen-oxygen, carbon monoxide oxidation, hydrocarbon oxidation

TUTORIALS/ PRACTICALS/ SEMINARS:

- Thermal properties of materials e.g. Polymers, organic compounds and nanocomposites (Thermo Gravimetric Analysis)
- Simulation studies of thermal properties of propellants and explosives

TEXT/REFERENCES:-

1. *Concise Chemical Thermodynamics, A.P.H. Peters, CRC Press, 2010*
2. *Basic Chemical Thermodynamics, E Brian Smith, World Scientific Publishing Company, 2004*
3. *Propellants & Explosives: Thermo chemical aspects of combustion, N.Kubota,Wisley VCH, 2002.*

AC- 604: CHEMICAL PROCESS DESIGN

Unit 1: Operation
Unit 2: Screening of processes and analysis: The nature of process synthesis and analysis, Product life cycle, Cost diagrams and quick screening of process alternatives
Unit 3: Membrane based separation systems: Equilibrium & non equilibrium processes (MF, UF, RO, PV, Liquid Membranes and gas separation processes).
Unit 4: Developing a conceptual design: Finding the best flow-sheet, Input information and batch vs. continuous, Input output structure of the flow sheet.
Unit 5: Other Topics: Heat Exchanger networks; Process development for energy harvesting, Recycle structure of the flow-sheet Computational methods in process design, Case study
Unit 6: Chemical Process Safety

TUTORIALS/ PRACTICALS/ SEMINARS:

- Process designing for large scale synthesis of organic compounds/nanoparticles.
- Separation of mixtures using distillation techniques.

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)*
4. *Basic Principles of Membrane Technology (2nd Edition) by Marcel Mulder, Springer.*
5. *Conceptual Design of Chemical Processes by James Douglas, McGraw Hill.*

AC-605: ADVANCED ANALYTICAL TECHNIQUES

Unit 1: Instrumental Analysis: Qualitative analysis, genesis of instrumental analysis.
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.
Unit 4: Spectroscopy: Ultra Violet-Visible Spectroscopy UV-VIS, Infra-Red spectroscopy (IR), Nuclear Magnetic Resonance (NMR), Mass spectroscopy, Atomic Absorption Spectroscopy (AAS)
Unit 5: XRD and SEM techniques
Unit 6: Analytical techniques for defence, cal-val, sensivity studies: Types and Implementations.
Unit 7: Hyphenated Techniques.

TUTORIALS/ PRACTICALS/ SEMINARS:

- Handling and demonstration of FTIR, UV-visible spectrophotometer, Mass spectrometer, NMR spectrometer, 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)*
6. *Analysis of Explosives by Yitrin&Yinon, Pergamon Press, 1981*

AC-606: CHEMICAL REACTION ENGINEERING

Unit 1: Introduction to basic principles of chemical engineering:
Unit 2: Non-Catalytic Fluid-particle reactions: Mechanism and examples
Unit 3: Types of Reactors: Homogeneous and Heterogeneous catalyst, Design of gas – solid catalytic reactors
Unit 4: Kinetics of reactions: Kinetics of Solid Catalyzed Reactions.
Unit 5: Classification of multiphase reactors: Qualitative description, examples of industrial importance.
Unit 6: Performance of multiphase reactors: Bubble columns, packed bubble columns, sectionalized bubble columns, plate columns, internal loop and external loop air-lift reactors, jet loop fixed beds, static mixers, Solid-Liquid and Gas – Solid fluidised Beds and solid-gas transport reactors, Stirred tank reactors.

Unit 7: Micro reactors

Unit 8: Other Topics: Mass transfer with Chemical Reaction in Fluid – Fluid systems. Model contactors, pilot plants, and collection of scale-up data, Hydrodynamics, process design.

TUTORIALS/ PRACTICALS/ SEMINARS

TEXT/REFERENCES:

1. *Chemical Reaction Engineering, O. Levenspiel, John Wiley & sons*
2. *Chemical Engineering Kinetics Smith J.M., Mcgraw-Hill, New York 1970*
3. *Elements of Chemical Reaction Engineering, Scott Foggler, Prentice Hall Series, 3rd Edition.*
4. *Chemical Reactor Analysis and Design, Froment G.F., Bischoff K.B., Wiley & Sons, 2011.*

AC-607: NANO-SCIENCE & TECHNOLOGY

Unit 1: Introduction: Definition and concept- dimensionality and size dependent phenomena.

Unit 2: Nano and Mesopores materials: Chemistry of size dependent variation in nanomaterials, reactivity etc.

Unit 3: Nano-fluids: Basic chemistry of nano-fluids, preparation of nano-fluids, analysis of nano-fluids, applications of nano-fluids.

Unit 4: Characterization of Nanomaterials

Unit 5: Nanostructures: Chemistry of Quantum dots, nanowires and nanotubes, 2D films.

Unit 6: Nano-energetic materials: Introduction, nano-thermites, Advantages and examples, synthesis and thermal properties of nano-thermites.

Unit 7: Nano-catalysts: Surface chemistry of nanoparticles, examples, photo-catalysis

Unit 8: Polymer nano-composites and hybrid materials: Preparation, Characterization, Applications

Unit 9: Nanotechnology for chemical industry: Application in pharmaceuticals, Paint, Coatings, rubber and polymers.

Unit 10: Nanomaterials for Energy applications: Thermo electricity, Solar, Photonics.

Unit 11: Other Topics: Application of nanochemistry/ nanomaterials in civil and defence sector, Characterization of nanoparticles by various analytical techniques

TUTORIALS/ PRACTICALS/ SEMINARS:

- 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*
5. *Nanocrystal Quantum Dots - Edited by Victor I. Klimov, Second Edition, CRC Press (Taylor & Francis Group)*
6. *Nanocomposite Materials, Prof. Goyal*

AC- 608 : SAFETY, HEALTH & HAZARD MANAGEMENT

Unit 1: Chemical Safety: Standards and regulations of chemical safety in Industries or Laboratories, Storage of hazardous chemicals, Compatibility and classification codes, Chemical risk analysis and management, Fire triangle and Handling of Toxic, Industrial Gases

Unit 2: Hazard Management: HAZOP and HAZAN techniques, Hazard in manufacture, Hazard prevention measures, Disposal of hazardous materials, UN hazards division.

Unit 3: Warfare: Classifications of explosives based on hazards, Nuclear, biological and chemical warfare safety

Unit 4: Health: Assessment of human factors, Health & Environment safety, Nano materials safety (Toxicology study).

Unit 5: Personal Protection.

Unit 6: MSDS for known / unknown compounds.

TUTORIALS/ PRACTICALS/ SEMINARS:

- Handling & demonstration of air-sensitive, pyrophoric and toxic chemicals
- Monitoring of effluents through Gas Chromatography/Ion Chromatography

TEXT/ REFERENCES:

1. *Safety and accident prevention in chemical operations John Wiley and sons, New York, 1982*
2. *Technical guidance for hazard analysis USEPA, FEMA, USDOT, 1987*
3. *Nanotechnology Environmental Health and Safety: Risks, Regulation and Management: M. Hull, D. Bowman, Elsevier, 2010*
4. *Manual on emergency preparedness for chemical hazard, Ministry of Environment and Forest, Govt. of India, New Delhi, 1989.*

AC- 609: NBC WARFARE (CONCEPTS & REMEDIATION)

Unit 1: Introduction to Nuclear science, Types of Nuclear Radiation

Unit 2: Nuclear science: Structure of nucleus, Mass defect, Binding energy, Nuclear reaction, Fission & Fusion nuclear reactions, Controlled & uncontrolled release of nuclear energy, Concepts of critical mass & critical volume, Principle of operation of fission reactor, Detection techniques of radiation

Unit 3: Nuclear Reactors:

Unit 4: Nuclear weapons: Principle, Effects: Blast, thermal and radiation, Nuclear bombs (Fission & Fusion Type) Yield of weapon, Protection against nuclear weapons, Detection techniques for radiation and disposal of nuclear wastes

Unit 5: Chemical & Biological weapons: Different chemical warfare agents, Their tactical roles / effects, Delivery systems, Biological warfare agents & their effects, Protection against biological, chemical warfare agents and their detection, decontamination of CW & BW Agents.

TUTORIALS/ PRACTICALS/ SEMINARS

TEXT/REFERENCES:

1. *Principles/Effects & Sensitivity, 1994, C. S. Grace, Brasey series*
2. *Chemical warfare agents, 1992, S.M.Somai*
3. *Biological weapons, 1999, Joshua Lederberg*

AC-610: ADVANCES IN CHEMICAL TECHNOLOGY

Unit 1: Introduction: Background and eminent discoveries in Chemical Technology

Unit 2: Frontiers in Electrochemistry: Equilibrium properties of electrolytes, electrode potential, electro analytical techniques, Electroplating and Electroless plating, Corrosion Chemistry.

Unit 3: Green Chemistry: Principals of green chemistry, sustainability, selected examples of green synthesis, life cycle assessment.

Unit 4: Biochemistry & Biotechnology: Cell Biology and Physiology, Bioenergetics, Industrial Biotechnology**.**

Unit 5: Chemistry of smart materials: Smart materials, their properties, distribution by type chemistry of macromolecules, phase change materials

Unit 6: Energy Devices and Materials:

TUTORIALS/ PRACTICALS/ SEMINARS

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.*
6. *Electrochemistry, Bockris & Reddy*

AC- 611: ENVIRONMENTAL SCIENCE & TECHNOLOGY

Unit 1: Atmospheric Chemistry: Composition, Structure, and Transport in the Atmosphere, Photochemistry, ozone, aerosols.
Unit 2: Water pollution and treatment: Background, water chemistry & microbiology, water quality and pollution, water treatments, BOD, COD.
Unit 3: Solid waste management: Solid Waste Management Pyramid – Key Technologies for SWM, relevant environmental regulations for waste disposal, site investigations.
Unit 4: Advance oxidation processes: Established AOP technologies e.g. H_2O_2/O_3, O_3/UV, emerging technologies.
Unit 5: Other Topics: Remediation of soil, Bioremediation and Biodegrdagration.
Unit 6: Environmental pollutants detection techniques: Gas sensors, etc.

TUTORIALS/ PRACTICALS/ SEMINARS:

- Toxic dye degradation
- Testing of drinking water quality
- Determination of heavy metals in waste water
- Detection of Gases, Effluent treatment

TEXT/REFERENCES:

1. *Introduction to Atmospheric Chemistry by P.V. Hobbs Cambridge University Press 2000.*
2. *Green Chemistry, An Introductory Text by M. Lancaster RSC Publishing 2010.*
3. *Handbook of Water Analysis by Leo M.L. Nollet, Leen S. P. De Gelder, CRC Press 2007*
4. *Handbook of soil analysis: Meineralogical, organic and inorganic methods by By Marc Pansu, Jacques Gautheyrou, Springer.*

AC- 612: TECHNOLOGY OF PAINTS, PIGMENTS AND VARNISHES

Unit 1: Introduction to Paints:
Unit 2: Introduction to Pigments:
Unit 3: Introduction to Varnishes:
Unit 4: Resin chemistry: The components and properties of paints, including resins, pigments, solvents and additives,

Unit 5: Types of pigments, varnishes; preparation & their applications, The chemical composition, physical properties, function, wear characteristics and properties of PPV,
Unit 6: Color standards, metamerism and color matching, Powder coating, Spray and electro-deposition techniques, Curing, testing methods for finished materials and quality control techniques,
Unit 7: Dye technology, Degradation of Paint surfaces

TUTORIALS/ PRACTICALS/ SEMINARS

TEXT/REFERENCES:

1. *Paint Technology Handbook, Rodger Talbert, CRC Press 2008*
2. *Modern Technology of Synthetic Resins & Their Applications, NIIR, Asia Pacific Business Press.*
3. *Industrial Organic Pigments: Production, Properties, Applications By Willy Herbst, Klaus Hunge, Wiley VCH, 2004.*

AC-613: EXPLOSIVES AND PYROTECHNIQUES

Unit 1: Explosives: Introduction, Classification, Nature of Explosives, Burning, Deflagration & Detonation, Initiation theories of explosives, Techniques of Initiation of Explosives, Thermo chemistry of explosives and various performance parameters of explosives, HE filling techniques, Hydrodynamic theory of detonation, HE applications in different warheads, Fuel- Air explosives, thermo baric weapon, PCB-TB, Recent trends- Insensitive Munitions (IM)

Unit 2: Selection criteria of high explosives (HE) for different warheads.

Unit 3: Pyrotechniques: Definition, classification, Ingredient, Various compositions, Performance parameters of pyro stores, Pyrotechnique combustion theory, Manufacture of pyro stores, Applications like color, smoke, sound, heat, etc. Recent Trends

Unit 4: Fundamentals of computational techniques, Programme NASA-CEC-711.

TUTORIALS/ PRACTICALS/ SEMINARS

TEXT/REFERENCES:

1. *Introduction to Technology of explosives, 1996, Paul Cooper, McGraw Hill, NY.*
2. *Science & Technology of Solid rocket Propellants, 2005, Haridwar Singh &HimanshuShekhar, Printwell, 2005.*
3. *Chemistry of Pyrotechnics, J.A. Conkling. CRC Press, 1986.*
4. *Explosives, by R. Meyer, J. Köhler, A. Homburg, Wiley VCH 2007.*
5. *High Energy Materials: Propellants, Explosives and Pyrotechniques J.P. Agarwal Wiley VCH 2010.*

AC- 614 : Rocket and Gun Propellants

Unit 1: Rocket Propellants: Definition and classification of Rocket propellants**,** Performance parameters of rocket propellants, Propellant ingredients & their properties/role**,** Liquid Propellants, gel propellants**,** Solid Rocket propellants: Processing techniques**,** Insulation, Linear & inhibition system

Unit 2: Gun Propellants: Classification and service requirements**,** High Energy (or nitramine) propellant, LOVA Propellant, Surface coated, double base, extruded impregnated (EI) gun propellant**,** Combustible Cartridge Case (CCC) & Bi-modular change systems (BMCS).

Unit 3: Cryogenic propellant & fuel rich propellants.

Unit 4: Performance evaluation.

Unit 5: Processing of Propellants: Solid Rocket Processing Technologies, Processing of Composite Propellants, Processing of Composite modified Double Base (CMDB) Propellants, Processing of Extruded Composite Propellants, Processing of Fuel Rich Propellants, Manufacturing of Gun Propellants

References:

1. *Science & Technology of Solid rocket Propellants, 2005, Haridwar Singh & Himanshu Shekhar, Printwell, 2005.*
2. *Solid Rocket Propulsion Technology, Alain Devanas, Pergamon Press, 1992*
3. *Rocket Propulsion Elements, G.P. Sutton, John Wiley & SONS.*
4. *High Explosives & Propellants by S. Fordham Pergamon Press 1980*
5. *High Energy Materials: Explosives, Propellants & Pyrotechnics, by J.P. Agarwal, Wiley VCH 2010.*

AC- 615: SURFACTANT TECHNOLOGY

Unit 1: Introduction to surfactants
Unit 2: Classification and application of colloids
Unit 3: Interfacial phenomena and solution properties
Unit 4: Various surfactant technologies
Unit 5: Wetting, spreading and capillary flow, surfactant adsorption
Unit 6: Nanoemulsions, Microemulsions and liposomes, niosomes
Unit 7: Applications of surfactants in nanomaterials

TUTORIALS/ PRACTICALS/ SEMINARS

TEXT/REFERENCES:

1. *1985, Ullman's Encyclopedia of Industrial Chemistry, 5 Edition, VCH, Verlagesellschaft mbH, D-6940 Weinheim, pulu*
2. *Kirk-Othmer's Encyclopedia of Chemical Technology, 4th Ed. John Wiley & Sons, New York, 1991.*
3. *Surfactant Science and Technology, Drew Myers, Wiley Interscience 2006.*

AC- 616: CATALYTIC PROCESSES

Unit 1: Introduction: Catalyst and Catalysis, Adsorption, Diffusion, Heterogeneouscatalysis, Homogeneous catalysis, Organocatalysis, solid acid base catalyst, photocatalysis, Electrocatalysis- General, water-splitting

Unit 2: Kinetics of reactions: Kinetics and reaction on surfaces

Unit 3: Catalysis using transition metals: Mo, Co, Ni, Cr, Pt, Pd, etc. Supported metal catalysts. , MOFs , Zeolytes.

Unit 4: Application: Catalyst for defence applications, Catalysis in petrochemical Industry, Functionality concepts for control of reaction selectivity and microkinetic models, Industrial processes based on solid catalysts.

Unit 5: Synthesis & characterization of catalyst: E.g. Homo & Hetro, Enzymatic

Unit 6: Catalysis for polymerization:

TUTORIALS/ PRACTICALS/ SEMINARS:

- Catalytic Polymerization of styrene or methyl methacrylate
- Catalytic Organic reactions
- Catalytic Inorganic reactions
- Identification of catalysts by various Analytical techniques

TEXT/REFERENCES:

1. *Homogeneous Catalysis: Understanding the Art. Piet W. N. M. van Leeuwen. 2008.*
2. *Chemistry and Chemical Engineering of CatalyticProcesses, Roel Prins. Sijthoef & Noordhoff, 1980.*
3. *Concepts of Modern Catalysis and Kinetics, Second Edition I. Chorkendorff, J. W. Niemantsverdriet, WILEY-VCH Verlag GmbH, 2007.*

M. Tech. in MATERIALS SCIENCE & CHEMICAL TECHNOLOGY

(ENERGETIC MATERIALS AND POLYMERS)

Semester I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	AC-601	Chemistry for Chemical Technology	3	1	4
2	AC-602	Polymer Science & Technology	3	1	4
3	AC-603	Thermodynamics and Combustion Process	3	1	4
4	AC-604	Chemical Process Design	3	1	4
5	AC-605	Advanced Analytical Techniques	3	1	4
6	AM-607	Mathematics for Engineers	3	1	4
		Total	**18**	**6**	**24**

Semester II

Sl. No.	Course Code	Course	Contact hours/week		Credits
			L	T/P	
1	AC-613	Explosives and Pyrotechniques	3	1	4
2	AC-614	Rocket & Gun Propellants	3	1	4
3		Elective – I [From Dept. of Applied Chemistry]	3	1	4
4		Elective – II [From Dept. of Applied Chemistry]	3	1	4
5		Elective – III	4	-	4
6		Elective – IV	4	-	4
		Total	**20**	**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	AC-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	AC-652	M.Tech. Dissertation Phase II	28		14
		Total	**28**		**14**

<u>List of Electives/ Self Study</u>

Sl. No.	Course Code	Course Name
1	AC-606	Chemical Reaction Engineering
2	AC-607	Nanochemical Technology
3	AC-608	Safety, Health and Hazard management
4	AC-609	NBC Warfare (Concepts & remediation)
5	AC-610	Advances in Chemical Technology
6	AC-611	Environmental Science & Technology
7	AC-612	Technology of paints, pigments and varnishes
8	AC-615	Surfactant Technology
9	AC-616	Catalytic Processes
10	ME-654	Advanced Heat And Mass Transfer
Courses offered in Applied Chemistry or other Departments, NPTEL, MOOC		

AC-601: CHEMISTRY FOR CHEMICAL TECHNOLOGY

Unit 1: Chemistry of air sensitive compounds & chalcogens: Electron deficient compounds, 18 e rules, S, Se, Te and their organic/inorganic compound e.g. alkyl/metal chalcogenides.
Unit 2: Chemistry of energetic compounds: Synthetic methods of advanced energetic compounds & their properties.
Unit 3: Biochemical Processes: Fermentation processes, biodiesel.
Unit 4: Fine Specialty Chemicals: Hydrazine's, nitrogen rich compounds
Unit 5: Medicinal Chemistry: Introduction, Drug Chemistry, Bio-molecules, Antimicrobial properties.
Unit 6: Technology of Dyes: Introduction, Types of Dyes, Application, Toxicity and Treatment
Unit 7: Chemistry of Natural Products & Industrial Applications: Types of Natural products, Extraction, Analysis, Industrial applications.

STUTORIALS/PRACTICALS/SEMINAR:

- Detection of toxic elements in waste effluents by use of ion chromatography and absorption spectroscopy
- Synthesis of Energetic chemicals (basic lead azide, tetryl)

TEXT/REFERENCES:-

1. *Inorganic Chemistry: Principles of Structure and Reactivity, J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi, Pearson Education, (2006).*
2. *Organic Synthesis, 3rd Edition, M.B. Smith, Academic Press, (2006).*
3. *The Organic Chemistry of Drug Design and Drug Action, R. B. Silverman, Elsevier, 2004*
4. *Chemical and Biochemical Reactors and Process Control, J. Metcalfe Coulson, John Francis Richardson, D. G. Peacock, Butterworth Hieneman, 2007*
5. *Speciality Chemicals: Innovations in Industrial Synthesis and Applications, B. Pearson, Elsevier Science Publisher, 1991.*

AC-602: POLYMER SCIENCE & TECHNOLOGY

Unit 1: Introduction to polymer chemistry: Definition, classification and characteristic, Condensation and addition polymers, Rubber, Elastomer & Properties of Polymers (Thermal, Electrical etc.)

Unit 2: Advanced Polymers: Conducting Polymers, Photoactive Polymers, Thermoplastic and Thermosetting polymers

Unit 3: Characterization of polymers:

Unit 4: Polymer blends: Polymer networks, gels, processing and application of blends,

Unit 5: Functional polymers: Composite formulation,electronics application, textiles, foul release, impact, adhesion, sealing, energy storage, energy devices, microwave / EMI shielding etc.

Unit 6: Polymers for defence applications: Kevlar, HTPB, EPDM etc.

Unit 7: Bio, Biodegradable and Biomedical polymers: Natural and synthetic biodegradable polymers, catalytic biodegradation, chitosan and polylactic acid based copolymers

Unit 8: Polymers for commercial applications: Acrylics, nylon, polycarbonate, polyamides, polyesters, nano-composites

Unit 9: Degradation Techniques & degradation of polymers

Unit 10: Polymer based devices

TUTORIALS/ PRACTICALS/ SEMINARS:

- Thermogravimetric analyses of polymers (degradation)
- Polymers film casting and its analysis by IR and UV-Visible spectroscopy

TEXT/REFERENCES:-

1. *Polymer Science & Technology (2nd Ed) by Joel R. Fried, Prentice Hall, 2014*
2. *Thermal Analysis of Polymers, fundamentals & application by Joseph D.Menczel& R. Porne Prime, Wiley, 2009.*

3. *Industrial Polymers, Specialities Polymers and their applications, Manas Chanda, Salil K. Roy, Series Editor: Donald E. Hudgin,CRC Press.*
4. *Polymer Chemistry & Physics of Modern Materials by JMG Cowie, CRC Press.*
5. *Text Book of Polymer Science by Billmeyer, John Wiley & Sons, 1984.*
6. *Introductory Polymer Chemistry, Gauri S. Misra New Age International Ltd., 1993.*
7. *Polymer by Vasant R. Gowariker, N. V. Viswanathan, JayadevSreedhar, New Age International (P) Ltd., New Delhi.*
8. *Principles of Polymerization, George Odion.*
9. *Polymers , Reynolds & Scothum*

AC-603: THERMODYNAMICS & COMBUSTION PROCESS

Unit 1: General equations of equilibrium: Vapor - liquid equilibrium in miscible Binary and multicomponent systems, methods for equilibria in complex multireacton systems, Homogeneous Closed Systems, Homogeneous Open Systems, Equilibrium in a Heterogeneous Closed System,
Unit 2: Thermodynamics of solutions: Gibbs-Duhem equation, The Phase Rule, The Chemical Potential, Activity and Activity Coefficient, Calculations of flash point, isobaric X-Y diagrams, Modified Raoults Law Group contribution methods for activity coefficients.
Unit 3: Azeotropy: Vapor-liquid equilibria in systems with partially miscible liquid phase. Liquid - liquid equilibria.
Unit 4: Combustion: An introduction, thermodynamics of combustion chemistry, combustion chemistry modeling combustion instability, flame, Combustion of solid rocket propellants, liquid propellants
Unit 5: Chain reaction or specific reactions: Hydrogen-oxygen, carbon monoxide oxidation, hydrocarbon oxidation

TUTORIALS/PRACTICALS/SEMINAR:

- Thermal properties of materials e.g. Polymers, organic compounds and nanocomposites (Thermo Gravimetric Analysis)
- Simulation studies of thermal properties of propellants and explosives

TEXT/REFERENCES:-

1. *Concise Chemical Thermodynamics, A.P.H. Peters, CRC Press, 2010*
2. *Basic Chemical Thermodynamics, E Brian Smith, World Scientific Publishing Company, 2004*
3. *Propellants & Explosives: Thermo chemical aspects of combustion, N.Kubota,Wisley VCH, 2002.*

AC-604 : CHEMICAL PROCESS DESIGN

Unit 1: Screening of processes and analysis: The nature of process synthesis and analysis, Product life cycle, Cost diagrams and quick screening of process alternatives

Unit 2: Membrane based separation systems: Equilibrium & non equilibrium processes (MF, UF, RO, PV, Liquid Membranes and gas separation processes).
Unit 3: Developing a conceptual design: Finding the best flow-sheet, Input information and batch vs. continuous, Input output structure of the flow sheet.
Unit 4: Other Topics: Heat Exchanger networks; Process development for energy harvesting, Recycle structure of the flow-sheet Computational methods in process design, Case study

TUTORIALS/PRACTICALS/SEMINAR:
- Process designing for large scale synthesis of organic compounds/nanoparticles.
- Separation of mixtures using distillation techniques.

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)*
4. *Basic Principles of Membrane Technology (2nd Edition) by Marcel Mulder, Springer.*
5. *Conceptual Design of Chemical Processes by James Douglas, McGraw Hill.*

AC-605: ADVANCED ANALYTICAL TECHNIQUES

Unit 1: Instrumental Analysis: Qualitative analysis, genesis of instrumental analysis, hyphenated techniques
Unit 2: Polymeric Techniques: Rheology Techniques, Molecular weight determination
Unit 3: Thermal Techniques: ThermoGravimetry (TG), Differential Thermal Analysis (DTA), and Differential Scanning Calorimetry (DSC)
Unit 4: Chromatographic Techniques: Gas Chromatography (GC), High Performance Liquid Chromatography (HPLC), Thin Layer Chromatography (TLC), Ion chromatography.
Unit 5: Spectroscopy: Ultra Violet-Visible Spectroscopy UV-VIS, Infra-Red spectroscopy (IR), Nuclear Magnetic Resonance (NMR), Mass spectroscopy, Atomic Absorption Spectroscopy (AAS)
Unit 6: XRD and SEM techniques
Unit 7: Analytical techniques for defence, cal-val, sensivity studies: Types and Implimentations.

TUTORIALS/PRACTICALS/SEMINAR:
- 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)*
6. *Analysis of Explosives by Yitrin&Yinon, Pergamon Press, 1981*

AC-606: ADVANCED CHEMICAL REACTION ENGINEERING

Unit 1: Non-Catalytic Fluid-particle reactions: Mechanism and examples
Unit 2: Catalyst for reactions: Homogeneous and Heterogeneous catalyst, Design of gas – solid catalytic reactors
Unit 3: Kinetics of reactions: Kinetics of Solid Catalyzed Reactions.
Unit 4: Classification of multiphase reactors: Qualitative description, examples of industrial importance.
Unit 5: Performance of multiphase reactors: Bubble columns, packed bubble columns, sectionalized bubble columns, plate columns, internal loop and external loop air-lift reactors, jet loop fixed beds, static mixers, Solid-Liquid and Gas – Solid fluidised Beds and solid-gas transport reactors, Stirred tank reactors.
Unit 6: Micro reactors
Other Topics: Mass transfer with Chemical Reaction in Fluid – Fluid systems. Model contactors, pilot plants, and collection of scale-up data, Hydrodynamics, process design.

TUTORIALS/PRACTICALS/SEMINAR

TEXT/REFERENCES:

1. *Chemical Reaction Engineering, O. Levenspiel, John Wiley & sons*
2. *Chemical Engineering Kinetics Smith J.M., Mcgraw-Hill, New York 1970*
3. *Elements of Chemical Reaction Engineering, Scott Foggler, Prentice Hall Series, 3rd Edition.*
4. *Chemical Reactor Analysis and Design, Froment G.F., Bischoff K.B., Wiley & Sons, 2011.*

AC-607: NANO-CHEMICAL TECHNOLOGY

Unit 1: Introduction: Definition and concept- dimensionality and size dependent phenomena.
Unit 2: Nano and Mesopores materials: Chemistry of size dependent variation in nanomaterials, reactivity etc.
Unit 3: Nano-fluids: Basic chemistry of nano-fluids, preparation of nano-fluids, analysis of nano-fluids, applications of nano-fluids.
Unit 4: Nanostructures: Chemistry of Quantum dots, nanowires and nanotubes, 2D films.
Unit 5: Nano-energetic materials: Introduction, nano-thermites, Advantages and examples, synthesis and thermal properties of nano-thermites.
Unit 6: Nano-catalysts: Surface chemistry of nanoparticles, examples, photo-catalysis

Unit 7: Polymer nano-composites and hybrid materials: Preparation, Characterization, Applications

Unit 8: Nanotechnology for chemical industry: Application in pharmaceuticals, Paint, Coatings, rubber and polymers.

Unit 9: Nanomaterials for Energy applications: Thermo electricity, Solar, Photonics.

Unit 10: Other Topics: Application of nanochemistry/ nanomaterials in civil and defence sector, Characterization of nanoparticles by various analytical techniques

TUTORIALS/PRACTICALS/SEMINAR:

- 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*

5 *Nanocrystal Quantum Dots - Edited by Victor I. Klimov, Second Edition, CRC Press (Taylor & Francis Group)*

6 *Nanocomposite Materials, Prof. Goyal*

AC- 608 : SAFETY, HEALTH & HAZARD MANAGEMENT

Unit 1: Chemical Safety: Standards and regulations of chemical safety in Industries or Laboratories, Storage of hazardous chemicals, Compatibility and classification codes, Chemical risk analysis and management, Fire triangle and Handling of Toxic, Industrial Gases

Unit 2: Hazard Management: HAZOP and HAZAN techniques, Hazard in manufacture, Hazard prevention measures, Disposal of hazardous materials

Unit 3: Warfare: Classifications of explosives based on hazards, Nuclear, biological and chemical warfare safety

Unit 4: Health: Assessment of human factors, Health & Environment safety **,** Nano materials safety (Toxicology study)

TUTORIALS/PRACTICALS/SEMINAR:

- Handling & demonstration of air-sensitive, pyrophoric and toxic chemicals
- Monitoring of effluents through Gas Chromatography/Ion Chromatography

TEXT/ REFERENCES:

1. *Safety and accident prevention in chemical operations John Wiley and sons, New York, 1982*

2. *Technical guidance for hazard analysis USEPA, FEMA, USDOT, 1987*
3. *Nanotechnology Environmental Health and Safety: Risks, Regulation and Management**:** M. Hull, D. Bowman, Elsevier, 2010*
4. *Manual on emergency preparedness for chemical hazard, Ministry of Environment and Forest, Govt. of India, New Delhi, 1989.*

AC- 609 : NBC WARFARE (CONCEPTS & REMEDIATION)

Unit 1: Nuclear science: Structure of nucleus, Mass defect, Binding energy, Nuclear reaction, Fission & Fusion nuclear reactions, Controlled & uncontrolled release of nuclear energy, Concepts of critical mass & critical volume, Principle of operation of fission reactor
Unit 2: Nuclear weapons: Principle, Effects: Blast, thermal and radiation, Nuclear bombs (Fission & Fusion Type) Yield of weapon, Protection against nuclear weapons

Unit 3: Chemical & Biological weapons: Different chemical warfare agents, Their tactical roles / effects, Delivery systems, Biological warfare agents & their effects, Protection against biological, chemical warfare agents

TUTORIALS/PRACTICALS/SEMINAR:

TEXT/REFERENCES:

1. *Principles/Effects & Sensitivity, 1994, C. S. Grace, Brasey series*
2. *Chemical warfare agents, 1992, S.M.Somai*
3. *Biological weapons, 1999, Joshua Lederberg*

AC-610: ADVANCES IN CHEMICAL TECHNOLOGY

Unit – 1: Introduction: Background and eminent discoveries in Chemical Technology
Unit – 2: Frontiers in Electrochemistry: Equilibrium properties of electrolytes, electrode potential, electro analytical techniques, Electroplating and Electroless plating, Corrosion Chemistry.
Unit – 3: Green Chemistry: Principals of green chemistry, sustainability, selected examples of green synthesis.
Unit – 4: Biochemistry & Biotechnology: Cell Biology and Physiology, Bioenergetics, Industrial Biotechnology**.**
Unit – 5: Chemistry of smart materials: Smart materials, their properties, distribution by type
chemistry of macromolecules, phase change materials
Energy Devices and Materials:

TUTORIALS/ PRACTICALS/ SEMINARS

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.*
6. *Electrochemistry, Bockris & Reddy*

AC- 611: ENVIRONMENTAL SCIENCE & TECHNOLOGY

Unit 1: Atmospheric Chemistry: Composition, Structure, and Transport in the Atmosphere, Photochemistry, ozone, aerosols.
Unit 2: Water pollution and treatment: Background, water chemistry & microbiology, water quality and pollution, water treatments.
Unit 3: Solid waste management: Solid Waste Management Pyramid – Key Technologies for SWM, relevant environmental regulations for waste disposal, site investigations.
Unit 4: Advance oxidation processes: Established AOP technologies e.g. H_2O_2/O_3, O_3/UV, emerging technologies.
Unit 5: Other Topics: Remediation of soil, Bioremediation and Biodegradation.

TUTORIALS/PRACTICALS/SEMINAR:

- Toxic dye degradation
- Testing of drinking water quality
- Determination of heavy metals in waste water

TEXT/REFERENCES:

1. *Introduction to Atmospheric Chemistry by P.V. Hobbs Cambridge University Press 2000.*
2. *Green Chemistry, An Introductory Text by M. Lancaster RSC Publishing 2010.*
3. *Handbook of Water Analysis by Leo M.L. Nollet, Leen S. P. De Gelder, CRC Press 2007*
4. *Handbook of soil analysis: Meineralogical, organic and inorganic methods by By Marc Pansu, Jacques Gautheyrou, Springer.*

AC- 612: TECHNOLOGY OF PAINTS, PIGMENTS AND VARNISHES

Unit 1: Topics: Resin chemistry, The components and properties of paints, including resins, pigments, solvents and additives, Types of pigments, varnishes; preparation & their applications, The chemical composition, physical properties, function, wear characteristics and properties of PPV, Color standards, metamerism and color matching, Powder coating, Spray and electro-deposition techniques, Curing, testing methods for finished materials and quality control techniques, Dye technology, Degradation of Paint surfaces

TUTORIALS/PRACTICALS/SEMINAR

TEXT/REFERENCES:

1. *Paint Technology Handbook, Rodger Talbert, CRC Press 2008*
2. *Modern Technology of Synthetic Resins & Their Applications, NIIR, Asia Pacific Business Press.*
3. *Industrial Organic Pigments: Production, Properties, Applications By Willy Herbst, Klaus Hunge, Wiley VCH, 2004.*

AC-613: EXPLOSIVES AND PYROTECHNIQUES

Unit 1: Explosives: Introduction, Classification, Nature of Explosives, Burning, Deflagration & Detonation, Initiation theories of explosives, Techniques of Initiation of Explosives, Thermo chemistry of explosives and various performance parameters of explosives, HE filling techniques, Hydrodynamic theory of detonation, HE applications in different warheads, Fuel- Air explosives, thermo baric weapon, PCB-TB, Recent trends- Insensitive Munitions (IM)

Unit 2: Selection criteria of high explosives (HE) for different warheads.

Unit 3: Pyrotechniques: Definition, classification, Ingredient, Various compositions, Performance parameters of pyro stores, Pyrotechnique combustion theory, Manufacture of pyro stores, Applications like color, smoke, sound, heat, etc. Recent Trends

Unit 4: Fundamentals of computational techniques, Programme NASA-CEC-711.

TUTORIALS/ PRACTICALS/ SEMINARS

TEXT/REFERENCES:

1. *Introduction to Technology of explosives, 1996, Paul Cooper, McGraw Hill, NY.*
2. *Science & Technology of Solid rocket Propellants, 2005, Haridwar Singh &Himanshu Shekhar, Printwell, 2005.*
3. *Chemistry of Pyrotechnics, J.A. Conkling. CRC Press, 1986.*
4. *Explosives, by R. Meyer, J. Köhler, A. Homburg, Wiley VCH 2007.*
5. *High Energy Materials: Propellants, Explosives and Pyrotechniques J.P. Agarwal Wiley VCH 2010.*

AC- 614 : Rocket and Gun Propellants

Unit 1: Rocket Propellants: Definition and classification of Rocket propellants**,** Performance parameters of rocket propellants, Propellant ingredients & their properties/role**,** Liquid Propellants, gel propellants**,** Solid Rocket propellants: Processing techniques**,** Insulation, Linear & inhibition system

Unit 2: Gun Propellants: Classification and service requirements**,** High Energy (or nitramine) propellant, LOVA Propellant, Surface coated, double base, extruded impregnated (EI) gun propellant**,** Combustible Cartridge Case (CCC) & Bi-modular change systems (BMCS).

Unit 3: Cryogenic propellant & fuel rich propellants.

Unit 4: Performance evaluation.

Unit 5: Processing of Propellants: Solid Rocket Processing Technologies, Processing of Composite Propellants, Processing of Composite modified Double Base (CMDB) Propellants, Processing of Extruded Composite Propellants, Processing of Fuel Rich Propellants, Manufacturing of Gun Propellants

References:

1. *Science & Technology of Solid rocket Propellants, 2005, Haridwar Singh & Himanshu Shekhar, Printwell, 2005.*
2. *Solid Rocket Propulsion Technology, Alain Devanas, Pergamon Press, 1992*
3. *Rocket Propulsion Elements, G.P. Sutton, John Wiley & SONS.*
4. *High Explosives & Propellants by S. Fordham Pergamon Press 1980*
5. *High Energy Materials: Explosives, Propellants & Pyrotechnics, by J.P. Agarwal, Wiley VCH 2010.*

AC- 615: SURFACTANT TECHNOLOGY

Unit 1: Introduction to surfactants
Unit 2: Classification and application of colloids
Unit 3: Interfacial phenomena and solution properties
Unit 4: Various surfactant technologies
Unit 5: Wetting, spreading and capillary flow, surfactant adsorption
Unit 6: Nanoemulsions, microemulsions and liposomes, niosomes
Unit 7: Applications of surfactants in nanomaterials

TUTORIALS/PRACTICALS/SEMINAR
TEXT/REFERENCES:

1. *1985, Ullman's Encyclopedia of Industrial Chemistry, 5 Edition, VCH, Verlagesellschaft mbH, D-6940 Weinheim, pulu*
2. *Kirk-Othmer's Encyclopedia of Chemical Technology, 4th Ed. John Wiley & Sons, New York, 1991.*
3. *Surfactant Science and Technology, Drew Myers, Wiley Interscience 2006.*

AC- 616: CATALYTIC PROCESSES

Unit 1: Introduction: Catalyst and Catalysis, Adsorption, Diffusion, Heterogeneouscatalysis, Homogeneous catalysis, Organocatalysis, solid acid base catalyst, photocatalysis, Electrocatalysis- General, water-splitting

Unit 2: Kinetics of reactions: Kinetics and reaction on surfaces

Unit 3: Catalysis using transition metals: Mo, Co, Ni, Cr, Pt, Pd, etc. Supported metal catalysts. , MOFs , Zeolytes.

Unit 4: Application: Catalyst for defence applications, Catalysis in petrochemical Industry, Functionality concepts for control of reaction selectivity and microkinetic models, Industrial processes based on solid catalysts.

Unit 5: Synthesis & characterization of catalyst: E.g. Homo & Hetro, Enzymatic:

Unit 6: Catalysis for polymerization:

TUTORIALS/ PRACTICALS/ SEMINARS:

- Catalytic Polymerization of styrene or methyl methacrylate
- Catalytic Organic reactions
- Catalytic Inorganic reactions
- Identification of catalysts by various Analytical techniques

TEXT/REFERENCES:

1. *Homogeneous Catalysis: Understanding the Art. Piet W. N. M. van Leeuwen. 2008.*
2. *Chemistry and Chemical Engineering of CatalyticProcesses, Roel Prins. Sijthoef&Noordhoff, 1980.*
3. *Concepts of Modern Catalysis and Kinetics, Second Edition I. Chorkendorff, J. W. Niemantsverdriet, WILEY-VCH Verlag GmbH, 2007.*

Department of Metallurgical and Materials ngineering

DEPARTMENT OF METALLURGICAL MATERIALS ENGINEERING

About the department:

The Department of Metallurgical and Materials Engineering aims to develop a core competence in teaching and research in the areas of materials 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 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.

This programme is open for civilian GATE qualified candidates, DRDO Scientists/Officers, Officers from Tri-services, Industries and PSU. This program is also open to friendly foreign countries.

At present, the Department is equipped with characterization facilities 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)
- 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
- CH-Analyzer
- Ball Milling
- PPMS

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 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. 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:

B.E./B.Tech or equivalent in any branch of Engineering/Technology; M.Sc or equivalent in any branch of Science.

Organization:

The programme is of four-semester duration. In first and second semester have six courses respectively including one lab in the first semester. Third semester comprises the dissertation work in addition to two courses and fourth semester have only the dissertation work. In the first, second and third semester the students have options to choose elective courses. In the first, second and third semesters there will be one mid semester examination and a final examination for theory subjects. After the second semester, scholarship students are encouraged do a summer internship for about one and half months at their place of 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. As part of the dissertation work in the third semester, the dissertation work will be evaluated by the expert committee at the end of the third semester. At the end of the final semester, students will submit their thesis before going for final evaluation and present their project works before the expert committee (consists of External / Internal members from various R&D organisations / Universities etc.). No credits are counted for attending an audit course.

M. Tech. in Materials Science and Chemical Technology (Materials Science and Technology)

Course Structure

Semester I

Sl. No.	Course Code	Course Name	Contact hours/week		Credits (*)
			L	T/P	
1	MM 601	Concepts in Metal andCeramic	3	2	4
2	MM 602	Materials Characterization	3	2	4
3	MM 603	Thermodynamics of Materials	3	1	4
4	MM 604	Polymers and CompositesTechnology	3	1	4
5	MM 605	Physical and Mechanical Metallurgy	3	2	4
6	MM 606	Introduction to Computational Materials Engineering	3	1	4
		TOTAL	**18**	**10**	**24**

Semester II

Sl. No.	Course Code	Course Name	Contact hours/week		Credits (*)
			L	T/P	
1	MM 607	Design of Materials	3	1	4
2	MM 608	Fatigue, Fracture and Failure Analysis	3	1	4
3		Elective I (from Department Electives)	3	2	4
4		Elective II (from Department Electives)	3	1	4
5		Elective III (from Open Electives)	3	1	4
6		Elective IV (from Open Electives)	3	1	4
		TOTAL	**18**	**7**	**24**

Semester III

Sl. No.	Course Code	Course Name	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 Name	Contact hours/week		Credits (*)
			L	T/P	
1	MM 652	M.Tech Dissertation Phase - II	28**		14
		TOTAL	**28**		**14**

* 1 credit in Theory/Tutorial means 1 contact hour and 1 credit in Practical/practice/project thesis means 2 contact hours in a week.

**Contact hours per week

List of Electives

Sr. No.	Course Code	Name of the Course
Electives from the Department		
1	MM 609	Materials Processing
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	Electrical and Electronic Materials
7	MM 615	Magnetism and Magnetic Materials
8	MM 616	Heat-treatment of Metals and alloys
9	MM617	Materials for High -Temperature Applications
10	MM 618	Advanced Steel Technology
11	MM 619	Millitary Materials
Open Electivesfrom other Departments		
12	ME 602	Advanced Mechanics of Materials
13	ME 603	Advanced Fluid and Thermal Science
14	ME 604	Advanced Materials and Processing

15	ME 607	Computational Fluid Dynamics
16	ME 608	Finite Element Methods
17	AP 614	Sensors and Actuators
18	AM 621	Advanced Modeling Techniques
19	EE 601	Microwave Engineering

Course Name: Concepts in Metal and Ceramic
Course Code: MM 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,
Unit 2:crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids: metallic crystal structure
Unit 3: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, Phase equlibria in ceramics

Unit 4: 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 5: Practical:Solid state,Sol-Gel, Hydrothermal and Co-precipitation process

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
Course Code: MM 602
Unit 1: Diffraction Techniques-Concepts of diffraction, scattering and radiation-matter interactions,X-ray diffraction: phase identification, strain andgrain size determination
Unit 2: 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, Electron diffraction in TEM,STM and AFM

Unit 3: Spectroscopic Techniques**-** Fundamental basis of Spectroscopic analysis EDS and WDS applications, X-ray Photon Spectroscopy and Auger electron spectroscopy

Unit 4: Thermal Analysis Techniques-DSC, DTA, TGA and Dilatometry, Electrochemical polarization characterization, Electrochemical Impedance spectroscopy.

Unit 5: Practical: XRD, TEM, SEM, Cyclic voltammetry, Tafelplot, and Salt Spray, weathrometer, cyclic corrosion test, cathodic protection monitoring, localised corrosion monitoring methods (SECM, SEVT)

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):

- *Materials Characterization, ASM Handbook Vol 10.*
- *Characterization of Materials, Vol 1, Elton N. Kaufmann*

Course Name:Thermodynamics of Materials

Course Code: MM 603

Unit 1: 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 2: Generation of Auxiliary Functions: Legendre transforms, Coefficient relations, Maxwells relations, Thermodynamic relations among state functions variables and its application to solids

Unit 3: Statistical definition of temperature and entropy, Micro- and Macro-states, Maxwell-Boltzmann distribution, Thermodynamic equilibrium: stable equilibrium states, criteria for equilibrium

Unit 4: 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

Unit 5: Free energy of binary system: Entropy of mixing, Enthalpy of mixing, Free energy of ideal, regular and real solutions, Activity, Ordered and intermediate phases, Types of solutions, Chemical potential, Unary and binary phase diagrams and Gibbs free energy

Text Book(s):

- *Ahindra Ghosh, Textbook of Materials and Metallurgical thermodynamics. Prentice Hall of INDIA 2003*

- *Taiji Nishizawa,Thermodynamics of microstructures, ASM International*

Reference Book(s):

- *R.T. DeHoff, Thermodynamics in Materials Science, McGraw-Hill, Singapore, 1993*
- *D. A. Porter and K. E. Easterling, Phase transformations in Metals and Alloys, Chapman and Hall, London, 1996*
- *David R. Gaskell, Introduction to the Thermodyanamics of Materials, Taylor & Francis, 1798*

Course Name: Polymer and Composite Technology

Course Code: MM 604

Unit 1: 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 2: Physical methods of polymer analysis such as IR, DSC, TGA, XRD etc, Viscoelasticity, Polymer blends and alloys: thermodynamics, morphology and properties.

Unit 3: Composites: Conventional polymer composites, Fiber reinforced composites, Nanofillers and their composites,

Unit 4: Composite manufacturing techniques: Solution-cast, Melt-mixing, Extrusion, Compression molding, Resin transfer, Resin infusion, Vacuum casting and electrospinning.

Unit 5: 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

Text Book(s):

- *V.R. Gowariker, Polymer Science, Wiley Eastern, 1995*
- *F. N. Billmeyer, Textbook of Polymer Science, Wiley Interscience, 1971.*

Reference Book(s):

- *Kumar and S. K. Gupta, Fundamentals and Polymer Science and Engineering, Tata McGraw-Hill, 1978*
- *Epel, J.N.:Engineering Plastics, Engineering Materials Handbook, ASM International 1988.*
- *Brydson, A.J. : Plastics Materials, Princeton, N.J., 1966.*

Course Name: Physical and Mechanical Metallurgy

Course Code: MM 605

Unit 1: Crystal defects/imperfaction in Metals, dislocations, burger vectors, dislocations multiplications, dislocation interactions, stacking faults,Phase rule, Phase diagram, Eutectic, Iron-Carbon diagram, TTT and CCT diagrams

Unit 2: Plastic deformation in single crystal, critical resolved shear strength, deformation by slip, and deformation by twinning. Dislocations pile-ups, dislocations climb and cross slip.

Unit 3: Strengthening mechanisms: Solid solution strengthening, strengthening from grain boundaries, strains hardening, strain ageing, annealing of cold worked materials, strengthening from particles, precipitation hardening

Unit 4: 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 5: Practical: Metal Polishing and Etching, Optical Microstructural Characterization, Wear and friction, hardness testing

Text Book(s):

- *Mechanical Metallurgy, G.E. Dieter, McGraw-Hill book company, 1988*

Reference Book(s):

- *Mechanical behaviour of Materials, Williams F Hosford, Cambridge University press, 2005*
- *Materials Science and Engineering by William D. Callister, JohnWiley& Sons, Inc.*
- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*
- *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.*

Course Name: Introduction to Computational Materials Engineering

Course Code:MM 606

Unit 1: Review of programming in high level languages such as Python / Matlab / Mathematica and low level languages such as C / C++ / Fortran

Unit 2: Fitting and visualization of multidimensional data; Quantification of experimental microstructures using programs as well as software tools

Unit 3: Application of linear algebra towards solution to a system of linear and non linear equations; Numerical integration; Numerical solution of diffusion equation;

Unit 4: Computational techniques such as phase field method and Monte Carlo towards evolution of microstructure; synthetic microstructures

Unit 5: Evaluation of properties from the computed microstructures using mean field and full field approaches; data analytics using principal component analysis; ICME approach

Text Book(s):

- Introduction to Computational Materials Science – Richard LeSar, Cambridge University Press (2013). ISBN: 9781316614877

Reference Book(s):

- Mathematical Methods for Physics and Engineering, 3rd Edition – R.F. Riley, M.P. Hobson, S.J. Bence, Cambridge University Press (2012). ISBN: 9780521139878
- Integrated Computational Materials Engineering (ICME) for Metals – Mark F. Horstemeyer, TMS (2012). ISBN: 9781118022528

- 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: Design of Materials

Course Code: MM607

Unit 1: First and Second law of diffusion, Solution to diffusion equations and error function, Types of diffusion, Krikendall effect and applications

Unit 2: Generic classes of Metallic alloys and applications, Equilibrium shapes of grains and phases, Applications of phase diagrams: Soft solders, Zone Refinement of Semiconductors, Bubble free Ice

Unit 3: Kinetics of nucleation, diffusive and Martensitic phase transformations, Fine grain castings, Rapid solidification and amorphous materials, Light alloys: Age-hardening and thermal stability

Unit 4: Mechanical properties of Ceramics, Statistics of Brittle fracture: Flaw size and dispersion of strength, Weibull distribution, Design of pressure windows

Unit 5: Fibrous, particulate and foamed composites, Improving stiffness, strength and toughness. Case studies in Defence applications: Turbine blades, bullet-proof vests, uses of metal matrix composites and carbon-carbon composites.

Text Book(s):

- *Engineering Materials 1 Michale F. Ashbey and David R. H. Jones; Butterworth-Heinmann, Elsevier Publications*
- *Engineering Materials 2 Michale F. Ashbey and David R. H. Jones; Butterworth-Heinmann, Elsevier Publications*

Reference Book(s):

- *D. A. Porter and K. E. Easterling, Phase transformations in Metals and Alloys, Chapman and Hall, London, 1996*
- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*

Course Name: Fatigue, Fracture and Failure Analysis

Course Code: MM 608

Unit 1: 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 2: Effect of Structural Features, Fatigue Crack Propagation, Stress Concentration & Fatigue, Size & Surface Effect, Effect of Metallurgical Variables& Enhancement of Fatigue Life,
Unit 3: Classification of Fracture, Theoretical Strength of Metals, Griffith Theory of Brittle Fracture, Metallographic features of Fracture, Fractography,

Unit 4: Dislocation Theory of Brittle Fracture, Effect of Tri-axial Stress, Strain Energy Release Rate, Stress Intensity Factor,

Unit 5: Fracture Toughness & Design, KIC , CTOD, JIntegral, R-Curve, Toughness of Metals & Alloys. Stress corrosion cracking.

Text Book(s):

- *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.*

ReferenceBook(s):

- *Deformation and fracture mechanics of engineering materials, 4th Ed., R. W. Hertzberg, John Wiley & Sons, 1995.*
- *Elementary engineering fracture mechanics By David BroekNoordhoff 1974.*
- *Fatigue and Fracture of Metals, W. M. Murray, John Wiley, 1952.*

Course Name: Materials Processing

Course Code:MM 609

Unit 1: Processing of Polymers- Extrusion, compounding, fibre spinning, injection moulding, compression moulding, Additive manufacturing

Unit 2: Processing of ceramics- Compaction, moulding, sintering, refractory manufacturing processes, glass manufacturing techniques.

Unit 3: Processing of Metals- Casting, Hot working, Cold working, Rolling, Annealing, Forging, Extrusion,

Unit 4: Wire drawing,Sheet metal forming, Joining Techniques, Friction stir welding, Powder Metallurgy

Unit 5: Practical:Metal processing- rolling, annealing;polymer processing-Extrusion and compression molding, electrospinning

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*

Reference Book(s)

- *Metallurgy, Applications, Advantages and Limitations, Klar, Erhard, ASM, 1983, Ohio.*
- *Plastics Processing Data Handbook (2nd Edition), Rosato, Dominick, 1997.*
- *Plastic Injection Molding: Manufacturing by Douglas M. Bryce, 2007.*
- *Concise encyclopedia of plastics, Rosato, Marlene G, 2005*
- *Extrusion: the definitive processing guide and handbook, Giles, Harold F.; Wagner, John R.; Mount, Eldridge M, 2005.*

Course Name: Nanomaterials and their application
Course Code: 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, Superhydrophobic 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 behaviour of nanomaterials: Fracture and creep;Nanomechanics and nanotribology; 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.

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: Non-Destructive Evaluation
Course Code: MM 611

Unit 1: Visual Inspection, Liquid Penetrant Testing, Magnetic Particle Testing,
Unit 2: Eddy Current Testing, Ultrasonic Testing,
Unit 3: Acoustic Emission Technique, Radiography Technique,
Unit 4: Residual Stress Analysis, In-situ Metallography, Automation and Robot in NDT,
Unit 5: Case study: Grain Size, Weldment and other Structural Components.

Test Book(s)

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*

- *Nondestructive Evaluation and quality control, ASM handbook, Volume 17,ASM International*

Course Name:Polymer Blends and Nanocomposites

Course Code:MM 612

Unit 1: 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 2: Blends of amorphous & semi-crystalline polymers, inter-penetrating networks, thermoplastic and thermoset blends, rubber toughened polymers, particulate and fiber reinforced composites.
Unit 3: Nanostructured materials like nanoclay, carbon nanotubes, graphene, magnetic nanoparticles etc. and polymernanocomposites. Surface treatment of the reinforcing materials and interface/interphase structures of composites/nanocomposites.
Unit 4: Various processing techniques like solution mixing, melt processing. Physical and thermo-mechanical properties of polymer blends, composites and nanocomposites.
Unit 5: Potential Applications in Defence.
Text Book(s)

- *Textbook of Polymer Science, Fred W. Billmeyer (Wiley)*
- *Polymer alloys and blends by L A Utracki*

Reference Book(s)

- *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

Course Name: Biomaterials

Course Code: MM 613

Unit 1: Introduction to biomaterials, Tissue Engineering, Biocompatibility, Biodegradation Biofluids and medical devices, Biostructures

Unit 2: Ceramic based biomaterials, metallic biomaterials, polymer based biomaterials, Biofluidici, medical devices, Biostructures

Unit 3: Nano-biomaterials: Self assembly of nanomaterials, hydrophilic, hydrophobic and surfaces, biomimicking

Unit 4: Medical imaging, electrospinning of scaffold structures, Additive manufacturing of medical devices, biofluidics and biostructure

Unit 5: 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*

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 Hall*

Course Name: Electrical and Electronic Materials

Course Code:MM 614

Unit 1: Band Theory of Solids, Semiconductors, Electron Effective Mass, Density of States in an Energy Band, Fermi-Dirac Statistics

Unit 2: Intrinsic Semiconductors, Extrinsic Semiconductors, Temperature Dependence of Conductivity, Recombination and Minority Carriers, Continuity Equations, Optical Absorption, Ideal *pn*Junction and Band Diagram, Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET),

Unit 3: Supercapacitors, Types of supercapacitor. Ceramic substrates (Al_2O_3, SiC, BeO, AlN, Glass ceramic etc.), Processing of Thick Film, Thin Film, Multi layer Packages, Properties of Ceramic Insulators, Ceramic Capacitor

Unit 4: Dielectrics-Barium titanate, Other titanate based dielectrics, Composition with high Pb content, Processing of thick and thin film capacitors, Integrated capacitors,

Unit 5: Relaxor Dielectrics, Piezoelectric Ceramics and electrostrictive materials, Powders and Processes, Piezoelectric ceramic applications. Nano Ceramics: Different Compositions, Synthesis, Applications, Introduction to electric vehicle.

Text Book(s):

- *Materials for Electronics: R.C. Buchanon.*
- *Introduction to Ceramics: W.D.Kingery*
- *Fundamentals of Ceramics: Barsoum*

Reference Book(s):

- *Physical Ceramics for Engineers: VanVlack*
- *Handbook of Ceramics: Editor S. Kumar Ceramic*
- *Electronic Ceramics: B.C.H Steele.*
- *Adv. Ceram. Materl. VolI by K Furuta& K U chino*

Course Name: Magnetism and Magnetic Materials

Course Code: MM 615

Unit 1: Moment of a current loop, Orbital angular momentum and magnetic moments, Spin magnetic moment, gyromagnetic ratio, Vector atom model.

Unit 2: Classical diamagnetism, Superconductors, Paramagnetic moments, classical paramagnetic.

Unit 3: Weiss molecular field, Brillioun function and spontaneous magnetization, Curie Weiss law, Magnetocaloric effect, Exchange interaction, Spin waves, Antiferrognetism and Néel temperature, Exchange Bias effect and applications, Ferrimagnetism: Spinel structure and Ferrite moments.

Unit 4: Uniaxial and Cubic anisotropy, Shape anisotropy, Crystal field effects, Origin of magnetic domains, Equilibrium domain size and domain wall, Néel and Bloch Walls

Unit 5: Differentiation between Soft and hard magnetic materials, Finemet alloys, Rare earth permanent magnets, Magnetostriction: TERFNOL-D, Multiferroics, Magnetic Anomaly Detection.

Text Book(s):

- *Introduction to Magnetic Materials*

B. D. Cullity and C. D. Graham; IEEE Press, A. JonWiley & Sons Publications

Reference Book(s):

- *Fausto Florillo, Measurement and Characterization of Magnetic Materials, Elsevier Academic Press, 2004*
- *Modern magnetic Materials: Principles and applications*
  Robert C. O'Handaley; Wiley-Interscience Publications

- *Physics of magnetism and Magnetic materials*
  K. H. J. Bushaw and F. R. de Boer; Kluwer Academic Publishers

Course Name: Heat-treatment of Metals and Alloys
Course Code:MM 616

Unit 1: Steel Heat-Treatment, Annealing, Stress relief annealing, Process Annealing, Normalizing, Spheroidizing, Tempering , Quenching, Hardening, TTT Curve, Hardenability,

Unit 2: Case hardening, carburizing, Nitriding, Boronizing,

Unit 3: Flame hardening, Induction hardening, Laser hardening, Electron beam hardening,

Unit 4: Heat treatment of Aluminium, Titanium and Magnesium Alloys

Unit 5: Deformation and annealing.

Text Book(s):

- Heat Treatment Principles & Techniques, TV Rajan, CP Sharma & Ashok Sharma Prntice Hall of India, New Delhi, 2007.
- Metallurgy for Engineers-EC Rollason, 4th Ed, Edward Arnold, UK, 1973.
- Introduction to Physical Metallurgy, S H Avner, TATA Mc-Graw Hill, New Delhi, 2001.

Reference Book(s)

- Engineering Physical Metallurgy by Yuri Lakhtin, Moscow, MIR Publishers, 1963.

- 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

Unit 1: Melt processing of Superalloy, Single crystal Superalloy, Processing of Superalloy, Alloying effect.

Unit 2: Oxide Dispersion Strengthened alloys. Powder Metallurgy

Unit 3: High temperature deformation, Room and high temperature Wear, Advanced coating materials

Unit 4: Fiber Reinforced Composite Superalloy,

Unit 5: Processing and properties of advanced Structural Ceramics.

Text Book(s):

- *Superalloys, supercomposites and super ceramics, ed. J. K Tien and T. Caulfield, Academic Press, 1989, Boston.*

- *High temperature structural materials, R. W. Cahn, Chapman and Hall, 1996, London.*

Reference Book(s):

- *Materials for High Temp. Engg. Applications, G. W. Meetham and M.H. Van de Voorde, Springer, 2000, Berlin.*
- *Friction, wear and Lubrications, K.C. Ludema, CRC Press, 1996.*
- *Powder Metallurgy: Science, Technology, and Materials Anish Upadhyaya and G. S. Upadhyaya, Taylor & Francis, 2011*

Course Name: Advanced Steel Technology

Course Code: MM 618

Unit 1: Strengthening mechanisms: Work hardening, Solid solution strengthening, Grain size refinement, Dispersion strengthening

Unit 2: Low Carbon steels: Austenite to ferrite transformation, High strength low alloys steels, Interstitial free steels, Dual phase and TRIP steels

Unit 3: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 5: Special steels: Bainite: Upper and lower Bainite microstructures, Bainite transformation mechanisms and transition, nanostructured Bainite; Marraging steels, Stainless steel, TWIP steels, Case studies for defence applications.

Text Book(s):

- *Steels: Processing, Structure, and Performance, George Krauss; ASM International*

Reference Book(s):

- *Steels: Microstructure and Properties HKDH Bhadeshia and Sir R. Honeycomb; Butterworth-Heinmann, Elsevier Publications*

Course Name: Military Materials

Course Code: MM 619

Unit 1: Overview metallic materials for military application, Needs of complex metals and alloys required for modern and sophisticated warfare weapons systems.

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, Aluminium alloy – Medium girder bridge and BR 90.

Unit 2: Special Alloys for Armour applications: Rolled Homogeneous Armour steels: Kanchan armour for Arjun tank, Steel armour plate, Aluminium alloy armour for light armoured vehicles, Body armour.

Unit 3: 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 4: 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 5: 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.

Text Book(s):

- *Alistair Doig, Military metallurgy, Maney publishing, 2002*

Reference Book(s):

- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*
- *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.*
- *Paul J Hazell, Armour Materials Theory and Design, CRC Press, 2015*

Department of Metallurgical and Materials Engineering

M. Tech in Materials Engineering

Brief Description:

The Department of Metallurgical and Materials Engineering aims to develop a core competence in teaching and research in the areas of materials 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 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.

This programme is open for civilian GATE qualified candidates, DRDO Scientists/Officers, Officers from Tri-services, Industries and PSU. This program is also open to friendly foreign countries.

Eligibility:

B.E./B.Tech or equivalent in any branch of Engineering/Technology; M.Sc or equivalent in any branch of science.

Organization:

The programme is of four-semester duration. In first and second semester have six courses respectively including one lab in the first semester. Third semester comprises the dissertation work in addition to two courses and fourth semester have only the dissertation work. In the first, second and third semester the students have options to choose elective courses. In the first, second and third semesters there will be one mid semester examination and a final examination for theory subjects. After the second semester, scholarship students are encouraged do a summer internship for about one and half months at their place of 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. As part of the dissertation work in the third semester, the dissertation work will be evaluated by the expert committee at the end of the third semester. At the end of the final semester, students will submit their thesis before going for final evaluation and present their project works before the expert committee (consists of External / Internal members from various R&D organisations / Universities etc.). No credits are counted for attending an audit course.

Course Structure

Semester I

Sl. No.	Course Code	Course Name	Contact hours/week		Credits (*)
			L	T/P	
1	MM 601	Concepts in Metal and Ceramic	3	2	4
2	MM 602	Materials Characterization	3	2	4
3	MM 603	Thermodynamics of materials	3	1	4
4	MM 604	Polymer and CompositeTechnology	3	1	4
5	MM 605	Physical and Mechanical Metallurgy	3	2	4
6	MM 606	Introduction to Computational Materials Engineering	3	1	4
		TOTAL	**18**	**9**	**24**

Semester II

Sl. No.	Course Code	Course Name	Contact hours/week		Credits (*)
			L	T/P	
1	MM 619	Millitary Materials	3	1	4
2	MM 608	Fatigue, Fracture and Failure Analysis	3	1	4
3		Elective I (from Department Electives)	3	1	4
4		Elective II (from Department Electives)	3	1	4
5		Elective III (from Open Electives)	3	1	4
6		Elective IV (from Open Electives)	3	1	4
		TOTAL	**18**	**6**	**24**

Semester III

Sl. No.	Course Code	Course Name	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 Name	Contact hours/week		Credits (*)
			L	T/P	
1	MM 652	M.Tech Dissertation Phase - II	28**		14
		TOTAL	**28**		**14**

* 1 credit in Theory/Tutorial means 1 contact hour and 1 credit in Practical/practice/project thesis means 2 contact hours in a week.

**Contact hours per week

List of Electives

Sr. No.	Course Code	Name of the Course
		Electives from the Department
1	MM 609	Materials Processing
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	Electrical and Electronic Materials
7	MM 615	Magnetism and Magnetic Materials
8	MM 616	Heat-treatment of Metals and alloys
9	MM 617	Materials for High -Temperature Applications
10	MM 618	Advanced Steel Technology

11	MM 607	Design of Materials
Open Electivesfrom other Departments		
12	ME 602	Advanced Mechanics of Materials
13	ME 603	Advanced Fluid and Thermal Science
14	ME 604	Advanced Materials and Processing
15	ME 607	Computational Fluid Dynamics
16	ME 608	Finite Element Methods
17	AP 614	Sensors and Actuators
18	AM 621	Advanced Modeling Techniques
19	EE 601	Microwave Engineering

Course Name: Concepts in Metal and Ceramic
Course Code: MM 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,
Unit 2:crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids: metallic crystal structure
Unit 3: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, Phase equlibria in ceramics

Unit 4: 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 5: Practical: Solid state, Sol-Gel, Hydrothermal and Co-precipitation process

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

Course Code: MM 602

Unit 1: Diffraction Techniques-Concepts of diffraction, scattering and radiation-matter interactions,X-ray diffraction: phase identification, strain andgrain size determination
Unit 2: 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, Electron diffraction in TEM, STM and AFM
Unit 3: Spectroscopic Techniques**-** Fundamental basis of Spectroscopic analysis EDS and WDS applications, X-ray Photon Spectroscopy and Auger electron spectroscopy
Unit 4: Thermal Analysis Techniques-DSC, DTA, TGA and Dilatometry, Electrochemical polarization characterization, Electrochemical Impedance spectroscopy.
Unit 5: Practical: XRD, TEM, SEM, Cyclic voltammetry, Tafelplot, and Salt Spray, weathrometer, cyclic corrosion test, cathodic protection monitoring, localised corrosion monitoring methods (SECM, SEVT)

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):

- *Materials Characterization, ASM Handbook Vol 10.*
- *Characterization of Materials, Vol 1, Elton N. Kaufmann*

Course Name:Thermodynamics of Materials

Course Code: MM 603

Unit 1: 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 2: Generation of Auxiliary Functions: Legendre transforms, Coefficient relations, Maxwells relations, Thermodynamic relations among state functions variables and its application to solids

Unit 3: Statistical definition of temperature and entropy, Micro- and Macro-states, Maxwell-Boltzmann distribution, Thermodynamic equilibrium: stable equilibrium states, criteria for equilibrium

Unit 4: 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

Unit 5: Free energy of binary system: Entropy of mixing, Enthalpy of mixing, Free energy of ideal, regular and real solutions, Activity, Ordered and intermediate phases, Types of solutions, Chemical potential, Unary and binary phase diagrams and Gibbs free energy

Text Book(s):

- *Ahindra Ghosh, Textbook of Materials and Metallurgical thermodynamics. Prentice Hall of INDIA 2003*

- *Taiji Nishizawa,Thermodynamics of microstructures, ASM International*

Reference Book(s):

- *R.T. DeHoff, Thermodynamics in Materials Science, McGraw-Hill, Singapore, 1993*
- *D. A. Porter and K. E. Easterling, Phase transformations in Metals and Alloys, Chapman and Hall, London, 1996*

- *David R. Gaskell, Introduction to the Thermodyanamics of Materials, Taylor & Francis, 1798*

Course Name: Polymer and Composite Technology

Course Code: MM 604

Unit 1: 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 2: Physical methods of polymer analysis such as IR, DSC, TGA, XRD etc, Viscoelasticity, Polymer blends and alloys: thermodynamics, morphology and properties.

Unit 3: Composites: Conventional polymer composites, Fiber reinforced composites, Nanofillers and their composites,

Unit 4: Composite manufacturing techniques: Solution-cast, Melt-mixing, Extrusion, Compression molding, Resin transfer, Resin infusion, Vacuum casting and electrospinning.

Unit 5: 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

Text Book(s):

- *V.R. Gowariker, Polymer Science, Wiley Eastern, 1995*
- *F. N. Billmeyer, Textbook of Polymer Science, Wiley Interscience, 1971.*

Reference Book(s):

- *Kumar and S. K. Gupta, Fundamentals and Polymer Science and Engineering, Tata McGraw-Hill, 1978*
- *Epel, J.N.:Engineering Plastics, Engineering Materials Handbook, ASM International 1988.*

Brydson, A.J. : Plastics Materials, Princeton, N.J., 1966.

Course Name: Physical and Mechanical Metallurgy

Course Code: MM 605

Unit 1: Crystal defects/imperfaction in Metals, dislocations, burger vectors, dislocations multiplications, dislocation interactions, stacking faults, Phase rule, Phase diagram, Eutectic, Iron-Carbon diagram, TTT and CCT diagrams

Unit 2: Plastic deformation in single crystal, critical resolved shear strength, deformation by slip, and deformation by twinning. Dislocations pile-ups, dislocations climb and cross slip.

Unit 3: Strengthening mechanisms: Solid solution strengthening, strengthening from grain boundaries, strains hardening, strain ageing, annealing of cold worked materials, strengthening from particles, precipitation hardening

Unit 4: 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 5: Practical: Metal Polishing and Etching, Optical Microstructural Characterization, Wear and friction, hardness testing

Text Book(s):

- *Mechanical Metallurgy, G.E. Dieter, McGraw-Hill book company, 1988*

Reference Book(s):

- *Mechanical behaviour of Materials, Williams F Hosford, Cambridge University press, 2005*
- *Materials Science and Engineering by William D. Callister, JohnWiley& Sons, Inc.*
- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*
- *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.*

Course Name: Introduction to Computational Materials Engineering

Course Code:MM 606

Unit 1: Review of programming in high level languages such as Python / Matlab / Mathematica and low level languages such as C / C++ / Fortran

Unit 2: Fitting and visualization of multidimensional data; Quantification of experimental microstructures using programs as well as software tools

Unit 3: Application of linear algebra towards solution to a system of linear and non linear equations; Numerical integration; Numerical solution of diffusion equation;

Unit 4: Computational techniques such as phase field method and Monte Carlo towards evolution of microstructure; synthetic microstructures

Unit 5: Evaluation of properties from the computed microstructures using mean field and full field approaches; data analytics using principal component analysis; ICME approach

Text Book(s):

- Introduction to Computational Materials Science – Richard LeSar, Cambridge University Press (2013). ISBN: 9781316614877

Reference Book(s):

- Mathematical Methods for Physics and Engineering, 3rd Edition – R.F. Riley, M.P. Hobson, S.J. Bence, Cambridge University Press (2012). ISBN: 9780521139878
- Integrated Computational Materials Engineering (ICME) for Metals – Mark F. Horstemeyer, TMS (2012). ISBN: 9781118022528
- 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: Military Materials

Course Code: MM 619

Unit 1: Overview metallic materials for military application, Needs of complex metals and alloys required for modern and sophisticated warfare weapons systems.

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, Aluminium alloy – Medium girder bridge and BR 90.

Unit 2: Special Alloys for Armour applications: Rolled Homogeneous Armour steels: Kanchan armour for Arjun tank, Steel armour plate, Aluminium alloy armour for light armoured vehicles, Body armour.

Unit 3: 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 4: 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 5: 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.

Text Book(s):

- *Alistair Doig, Military metallurgy, Maney publishing, 2002*

Reference Book(s):

- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*
- *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.*
- *Paul J Hazell, Armour Materials Theory and Design, CRC Press, 2015*

Course Name: Fatigue, Fracture and Failure Analysis

Course Code: MM 608

Unit 1: 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 2: Effect of Structural Features, Fatigue Crack Propagation, Stress Concentration & Fatigue, Size & Surface Effect, Effect of Metallurgical Variables& Enhancement of Fatigue Life,
Unit 3: Classification of Fracture, Theoretical Strength of Metals, Griffith Theory of Brittle Fracture, Metallographic features of Fracture, Fractography,
Unit 4: Dislocation Theory of Brittle Fracture, Effect of Tri-axial Stress, Strain Energy Release Rate, Stress Intensity Factor,
Unit 5: Fracture Toughness & Design, KIC , CTOD, JIntegral, R-Curve, Toughness of Metals & Alloys. Stress corrosion cracking.
Text Book(s):

- *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.*

ReferenceBook(s):

- *Deformation and fracture mechanics of engineering materials, 4th Ed., R. W. Hertzberg, John Wiley & Sons, 1995.*
- *Elementary engineering fracture mechanics By David BroekNoordhoff 1974.*
- *Fatigue and Fracture of Metals, W. M. Murray, John Wiley, 1952.*

Course Name: Materials Processing

Course Code:MM 609

Unit 1: Processing of Polymers- Extrusion, compounding, fibre spinning, injection moulding, compression moulding, Additive manufacturing
Unit 2: Processing of ceramics- Compaction, moulding, sintering, refractory manufacturing processes, glass manufacturing techniques.
Unit 3: Processing of Metals- Casting, Hot working, Cold working, Rolling, Annealing, Forging, Extrusion,
Unit 4: Wire drawing, Sheet metal forming, Joining Techniques, Friction stir welding, Powder Metallurgy
Unit 5: Practical: Metal processing- rolling, annealing; polymer processing-Extrusion and compression molding, electrospinning
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*

Reference Book(s)

- *Metallurgy, Applications, Advantages and Limitations, Klar, Erhard, ASM, 1983, Ohio.*
- *Plastics Processing Data Handbook (2nd Edition), Rosato, Dominick, 1997.*
- *Plastic Injection Molding: Manufacturing by Douglas M. Bryce, 2007.*
- *Concise encyclopedia of plastics, Rosato, Marlene G, 2005*
- *Extrusion: the definitive processing guide and handbook, Giles, Harold F.; Wagner, John R.; Mount, Eldridge M, 2005.*

Course Name: Nanomaterials and their application

Course Code: 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, Superhydrophobic 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 behaviour of nanomaterials: Fracture and creep;Nanomechanics and nanotribology; 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.

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: Non-Destructive Evaluation

Course Code: MM 611

Unit 1: Visual Inspection, Liquid Penetrant Testing, Magnetic Particle Testing,
Unit 2: Eddy Current Testing, Ultrasonic Testing,

Unit 3: Acoustic Emission Technique, Radiography Technique,

Unit 4: Residual Stress Analysis, In-situ Metallography, Automation and Robot in NDT,

Unit 5: Case study: Grain Size, Weldment and other Structural Components.

Test Book(s)

4. *Non-destructive Testing of welds, Baldev Raj, C.V. Subramanian and T. Jayakumar, Narosa Publishing House, 2000, Delhi.*

Reference book(s)

5. *International Advances in non-destructive testing, (Ed.) W. J. Mcgonnagle, Gordon and Breach Science Publishers, 1981, NY.*
6. *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 Blends and Nanocomposites

Course Code:MM 612

Unit 1: 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 2: Blends of amorphous & semi-crystalline polymers, inter-penetrating networks, thermoplastic and thermoset blends, rubber toughened polymers, particulate and fiber reinforced composites.

Unit 3: Nanostructured materials like nanoclay, carbon nanotubes, graphene, magnetic nanoparticles etc. and polymernanocomposites. Surface treatment of the reinforcing materials and interface/interphase structures of composites/nanocomposites.

Unit 4: Various processing techniques like solution mixing, melt processing. Physical and thermo-mechanical properties of polymer blends, composites and nanocomposites.

Unit 5: Potential Applications in Defence.

Text Book(s)

- *Textbook of Polymer Science, Fred W. Billmeyer (Wiley)*
- *Polymer alloys and blends by L AUtracki*

Reference Book(s)

- *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

Course Name: Biomaterials

Course Code: MM 613

Unit 1: Introduction to biomaterials, Tissue Engineering, Biocompatibility, Biodegradation Biofluids and medical devices, Biostructures

Unit 2: Ceramic based biomaterials, metallic biomaterials, polymer based biomaterials, Biofluidici, medical devices, Biostructures

Unit 3: Nano-biomaterials: Self assembly of nanomaterials, hydrophilic, hydrophobic and surfaces, biomimicking

Unit 4: Medical imaging, electrospinning of scaffold structures, Additive manufacturing of medical devices, biofluidics and biostructure

Unit 5: 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*

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 Hall*

Course Name: Electrical and Electronic Materials

Course Code:MM 614

Unit 1: Band Theory of Solids, Semiconductors, Electron Effective Mass, Density of States in an Energy Band, Fermi-Dirac Statistics

Unit 2: Intrinsic Semiconductors, Extrinsic Semiconductors, Temperature Dependence of Conductivity, Recombination and Minority Carriers, Continuity Equations, Optical Absorption, Ideal *pn*Junction and Band Diagram, Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET),

Unit 3: Supercapacitors, Types of supercapacitor. Ceramic substrates (Al_2O_3, SiC, BeO, AlN, Glass ceramic etc.), Processing of Thick Film, Thin Film, Multi layer Packages, Properties of Ceramic Insulators, Ceramic Capacitor

Unit 4: Dielectrics-Barium titanate, Other titanate based dielectrics, Composition with high Pb content, Processing of thick and thin film capacitors, Integrated capacitors,

Unit 5: Relaxor Dielectrics, Piezoelectric Ceramics and electrostrictive materials, Powders and Processes, Piezoelectric ceramic applications. Nano Ceramics: Different Compositions, Synthesis, Applications, Introduction to electric vehicle.

Text Book(s)

- *Materials for Electronics: R.C. Buchanon.*
- *Introduction to Ceramics: W.D.Kingery*
- *Fundamentals of Ceramics: Barsoum*

Reference Book(s)

- *Physical Ceramics for Engineers: VanVlack*
- *Handbook of Ceramics: Editor S. Kumar Ceramic*
- *Electronic Ceramics: B.C.H Steele.*
- *Adv. Ceram. Materl. VolI by K Furuta& K U chino*

Course Name: Magnetism and Magnetic Materials

Course Code: MM 615

Unit 1: Moment of a current loop, Orbital angular momentum and magnetic moments, Spin magnetic moment, gyromagnetic ratio, Vector atom model.

Unit 2: Classical diamagnetism, Superconductors, Paramagnetic moments, classical paramagnetic.

Unit 3: Weiss molecular field, Brillioun function and spontaneous magnetization, Curie Weiss law, Magnetocaloric effect, Exchange interaction, Spin waves, Antiferrognetism and Néel temperature, Exchange Bias effect and applications, Ferrimagnetism: Spinel structure and Ferrite moments.

Unit 4: Uniaxial and Cubic anisotropy, Shape anisotropy, Crystal field effects, Origin of magnetic domains, Equilibrium domain size and domain wall, Néel and Bloch Walls

Unit 5: Differentiation between Soft and hard magnetic materials, Finemet alloys, Rare earth permanent magnets, Magnetostriction: TERFNOL-D, Multiferroics, Magnetic Anomaly Detection.

Text Book(s):

- *Introduction to Magnetic Materials*

B. D. Cullity and C. D. Graham; IEEE Press, A. JonWiley & Sons Publications

Reference Book(s):

- *Fausto Florillo, Measurement and Characterization of Magnetic Materials, Elsevier Academic Press, 2004*
- *Modern magnetic Materials: Principles and applications*
  Robert C. O'Handaley; Wiley-Interscience Publications

- *Physics of magnetism and Magnetic materials*

K. H. J. Bushaw and F. R. de Boer; Kluwer Academic Publishers

Course Name: Heat-treatment of Metals and Alloys

Course Code:MM 616

Unit 1: Steel Heat-Treatment, Annealing, Stress relief annealing, Process Annealing, Normalizing, Spheroidizing, Tempering , Quenching, Hardening, TTT Curve, Hardenability,
Unit 2: Case hardening, carburizing, Nitriding, Boronizing,
Unit 3: Flame hardening, Induction hardening, Laser hardening, Electron beam hardening,
Unit 4: Heat treatment of Aluminium, Titanium and Magnesium Alloys
Unit 5: Deformation and annealing.
Text Book(s):

- Heat Treatment Principles & Techniques, TV Rajan, CP Sharma & Ashok Sharma Prntice Hall of India, New Delhi, 2007.
- Metallurgy for Engineers-EC Rollason, 4th Ed, Edward Arnold, UK, 1973.
- Introduction to Physical Metallurgy, S H Avner, TATA Mc-Graw Hill, New Delhi, 2001.

Reference Book(s)

- Engineering Physical Metallurgy by Yuri Lakhtin, Moscow, MIR Publishers, 1963.
- 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

Unit 1: Melt processing of Superalloy, Single crystal Superalloy, Processing of Superalloy, Alloying effect.
Unit 2: Oxide Dispersion Strengthened alloys. Powder Metallurgy
Unit 3: High temperature deformation, Room and high temperature Wear, Advanced coating materials
Unit 4: Fiber Reinforced Composite Superalloy,
Unit 5: Processing and properties of advanced Structural Ceramics.
Text Book(s):

- *Superalloys, supercomposites and super ceramics, ed. J. K Tien and T. Caulfield, Academic Press, 1989, Boston.*
- *High temperature structural materials, R. W. Cahn, Chapman and Hall, 1996, London.*

Reference Book(s):

- *Materials for High Temp. Engg. Applications, G. W. Meetham and M.H. Van de Voorde, Springer, 2000, Berlin.*
- *Friction, wear and Lubrications, K.C. Ludema, CRC Press, 1996.*
- *Powder Metallurgy: Science, Technology, and Materials Anish Upadhyaya and G. S. Upadhyaya, Taylor & Francis, 2011*

Course Name: Advanced Steel Technology

Course Code: MM 618

Unit 1: Strengthening mechanisms: Work hardening, Solid solution strengthening, Grain size refinement, Dispersion strengthening

Unit 2: Low Carbon steels: Austenite to ferrite transformation, High strength low alloys steels, Interstitial free steels, Dual phase and TRIP steels

Unit 3: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 5: Special steels: Bainite: Upper and lower Bainite microstructures, Bainite transformation mechanisms and transition, nanostructured Bainite; Marraging steels, Stainless steel, TWIP steels, Case studies for defence applications.

Text Book(s):

- *Steels: Processing, Structure, and Performance, George Krauss; ASM International*

Reference Book(s):

- *Steels: Microstructure and Properties HKDH Bhadeshia and Sir R. Honeycomb; Butterworth-Heinmann, Elsevier Publications*

Course Name: Design of Materials

Course Code: MM607

Unit 1: First and Second law of diffusion, Solution to diffusion equations and error function, Types of diffusion, Krikendall effect and applications

Unit 2: Generic classes of Metallic alloys and applications, Equilibrium shapes of grains and phases, Applications of phase diagrams: Soft solders, Zone Refinement of Semiconductors, Bubble free Ice

Unit 3: Kinetics of nucleation, diffusive and Martensitic phase transformations, Fine grain castings, Rapid solidification and amorphous materials, Light alloys: Age-hardening and thermal stability

Unit 4: Mechanical properties of Ceramics, Statistics of Brittle fracture: Flaw size and dispersion of strength, Weibull distribution, Design of pressure windows

Unit 5: Fibrous, particulate and foamed composites, Improving stiffness, strength and toughness. Case studies in Defence applications: Turbine blades, bullet-proof vests, uses of metal matrix composites and carbon-carbon composites.

Text Book(s):

- *Engineering Materials 1 Michale F. Ashbey and David R. H. Jones; Butterworth-Heinmann, Elsevier Publications*
- *Engineering Materials 2 Michale F. Ashbey and David R. H. Jones; Butterworth-Heinmann, Elsevier Publications*

Reference Book(s):

- *D. A. Porter and K. E. Easterling, Phase transformations in Metals and Alloys, Chapman and Hall, London, 1996*
- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*

Department of Metallurgical and Materials Engineering

M. Tech in Corrosion Technology

Brief Description:

The Department of Metallurgical and Materials Engineering aims to develop a core competence in teaching and research in the areas of materials 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 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.

This programme is open for DRDO Scientists/Officers, Officers from Tri-services, Industries, PSU. This program is also open to friendly foreign countries.

At present, the Department is equipped with characterization facilities 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)
- 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
- Piezo-meter
- Corona Poling Unit
- UV-Visible Spectroscopy
- Contact Angle measurement unit
- PPMS
- Ball Milling
- CH-Analyzer

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 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. 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:

B.E. / B. Tech or equivalent in any branch of Engineering/Technology; M.Sc or equivalent in any branch of Science.

Organization:

The programme is of four-semester duration. In first and second semester have six courses respectively including one lab in the first semester. Third semester comprises the dissertation work in addition to two courses and fourth semester have only the dissertation work. In the first, second and third semester the students have options to choose elective courses. In the first, second and third semesters there will be one mid semester examination and a final examination for theory subjects. After the second semester, scholarship students are encouraged do a summer internship for about one and half months at their place of 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. As part of the dissertation work in the third semester, the dissertation work will be evaluated by the expert committee at the end of the third semester. At the end of the final semester, students will submit their thesis before going for final evaluation and present their project works before the expert committee (consists of External / Internal members from various R&D organisations / Universities etc.). No credits are counted for attending an audit course.

Course Structure

Semester I

Sl.No	Course Code	Course	Contact hours/week		Total Credits (*)
			L	T/P	
1	MM 601	Concepts in Metal and Ceramic	3	2	4
2	MM 620	Introduction to Corrosion	3	1	4
3	MM 621	Welding Science and Technology	3	1	4
4	MM 602	Materials Characterization	3	2	4
5	MM 605	Physical and Mechanical Metallurgy	3	2	4
6	MM 606	Introduction to Computational Materials Engineering	3	1	4
Total			18	9	24

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

Semester II

Sl.No	Course Code	Course Name	Contact hours/week		Credits
			L	T/P	
1	MM 622	High temperature Corrosion	3	2	5
2	MM 623	Corrosion mitigation	3	1	4
3		Elective – I (from Department Electives)	3	1	4
4		Elective – II (from Department Electives)	3	1	4
5		Elective – III (from open Electives)	3	1	4
6		Elective – IV (from open Electives)	3	1	4
Total			18	7	24

Semester III

Sl.No	Course Code	Course Name	Contact hours/week		Credits
			L	T/P	
1	MM651	M.Tech Dissertation Phase – I	28		14
Total			28		14

Semester IV

Sl.No	Course Code	Course Name	Contact hours/week		Credits
			L	T/P	
1	MM652	M.Tech Dissertation Phase – II	28		14
Total			28		14

* 1 Credit in Theory/Tutorial means 1 contact hour and 1 credit in practical/Project Thesis means 2 contact hours in a week

List of Electives

S.N.	Course code	Name of the course
Electives from the Department		
1	MM610	Nanomaterialsand Their Applications
2	MM 607	Design of Materials
3	MM 608	Fatigue, Fracture, and Failure Analysis
4	MM 617	Materials for High temperature applications
5	MM 611	Non-Destructive Evaluations
6	MM 616	Heat treatment of Metals and alloys
7	MM 624	Advanced Coating
8	MM 625	Surface Science and Engineering
9	MM 612	Polymers Blends and Nanocomposites
10	MM 626	Reliability Engineering

Electives from other Departments		
11	ME602	Advanced Mechanics of Materials
12	ME603	Advanced Fluid and Thermal Science
13	ME604	Advanced Materials and Processing
14	ME607	Computational Fluid Dynamics
15	ME608	Finite Element Methods
16	AP 610	Nanotechnology
17	AP614	Sensors and Actuators
18	AM621	Advanced Modelling Techniques
19	EE601	Microwave Engineering

Course Name: Concepts in Metal and Ceramic

Course Code: MM 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,
Unit 2:crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids: metallic crystal structure
Unit 3: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, Phase equlibria in ceramics

Unit 4: 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 5: Practical: Solid state, Sol-Gel, Hydrothermal and Co-precipitation process

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: Introductions to Corrosion

Course Code: MM 620

Unit 1: 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 2: Electrode Kinetics and Polarization Phenomenon: Electrode – Solution interface – Definition & types of polarization. Exchange current density and polarization relationships. Polarization techniques – corrosion rate determination.
Unit 3: Mixed Potential concepts and Basics.Mixed potential theory – bimetallic couples. Activation and diffusion controlled mixed electrodes.Origin of electrochemical noise and its application.
Unit 4: Forms of Corrosion – Uniform, Localized & Metallurgical influenced – Pitting, Crevice, Galvanic & Intergranular Corrosion, Mechanically Assisted, Environmentally Induced & Microbiologically influenced Corrosion.
Unit 5: Nersteqn, 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.
TextBook(s):
- *Mars G. Fontana, Corrosion Engineerig, 3rd Ed., McGraw-Hill, Singapore, 1987*

Reference Book(s):
- *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

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 2: 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 3: 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 4: Application of above principles to welding of carbon and alloy steels, cast irons, stainless steels, aluminium and titanium alloys. Weld decay, problems associated with welding of metals and alloys. Stabilized alloy,

Unit 5: Pre and post welding Heat treatment processes, Failure analysis

Text Book(s):

- *K. Easterling, Introduction to Physical Metallurgy of Welding, Butterworths Pub., 1983.*

Reference Book(s)

- *Sindo Kou, Welding Metallurgy, John Wiley & Sons, New York, 1987.*
- *S.A. David (Ed.), Advances in Welding Science and Technology, American Society for Metals, Ohio, 1986.*

Course Name: Materials Characterization

Course Code: MM 602

Unit 1: Diffraction Techniques-Concepts of diffraction, scattering and radiation-matter interactions,X-ray diffraction: phase identification, strain andgrain size determination

Unit 2: 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, Electron diffraction in TEM, STM and AFM

Unit 3: Spectroscopic Techniques**-** Fundamental basis of Spectroscopic analysis EDS and WDS applications, X-ray Photon Spectroscopy and Auger electron spectroscopy

Unit 4: Thermal Analysis Techniques-DSC, DTA, TGA and Dilatometry, Electrochemical polarization characterization, Electrochemical Impedance spectroscopy.

Unit 5: Practical: XRD, TEM, SEM, Cyclic voltammetry, Tafelplot, and Salt Spray, weathrometer, cyclic corrosion test, cathodic protection monitoring, localised corrosion monitoring methods (SECM, SEVT)

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):

- *Materials Characterization, ASM Handbook Vol 10.*
  Characterization of Materials, Vol 1, Elton N. Kaufmann

Course Name: Physical and Mechanical Metallurgy

Course Code: MM 605

Unit 1: Crystal defects/imperfaction in Metals, dislocations, burger vectors, dislocations multiplications, dislocation interactions, stacking faults, Phase rule, Phase diagram, Eutectic, Iron-Carbon diagram, TTT and CCT diagrams

Unit 2: Plastic deformation in single crystal, critical resolved shear strength, deformation by slip, and deformation by twinning. Dislocations pile-ups, dislocations climb and cross slip.

Unit 3: Strengthening mechanisms: Solid solution strengthening, strengthening from grain boundaries, strains hardening, strain ageing, annealing of cold worked materials, strengthening from particles, precipitation hardening

Unit 4: 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 5: Practical: Metal Polishing and Etching, Optical Microstructural Characterization, Wear and friction, hardness testing

Text Book(s):

- *Mechanical Metallurgy, G.E. Dieter, McGraw-Hill book company, 1988*

Reference Book(s):

- *Mechanical behaviour of Materials, Williams F Hosford, Cambridge University press, 2005*
- *Materials Science and Engineering by William D. Callister, JohnWiley& Sons, Inc.*
- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*
- *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.*

Course Name: Introduction to Computational Materials Engineering

Course Code:MM 606

Unit 1: Review of programming in high level languages such as Python / Matlab / Mathematica and low level languages such as C / C++ / Fortran

Unit 2: Fitting and visualization of multidimensional data; Quantification of experimental microstructures using programs as well as software tools

Unit 3: Application of linear algebra towards solution to a system of linear and non linear equations; Numerical integration; Numerical solution of diffusion equation;

Unit 4: Computational techniques such as phase field method and Monte Carlo towards evolution of microstructure; synthetic microstructures

Unit 5: Evaluation of properties from the computed microstructures using mean field and full field approaches; data analytics using principal component analysis; ICME approach

Text Book(s):

- Introduction to Computational Materials Science – Richard LeSar, Cambridge University Press (2013). ISBN: 9781316614877

Reference Book(s):

- Mathematical Methods for Physics and Engineering, 3rd Edition – R.F. Riley, M.P. Hobson, S.J. Bence, Cambridge University Press (2012). ISBN: 9780521139878
- Integrated Computational Materials Engineering (ICME) for Metals – Mark F. Horstemeyer, TMS (2012). ISBN: 9781118022528
- 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: High Temperature Corrosion

Course Code: MM 622

Unit 1: Free energy, Partial pressure, Ellingham diagram
Unit 2: 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 3: 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 4: Corrosion product evaporation, analyses of kinetic data; alloy oxidation-kinetics, mechanisms, morphology, hot corrosion of metals and alloys-mechanisms and examples.
Unit 5: High temperature corrosion in various applications
Unit 6: Measurements of High – Temperature Degradation, High Temperature Corrosion & Degradation Processes.
Unit 7: High Temperature Corrosion Testing
TextBook(s):
- *Per Kofstad, High Temperature Corrosion, Elsevier Applied Science, 1988.*
- *U.R. Evans, Corrosion and Oxidation of Metals, Arnold Publ., London, 1981.*

Reference Book(s):
- *N. Birks and G.H. Meier, Introduction to Oxidation of Metals, Edward Arnold, London, 1983.*
- *A.S. Khanna, Introduction to High Temperature Oxidation and Corrosion, ASM International, Materials Park, Ohio, 2002.*
- *Phase transformation in metals and alloys, Porter and Easterling.*

Course Name: Corrosion Mitigation
Course Code: MM 623

Unit 1: Protective Coatings – Introduction, coatings & Coating Processes, Supplementary protection systems, Surface preparation. Classification of inhibitors, Corrosion inhibition Mechanism, Selection of an inhibitor system.
Unit 2: 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 3: Cathodic and Anodic Protection – principles & classifications, mechanism of Cathodic and anodic protections – influencing factors and Monitoring,
Unit 4: Corrosion protection in extreme environment such as nuclear irradiation, high pressure etc.
Unit 5: 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.

TextBook(s):

- *Corrosion: Environment and Industries, Metals Handbook, Vol. 13c, Park Ohio, 1984, 10th Ed., ASM Metals, Ohio, 1987.*
- *N.D. Tomashov, Theory of Corrosion and Protection of Metals, Macmillan, 1967.*
- *M.G. Fontana, Corrosion Engineering, 3rd Ed., McGraw-Hill, 1985. 4. H.H. Uhlig, Corrosion & Corrosion Control, Wiley, 1985.*

Reference Book(s)

- *R. Lambourne and T.A. Strivens, Paint and Surface Coatings, Ellis Horwood D, Chichster, 1987.*
- *C.G. Munger, Corrosion Prevention by Protective Coatings, NACE Pub., Houston, 1984.*
- *Surface Finishing, Cleaning & Coatings, ASM Handbook, Vol. 5, 1994.*
- *J. Biesiek and J. Weber Portcullis, Electrolytic and Chemical Conversion Coatings, Red Hill Press, 1976.*
- *F.A. Lowenheim, Electroplating: Fundamentals of Surface Finishing, McGraw-Hill, New York, 1978.*

Course Name: Fatigue, Fracture and Failure Analysis

Course Code: MM 608

Unit 1: 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 2: Effect of Structural Features, Fatigue Crack Propagation, Stress Concentration & Fatigue, Size & Surface Effect, Effect of Metallurgical Variables& Enhancement of Fatigue Life,

Unit 3: Classification of Fracture, Theoretical Strength of Metals, Griffith Theory of Brittle Fracture, Metallographic features of Fracture, Fractography,

Unit 4: Dislocation Theory of Brittle Fracture, Effect of Tri-axial Stress, Strain Energy Release Rate, Stress Intensity Factor,

Unit 5: Fracture Toughness & Design, KIC , CTOD, JIntegral, R-Curve, Toughness of Metals & Alloys. Stress corrosion cracking.

Text Book(s):

- *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.*

ReferenceBook(s):

- *Deformation and fracture mechanics of engineering materials, 4th Ed., R. W. Hertzberg, John Wiley & Sons, 1995.*
- *Elementary engineering fracture mechanics By David BroekNoordhoff 1974.*
- *Fatigue and Fracture of Metals, W. M. Murray, John Wiley, 1952.*

Course Name: Nanomaterials and their application

Course Code: 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, Superhydrophobic 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 behaviour of nanomaterials: Fracture and creep;Nanomechanics and nanotribology; 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.

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: Advanced Coatings
Course Code: MM 624

Unit 1: Requirement of protective coatings, classification of organic, polymeric and inorganic coatings, conversion coatings, metallic coatings, electrodeposition and elecotroless coatings.

Unit 2: Paint coatings for corrosion protection, role of resins, pigment, additives and solvents.

Unit 3: 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 4:Coatings for underground pipelines, storage tanks, overhead pipelines, offshore structures, ship hulls, risers, reinforced bars and concrete structures. Testing and evaluation. TBC, EBC

Unit 5: Case studies

Text Book(s):

- *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.*

Reference Book(s):

- *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: Non-Destructive Evaluation

Course Code: MM 611

Unit 1: Visual Inspection, Liquid Penetrant Testing, Magnetic Particle Testing,

Unit 2: Eddy Current Testing, Ultrasonic Testing,

Unit 3: Acoustic Emission Technique, Radiography Technique,

Unit 4: Residual Stress Analysis, In-situ Metallography, Automation and Robot in NDT,

Unit 5: Case study: Grain Size, Weldment and other Structural Components.

Test Book(s)

7. *Non-destructive Testing of welds, Baldev Raj, C.V. Subramanian and T. Jayakumar, Narosa Publishing House, 2000, Delhi.*

Reference book(s)

8. *International Advances in non-destructive testing, (Ed.) W. J. Mcgonnagle, Gordon and Breach Science Publishers, 1981, NY.*
9. *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: Surface Science and Engineering

Course Code: MM 625

Unit 1: Theory of surface reconstructions, electronic properties of surfaces, interfaces and overlayers. Characterisation of surfaces by photons, electrons and ions as probes.

Unit 2: The effect of substrate surface structure on the overlayer properties. Theoretical and experimental evaluation of surface energies,

Unit 3: Solidliquid and solid-gas interfaces-surface potentials, colloids, sedimentation, adsorption and reaction on surfaces. Damage of the surfaces by corrosion and wear.

Unit 4: Wear mechanisms and categories of wear. Surface modifications by diffusion, heat treatment and by coatings, Surface Processing laser, electrons and ions.

Unit 5: Physical and vapour deposition, CVD, ion-implantation, thermal spray coating.

Test Book(s):

- *M. Prutton, Surface Physics, 2nd Ed., Clarendon Press, Oxford, 1983.*
- *A.W. Adamson, Physical Chemistry of Surfaces, 3rd Ed., Wiley, 1976.*

Reference Book(s):

- *K.G. Budinski, Surface Engineering for Wear Resistance, Prentice-Hall, 1988.*
- *K.H. ZumGahr, Microstructure and Wear of Materials, Elsevier, 1987.*

Course Name: Design of Materials

Course Code: MM607

Unit 1: First and Second law of diffusion, Solution to diffusion equations and error function, Types of diffusion, Krikendall effect and applications

Unit 2: Generic classes of Metallic alloys and applications, Equilibrium shapes of grains and phases, Applications of phase diagrams: Soft solders, Zone Refinement of Semiconductors, Bubble free Ice

Unit 3: Kinetics of nucleation, diffusive and Martensitic phase transformations, Fine grain castings, Rapid solidification and amorphous materials, Light alloys: Age-hardening and thermal stability

Unit 4: Mechanical properties of Ceramics, Statistics of Brittle fracture: Flaw size and dispersion of strength, Weibull distribution, Design of pressure windows

Unit 5: Fibrous, particulate and foamed composites, Improving stiffness, strength and toughness. Case studies in Defence applications: Turbine blades, bullet-proof vests, uses of metal matrix composites and carbon-carbon composites.

Text Book(s):

- *Engineering Materials 1 Michale F. Ashbey and David R. H. Jones; Butterworth-Heinmann, Elsevier Publications*
- *Engineering Materials 2 Michale F. Ashbey and David R. H. Jones; Butterworth-Heinmann, Elsevier Publications*

Reference Book(s):

- *D. A. Porter and K. E. Easterling, Phase transformations in Metals and Alloys, Chapman and Hall, London, 1996*
- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*

Course Name: Reliability Engineering
Course Code: MM 626

UnitI: 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

Unit2: Failure Mode and Effect Analysis (FMEA) Basic Principles and General Fundamentals of FMEA Methodology

Unit3: Design of Experiments Analysis of Variance Technique-Strategy of Experimental Design

Unit4: 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.

Unit5: 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.

Text Book(s):

- *G. Haribaskaran, Probability, Queuing Theory & Reliability Engineering, Laxmi publications, Second Edition.*
- *D. H. Besterfield, Glen H. Besterfield and M. Besterfield-Sacre, Total Quality Management, Pearson Publications, Third Edition.*

Reference Book(s):

- *E. Walpole, H. Myers and L. Myers, Probability and Statistics for engineering and Scientists, Pearson Publications, Eighth Edition.*
- *BrendBretsche, Reliability in Automotive and Mechanical Engineering, Springer Publications.*
- *G. Pahl, W. Bietz, J. Feldhusen and K. H. Grote, Engineering Design a Systematic approach, Springer Publications, Third Edition.*
- *V. Sankar, System Reliability Concepts, Himalaya Publishing House, 2015.*
- *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, 2003.*

Course Name: Materials for High-Temperature Applications

Course Code: MM 617

Unit 1: Melt processing of Superalloy, Single crystal Superalloy, Processing of Superalloy, Alloying effect.

Unit 2: Oxide Dispersion Strengthened alloys. Powder Metallurgy

Unit 3: High temperature deformation, Room and high temperature Wear, Advanced coating materials

Unit 4: Fiber Reinforced Composite Superalloy,

Unit 5: Processing and properties of advanced Structural Ceramics.

Text Book(s):

- *Superalloys, supercomposites and super ceramics, ed. J. K Tien and T. Caulfield, Academic Press, 1989, Boston.*
- *High temperature structural materials, R. W. Cahn, Chapman and Hall, 1996, London.*

Reference Book(s):

- *Materials for High Temp. Engg. Applications, G. W. Meetham and M.H. Van de Voorde, Springer, 2000, Berlin.*
- *Friction, wear and Lubrications, K.C. Ludema, CRC Press, 1996.*
- *Powder Metallurgy: Science, Technology, and Materials Anish Upadhyaya and G. S. Upadhyaya, Taylor & Francis, 2011*

Course Name: Heat-treatment of Metals and Alloys

Course Code:MM 616

Unit 1: Steel Heat-Treatment, Annealing, Stress relief annealing, Process Annealing, Normalizing, Spheroidizing, Tempering , Quenching, Hardening, TTT Curve, Hardenability,

Unit 2: Case hardening, carburizing, Nitriding, Boronizing,

Unit 3: Flame hardening, Induction hardening, Laser hardening, Electron beam hardening,

Unit 4: Heat treatment of Aluminium, Titanium and Magnesium Alloys

Unit 5: Deformation and annealing.

Text Book(s):

- Heat Treatment Principles & Techniques, TV Rajan, CP Sharma & Ashok Sharma Practice Hall of India, New Delhi, 2007.
- Metallurgy for Engineers-EC Rollason, 4th Ed, Edward Arnold, UK, 1973.
- Introduction to Physical Metallurgy, S H Avner, TATA Mc-Graw Hill, New Delhi, 2001.

Reference Book(s)

- Engineering Physical Metallurgy by Yuri Lakhtin, Moscow, MIR Publishers, 1963.
- Grain boundary migration in metals: thermodynamics, kinetics, applications, G. Gottstein & L. Shvindlerman, Boca Raton (FL), CRC, 1999

Course Name: Polymer Blends and Nanocomposites

Course Code:MM 612

Unit 1: 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 2: Blends of amorphous & semi-crystalline polymers, inter-penetrating networks, thermoplastic and thermoset blends, rubber toughened polymers, particulate and fiber reinforced composites.

Unit 3: Nanostructured materials like nanoclay, carbon nanotubes, graphene, magnetic nanoparticles etc. and polymernanocomposites. Surface treatment of the reinforcing materials and interface/interphase structures of composites/nanocomposites.

Unit 4: Various processing techniques like solution mixing, melt processing. Physical and thermo-mechanical properties of polymer blends, composites and nanocomposites.

Unit 5: Potential Applications in Defence.

Text Book(s)

- *Textbook of Polymer Science, Fred W. Billmeyer (Wiley)*
- *Polymer alloys and blends by L AUtracki*

Reference Book(s)

- *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

M.Sc. Food Technology
Department of Applied Chemistry

(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			21
	ACFT 514	Seminar	3	1	4
Credits		Total			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 any Department

Elective II

1	AC-605	Advanced Analytical Techniques
2	AC-604	Chemical Process Design
3	ACFT 515	Advanced Food Technology
4		Open Elective from any Department
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 control for 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.

Unit-8. Food Terrorism: Concept of Bio/Food terrorism and their remediation methods

Unit-9: Basic Food Testing Kits

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.,

Unit-3. 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-4. Introduction to Nutraceuticals: definitions, synonymous terms, basis of claims for a compounds as a nutraceutical, regulatory issues for nutraceuticals.

Unit-5. **Study of Defence Ration Scales**

Unit-6. Protection of Food During Nuclear Fallout. Types of food and their protection during nuclear war, classification of food items which are affected by nuclear radiations, arrangements/fortifications, delivery of rations in nuclear environment

Unit-7: **Food and Thought**: Effect of Food on Human psychology

Unit-8: **Junk food**: Junk Foods and their health effects.

Unit-9: **Monsoon/Sea Sickness Diet**: Issues faced by IN related to monsoon/sea sickness diet.

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.

Unit-5. Natural preservation methods using sugar, high salt and fermentation.

Unit-6: Perishability of the items. Studies on decrease perishability of items onboard ships/submarines by improving storing conditions, types of packaging, material of packaging, need of washing of fruits and vegetables using nitrogen etc.

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

Fellows, P. and Ellis H. 1990. Food Processing Technology: Principles and Practice, New York.
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. Downstream process. 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, New Delhi.
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.

Unit-3: 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.

Unit-4: 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.

Unit-5: 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 practical approach, Mortimre, S., and Wallace, C., (2005) 2nd Ed, Aspen.
3. American Society for Quality by Surak, J.G., and Wilson, S. (2007), 2nd Ed., Quality Press

TECHNOLOGY OF MILK AND MILK PRODUCTS (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 dairy equipments. 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, dahi shrikhand 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, and products Fermented and non-fermented beverages, Fruit and vegetable, beverages and 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.
12. 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

Reference

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 and designed meat products. 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: Theory of 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

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 smart materials: 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.

Research Methodology (DRC-601)

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: Thermo Gravimetry (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.

Unit-2: 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).

Unit-3: High hydrostatic pressure in food processing, High intensity pulsed electric field processing, High pressure CO_2 processing, Ozone (O_3) 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-4. 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 200

PG DIPLOMA IN FIRE ENGINEERING AND INTEGRATED SAFETY

SEMESTER WISE COURSE STRUCTURE

Semester I

SN	Course Code	Course Title	L	T	P	C
THEORY :						
1	FE -501	Probability, Statistical & Simulation techniques	4	-	-	4
2	FE -502	Combustion and Heat transfer	4	-	-	4
3	FE -503	Industrial safety	4	-	-	4
4	FE -504	Electrical Safety	4			4
5	FE -505	Quality and Reliability Engineering	4			4
6	FE- 506	**Elective– I** A. Environment Safety OR B. Nuclear and radiation safety	4			4
PRACTICAL Allotment of project topic*						
7	FE -507	Industrial Safety Laboratory	-	-	4	2
		TOTAL				26

***Internal project supervisors will be from DIAT and external will be from CFEES**

Semester II

SN	Course Code	Course Title	L	T	P	C
THEORY :						
1	FE – 507	Fire safety	4			4
2	FE – 509	SHE Legislation	4			4
3	FE – 510	Risk and hazard assessment	4			4
4	FE – 511	Explosive safety: Accident investigation and control measures	4			4
5	FE – 512	Elective II A. Human Factors and Behaviour based safety	4			4
PRACTICALS						
6	FE – 513	**Fire safety practical**	-		4	2
	FE - 514	Project work	-		8	4
TOTAL						26

SYLLABUS DETAILS
Semester I

AM – 501 : PROBABILITY, STATISTICAL & SIMULATION TECHNIQUES

UNIT I PROBABILITY AND RANDOM VARIABLE

Probability – Random variables – Moments – Moment generating function – Standard distributions –Functions of random variables – Two-dimensional R.Vs – Correlation and Regression.

UNIT II ESTIMATION THEORY

Principle of least squares – Regression – Multiple and Partial correlations – Estimation of Parameters– Maximum likelihood estimates – Method of moments.

UNIT III TESTING OF HYPOTHESIS

Sampling distributions – Test based on Normal, t-distribution, chi-square, and F-distributions – Analysis of variance – One-way and two way classifications.

UNIT IV INTRODUCTION TO SIMULATION:

Introduction to modelling and simulation, Classification of systems into continuous and discrete, Structural characterization of mathematical model and validation techniques.

REFERENCES

1. Freund John, E and Miller, Irvin, "Probability and Statistics for Engineering", 5th Edition, Prentice Hall, 1994.
2. Jay, L.Devore, "Probability and Statistics for Engineering and Sciences", Brooks Cole Publishing Company, Monterey, California, 1982.
3. Anderson, O.D, "Time series Analysis: Theory and Practice", I.North-Holland, Amsterdam, 1982.
4. Gupta, S.C and Kapoor, V.K., "Fundamentals of Mathematical Statistics", Sultan Chand and Sons, New Delhi, 1999.
5.Modelling Mathematical Methods & Scientific Computations, 1995, Nicola Bellomo & Luigi Preziosi, CRC Press.
6. Systems Modelling and Analysis, 2003, I.J. Nagrath, M. Gopal, Tata McGraw Hill, New Delhi.

ME - 502 : COMBUSTION AND HEAT TRANSFER:

UNIT I

Basic principles including chemical equilibrium, Arrhenius law, and Rankine-Hugoniot relations. Multi-component conservation equations with chemical reaction will be introduced. Combustion of fuel in premixed flames and in non-premixed flames gaseous fuels, liquid fuels, and solid fuels.

UNIT II

Various characteristics of premixed and diffusion flames which covers flame structure, flame stability, flame stabilization, flammability limit, quenching distance, and thermal explosion.

UNIT III

Combustion phenomena in gas turbines, gasoline engines, diesel engines and power plants. A matched asymptotic expansion technique and its application in analyzing flame structures.

UNIT IV MODES OF HEAT TRANSFER

Conduction: General Differential equation of Heat Conduction– Cartesian and Polar Coordinates – One Dimensional Steady State Heat Conduction –– plane and Composite Systems – Conduction with Internal Heat Generation.

Convection: Free and Forced Convection - Hydrodynamic and Thermal Boundary Layer. Free and Forced Convection during external flow over Plates and Cylinders and Internal flow through tubes.

Radiation:

Black Body Radiation – Grey body radiation - Shape Factor – Electrical Analogy – Radiation Shields. Radiation through gases.

Textbook :

1. "Combustion – Physical and Chemical principles, Modelling and Simulation, Experiments, Pollutant formation " by Warnatz, Maas and Dibble
2. "An introduction to Combustion – Concepts and Application", by Stephen R. Turns
3. Nag, P.K., "Heat Transfer", Tata McGraw Hill, New Delhi, 2002
New Delhi,
4. Yadav, R., "Heat and Mass Transfer", Central Publishing House, 1995.

MS/CF – 503 : INDUSTRIAL SAFETY

UNIT I PHYSICAL HAZARDS

Noise, compensation aspects, noise exposure regulation, properties of sound, occupational damage, risk factors, sound measuring instruments, octave band analyzer, noise networks, noise surveys, noise control program, industrial audiometry, hearing conservation programs-vibration, types, effects, instruments, surveying procedure, permissible exposure limit.
Ionizing radiation, types, effects, monitoring instruments, control programs, OSHA standard-nonionizing radiations, effects, types, radar hazards, microwaves and radio-waves, lasers, TLV-cold environments, hypothermia, wind chill index, control measures- hot environments, thermal comfort, heat stress indices, acclimatization, estimation and control

UNIT II CHEMICAL HAZARDS

Recognition of chemical hazards-dust, fumes, mist, vapour, fog, gases, types, concentration, Exposure vs. dose, TLV - Methods of Evaluation, process or operation description, Field Survey, Sampling methodology, Comparison with OSHAS Standard. Air Sampling instruments, Types, Measurement Procedures, Instruments Procedures, Gas and Vapour monitors, dust sample collection devices, personal sampling, Methods of Control - Engineering Control, Design maintenance considerations, design specifications - General Control Methods.

UNIT III OCCUPATIONAL PHYSIOLOGY

Man as a system component – allocation of functions – efficiency – occupational work capacity – aerobic and anaerobic work – evaluation of physiological requirements of jobs – parameters of measurements – categorization of job heaviness – work organization – stress – strain – fatigue – rest pauses – shift work – personal hygiene.

UNIT IV PERSONAL PROTECTION

Concepts of personal protective equipment – types – selection of PPE – invisible protective barriers – procurement, storage, inspection and testing – quality – standards – ergonomic considerations in personal protective equipment design.

UNIT V INDUSTRIAL SAFETY AUDITS

A. INTRODUCTION

Components of safety audit, types of audit, audit methodology, non conformity reporting (NCR), audit checklist and report – review of inspection, remarks by government agencies, consultants, experts –perusal of accident and safety records, formats – implementation of audit indication - liaison with departments to ensure co-ordination – check list – identification of unsafe acts of workers and unsafe conditions in the shop floor.

B. SPECIFICATIONS FOR SAFETY AUDIT

BIS : 14489: Objective ,scope and procedure of occupational safety and health audit, Making of check list and survey

REFERENCE

1. Encyclopaedia of "Occupational Health and Safety", Vol.I and II, published by International Labour Office, Geneva, 1985
2. Hand book of "Occupational Safety and Health", National Safety Council, Chicago, 1982
3. Indian standard : 14489 Code of practice on on occupational safety and health

EE/AP – 504 : ELECTRICAL SAFETY

UNIT I CONCEPTS AND STATUTORY REQUIREMENTS

Introduction – electrostatics, electro magnetism, stored energy, energy radiation and electromagnetic interference – Working principles of electrical equipment-Indian electricity act and rules-statutory requirements from electrical inspectorate-international standards on electrical safety – first aid-cardiopulmonary resuscitation(CPR).

UNIT II ELECTRICAL HAZARDS

Primary and secondary hazards-shocks, burns, scalds, falls-human safety in the use of electricity.Energy leakage-clearances and insulation-classes of insulation-voltage classifications-excess energy current surges-Safety in handling of war equipment-over current and short circuit current-heating effects of current-electromagnetic forces-corona effect-static electricity –definition, sources, hazardous conditions, control, electrical causes of fire and explosion-ionization, spark and arc ignition energy-national electrical safety code ANSI.Lightning, hazards, lightning arrestor, installation – earthing, specifications, earth resistance, earth pit maintenance.

UNIT III PROTECTION SYSTEMS

Fuse, circuit breakers and overload relays – protection against over voltage and under voltage – safelimits of amperage – voltage –safe distance from lines-capacity and protection of conductor-joints-and connections, overload and short circuit protection-no load protection-earth fault protection.FRLS insulation-insulation and continuity test-system grounding-equipment grounding-earth leakage circuit breaker (ELCB)-cable wires-maintenance of ground-ground fault circuit interrupter-use of low voltage-electrical guards-Personal protective equipment – safety in handling hand held electrical appliances tools and medical equipment.

UNIT IV SELECTION, INSTALLATION, OPERATION AND MAINTENANCE

Role of environment in selection-safety aspects in application - protection and interlock-self diagnostic features and fail safe concepts-lock out and work permit system-discharge rod and earthing devices safety in the use of portable tools-cabling and cable joints-preventive maintenance.Classification of hazardous zones-intrinsically safe and explosion proof electrical apparatus-increase safe equipment-their selection for different zones-temperature classification-grouping of gases-use of barriers and isolators-equipment certifying agencies.

TEXT BOOK:

1. Fordham Cooper, W., "Electrical Safety Engineering" Butterworth and Company, London, 1986.
2. "Accident prevention manual for industrial operations", N.S.C.,Chicago, 1982.
3. Indian Electricity Act and Rules, Government of India.
4. Power Engineers – Handbook of TNEB, Chennai, 1989.
5. Martin Glov Electrostatic Hazards in powder handling, Research Studies Pvt.LTd., England, 1988.

MS/AC/AP- 505 ELECTIVE - I

A. ENVIRONMENT SAFETY

UNIT I AIR POLLUTION

Classification and properties of air pollutants – Pollution sources – Effects of air pollutants on human beings, Animals, Plants and Materials - automobile pollution-hazards of air pollution-concept of clean coal combustion technology - ultra violet radiation, infrared radiation, radiation from sun-hazards due to depletion of ozone - deforestation-ozone holes-automobile exhausts-chemical factory stack emissions-CFC.

UNIT II WATER POLLUTION

Classification of water pollutants-health hazards-sampling and analysis of water-water treatment different industrial effluents and their treatment and disposal -advanced wastewater treatment effluent quality standards and laws- chemical industries, tannery, textile effluents-common treatment.

UNIT III HAZARDOUS WASTE MANAGEMENT

Hazardous waste management in India-waste identification, characterization and classificationtechnological options for collection, treatment and disposal of hazardous waste-selection charts for the treatment of different hazardous wastes-methods of collection and disposal of solid wastes-health hazards-toxic and radioactive wastes-incineration and vitrification - hazards due to bio-processdilution-standards and restrictions, recycling and reuse.

UNIT IV ENVIRONMENTAL MEASUREMENT AND CONTROL

Sampling and analysis – dust monitor – gas analyzer, particle size analyzer – lux meter-pH meter – gas chromatograph – atomic absorption spectrometer. Gravitational settling chambers-cyclone separators-scrubbers-electrostatic precipitator - bag filter – maintenance - control of gaseous emission by adsorption, absorption and combustion methodsPollution Control Board-laws.

UNIT V POLLUTION CONTROL IN PROCESS INDUSTRIES
Pollution control in process industries like cement, paper, petroleum-petroleum products-textile tanneries-thermal power plants – dying and pigment industries - eco-friendly energy.

REFERENCES

1. Rao, CS, “Environmental pollution engineering:, Wiley Eastern Limited, New Delhi, 1992.
2. S.P.Mahajan, “Pollution control in process industries”, Tata McGraw Hill Publishing Company, New Delhi, 1993.
3. Varma and Braner, “Air pollution equipment”, Springer Publishers, Second Edition.

B. NUCLEAR AND RADIATION SAFETY

UNIT I INTRODUCTION
Binding energy – fission process – radio activity – alpha, beta and gamma rays radioactive decay – decay schemes – effects of radiation – neutron interaction – cross section – reaction rate – neutron moderation – multiplication – scattering – collision – fast fission – resonance escape – thermal utilization – criticality.

UNIT II REACTOR CONTROL
Control requirements in design considerations – means of control – control and shut down rods – their operation and operational problems – control rod worth – control instrumentation and monitoring – online central data processing system.

UNIT III REACTOR TYPES
Boiling water reactors – radioactivity of steam system – direct cycle and dual cycle power plants, pressurized water reactors and pressurized heavy water reactors – fast breeder reactors and their role in power generation in the Indian context – conversion and breeding – doubling time – liquid metal coolants – nuclear power plants in India.

UNIT IV SAFETY OF NUCLEAR REACTORS
Safety design principles – engineered safety features – site related factors – safety related systems – heat transport systems – reactor control and protection system – fire protection system – quality assurance in plant components – operational safety – safety regulation process – public awareness and emergency preparedness. Accident Case studies- Three Mile island and Chernobyl accident.

UNIT V RADIATION CONTROL
Radiation shielding – radiation dose – dose measurements – units of exposure – exposure limits – barriers for control of radioactivity release – control of radiation exposure to plant personnel – health physics surveillance – waste management and disposal practices – environmental releases.

REFERENCES
1. M.M.E.L.Wakil, “Nuclear Power Engineering”, International Text Book Co.
2. StermanU.S.’”Thermal and Nuclear Power Stations”, MIR Publications, Moscow, 1986.
3. “Loss prevention in the process Industries” Frank P.Lees Butterworth-Hein-UK, 1990.
4. M.M.E.L.Wakil, “Nuclear Energy Conversion”, International Text Book Co.
5. R.L.Murray, “Introduction to Nuclear Engineering”, Prentice Hall.
6. Sri Ram K, “Basic Nuclear Engineering” Wiley Eastern Ltd., New Delhi, 1990.
7. Loffness, R.L., “Nuclear Power Plant” Van Nostrand Publications, 1979.

MS – 506 INDUSTRIAL SAFETY LABORATORY

UNIT I NOISE LEVEL MEASUREMENT AND ANALYSIS
Measurement of sound pressure level in dB for Impact, continuous and intermittent sources at various networks, peak and average values.

UNIT II FRICTION TEST
Explosive materials like barium nitrate, gun powder, white powder, amorces composition etc.

UNIT III IMPACT TEST
Explosive materials like gun powder, white powder, amerces composition etc.
Burst strength test of packaging materials like paper bags, corrugated cartoons, wood etc.
Auto ignition temperature test.

UNIT IV EXHAUST GAS MEASUREMENT AND ANALYSIS
Measurement of SOx, NOx, COx, and hydrocarbons.

UNIT V ENVIRONMENTAL PARAMETER MEASUREMENT
Dry Bulb Temperature, Wet Bulb Temperature,Determination of relative humidity, wind flow and effective corrective effective.
Particle size Measurement
Air sampling analysis

UNIT VI Static charge testing
on plastic, rubber, ferrous and non-ferrous materials.

UNIT VII Illumination testing–
by lux meter and photo meter.

UNIT VIII Electrical safety
Insulation resistance for motors and cabels
Estimation of earth resistance
Earth continuity test
Sensitivity test for ELCB

UNIT IX Softwares : Introduction and Use
Accident Analysis
Safety Audit Packages
Consequence Analysis (CISCON)
Fire, Explosion and Toxicity Index (FETI)
Reliability Analysis for Mechanical system and Electrical System
Failure Mode Analysis

Equipments Required

1. Noise level meter :
2. Friction tester :
3. Impact tester :
4. Exhaust gas analyszer:
5. High volume sampler :

6. PPE Set :
7. Static charge tester :
8. First aid kit :
9. Software : CISION, FETI and Failure Mode analysis

CF – 507 : FIRE SAFETY

UNIT I PHYSICS AND CHEMISTRY OF FIRE

Sources of ignition – fire triangle – fire tetrahedron - principles of fire extinguishment - various classes of fires – types of fire extinguishing medias and fire extinguishers – foam making equipment ,their method of use

Fire properties of solid, liquid and gases –flash point, flammability limits, spontaneous combustion, fire spread - toxicity of products of combustion - theory of combustion and explosion – vapour clouds – flash fire – jet fires – pool fires – unconfined vapour cloud explosion, shock waves - auto-ignition – boiling liquid expanding vapour

UNIT IIFIRE PREVENTION AND PROTECTION

Active and passive fire protection systems, Advanced / latest fire prevention and fire protection systems. Fire accidents in the past and their case studies. Explosion – case studies.

UNIT III INDUSTRIAL FIRE PROTECTION SYSTEMS

Sprinkler-hydrants-stand pipes – special fire suppression systems like deluge and emulsifier, Water mist system. Selection criteria of the above installations, reliability, maintenance, evaluation and standards –Fire detectionand alarm systems. Other suppression systems – CO2 system, foam system, dry chemical powder (DCP) system, halon system – need for halon replacement –halon alternatives - smoke venting. Portable fire extinguishers – flammable liquids tank farms, firefighting systems.

UNIT IV EXPLOSION PROTECTING SYSTEMS

Principles of explosion-detonation and blast waves-explosion parameters – Explosion Protection,Containment, Flame Arrestors, isolation, suppression, venting, explosion relief of large enclosure explosion venting-inert gases, plant for generation of inert gas-rupture disc in process vessels and lines explosion, suppression system based on carbon dioxide (CO2) and halons-hazards in LPG, ammonia (NH3), sulphur dioxide (SO2), chlorine (Cl2) etc.

REFERENCES

1. Derek, James, “Fire Prevention Hand Book”, Butter Worths and Company, London, 1986.
2. Gupta, R.S., “Hand Book of Fire Technology” Orient Longman, Bombay 1977.
3. “Accident Prevention manual for industrial operations” N.S.C., Chicago, 1982.
4. DinkoTuhtar, “Fire and explosion protection”
5. “Davis Daniel et al, “Hand Book of fire technology”
6. Fire fighters hazardous materials reference book Fire Prevention in Factories”, anNostrand Rein Hold, New York, 1991.
7. “Fire Prevention and fire fighting”, Loss prevention Association, India.
8. Relevant Indian Acts and rules, Government of India.

CF – 508 : DISASTER MANAGEMENT

UNIT I Meaning and types of disasters:
1. Manmade and natural – earthquakes, volcanoes, landslides, floods, cyclones, tsunamis, anthropogenic, industrial, chemical and environmental, fire etc. Stages of a disaster mitigation plan- pre-disaster planning, disaster preparedness, monitoring phase, emergency response or damage assessment, recovery and relief phase.

2. Earthquakes: Causative factors, hazard assessment, selection of factors, creation of thematic data layers, preparation of seismic hazard zonation maps, regional risk assessment, risk mitigation plans; Tsunami and its impact, Case studies

3. Landslides: Causative factors, hazard assessment, selection of factors – triggering and nontriggering, creation of thematic data layers, preparation of landslide hazard zonation maps, regional and site specific risk assessments, risk mitigation plans; Case studies

4. Cyclones and Flooding: Cyclone: cyclone related parameters and effects on land and sea – damage assessment. Flooding: causes, flood prone area demarcation, analysis and management, risk assessment; Case studies

5. Drought and Desertification: Types of droughts, factors influencing droughts, identification of variables, delimiting drought prone areas, processes of desertification, over utilization of water and land resources. ; Case studies.

6. Anthropogenic Disasters: Atmospheric Disasters: Ozone layer depletion, green house / global warming – acid rain – snow melt – sea level rise – related problems. Case studies; Marine Disasters: oil spill and chemical pollution, coastal erosion and deposition, factor identification, management strategies; Case studies.

UNIT II Introduction to disaster management:
1. Definition and Introduction to disaster management, Disaster management before, during and after disaster event, disaster management cycle, preparedness, prevention, mitigation and response, relief ,reconstruction, rehabilitation activities. Disaster management in India.
Disaster as an opportunity for development, Disasters Vs development: Disaster-development linkages, interaction of socio-economic developmental activities and disasters, development plans incorporating disaster risks.

2**. Emerging approaches in disaster management:** 1. Pre- disaster stage (preparedness) (a) Preparing hazard zonation and maps, Predictability/ forecasting & warning (b) Preparing disaster preparedness plan (c) Land use and zoning (d) Preparedness through (IEC) Information, education & Communication, 2. Emergency Stage (a) Rescue training for search & operations at national & regional level (b) Immediate relief (c) Assessment surveys Post Disaster stage-Rehabilitation.**Disaster Mitigation:** Warning and evacuation, do's and don't about disaster, damage survey for designing aid package and detailed survey for reconstruction, repair and retrofitting, post disaster surveys, long term measures- Disaster resistant construction, retrofitting cost-benefit analysis

3. **Institutional setup & programmes in India:** Institutions & National Centers for Natural Disaster reduction, Environmental Legislations in India, Awareness, Conservation Movement, Education & training. Voluntary action, voluntary organization and non-government organizations and their role in Disaster Management. Social Action Groups, Advocacy

Initiatives, Civil Society Organizations and Social Movements and their role in disaster management.

4. **Standardization of the assessment of economic and social aspects:** Standardization of the assessment of economic, social and environmental aspects/losses of disaster management for comparative purposes and for an approach that reflects the reality on the community level. Community-based disaster management. Risk sharing and risk transfer (Insurance). Valuation of losses. Response strategies at National, Regional and community level.

5. **Knowledge Management:** Disaster knowledge management at international, national and regional level and strategies of handling disasters. Sharing of disaster handling strategies at all levels. Case studies focusing on socio-economic and technical issues related to disasters about India, China, Indonesia and other Asian countries who have suffered from disasters

6. **Strategic Disaster Management**: Understanding the application of the principles and procedures of strategic management in the domain of disaster mitigation and management. Strategy formulation, understanding strategic intent, vision, mission for better forecasting of disaster threats and their prevention and strategic management of disaster. Strategic management principles, methods and tools. planning, organizing, leadership and monitoring and evaluation of all role-players in disaster management.

7.**Information Technology in Disaster Management**: Understanding the link between information and decision-making. Understanding and classifying information systems that can have an impact on the dynamic disaster environment

8. **Disaster Management Act:**Disaster management policy; Techno legal aspect: Techno-Legal and Techno-Financial workdevelopment control regulations and building bye-laws registration, qualification and duties of professionals, disaster response policy

UNIT III. Post disaster issues and sustainable development

1. Post Disaster Reconstruction and recovery for sustainable development, issues and policies

2. Sustainable Development :Introduction to Sustainable Development-Bio Diversity-Atmospheric pollution-Global warming and Ozone Depletion-ODS banking and phasing out-Sea level rise-El Nino and climate changes-Ecofriendly products-Green movements-Green philosophy-Environmental Policies-Environmental ImpactAssessment-case studies.

UNIT IV .CBRN

1. Bioterrorism – Bioterror agents: Bacterial and viral; bioterrorism- introduction of plant and animal diseases

2. Infectious diseases – Infectious agents, mortality due to major bacterial outbreaks, spread of bacterial infections and the never ending fight, pathogens and multiple drug resistance, means of detecting and mitigating bacterial pathogens

3. Viral diseases - Outbreaks and incidences; Viral outbreaks – SARS, Bird flu, Swine flu and HIV, detection and mitigation of viral agents

4. Chemical Emergencies: Pesticides, industrial pollutants, heavy metal contamination.

5. Radiation emergencies: Nuclear radiation leakage, Chernobyl disaster and implications on biological systems, effect on genetic material; Mutations-chromosomal

6. Biotechnology and Biodiversity : Issues of Biodiversity, value of biodiversity; Emergence of Biotechnology; Biotechnology and promises to society; Biotechnology Techniques; Managing the Hazards of Genetic Engineering, regulations and control of biotechnology; Biosafety

REFERENCES

1 Management: A Global Perspective, Weihrich, H. and Koontz, H., New York, McGraw Hill 2006
2 Disaster Management: A Disaster Managers Handbook, Carter, W.N., Manila, ADB. 2006 3 Mohanty, Ranjita and Prayag Mehta, NGOs and Civil Society, New Delhi: Sanskriti Publications. 2002
4 Siwach, Raj Kumar Voluntary Organizations and Social Welfare, Shanker Publications, Delhi, 2004
5 R.B. Singh (Ed) Disaster Management, Rawat Publication, New Delhi. 2000
6. John A. M., Natural Hazards and Environmental Change, Bill McGuire 2002
7. Marcel, M., Flood risk management, Deltares 2010 2. Schumann, A., Flood Risk Assessment & Management, Springer Publication 2010
8. Central Water Commission, Manual on Flood Forecasting 1980
9. Reiter, L., Earthquake Hazard Analysis: Issues and Insights, Columbia University Press 2000
10. Hyndman D. and Hyndman D., Natural Hazard and Disasters, Brooks/Cole 2006
11. Bryant E., Natural Hazards, Cambridge University Press 2005
12. Disaster Management: A Disaster Managers Handbook, Carter, W.N., Manila, ADB. 2006
13.Mitigation of Natural hazards and Disasters: International perspective. Haque, C. Emdad, Springer, Dordrecht. 2005
14. Natural hazard risk assessment and Public policy. Petak, W.J. and Atkinson, A.D. Springer Verlag, NY 1982
15. Talwar A.K. and Juneja S., Cyclone Disaster Management, Commonwealth Publishers 2009
16. Dowrick D.J., Earthquake Risk Reduction, John Wiley &Sons 2003
17. Reiter, L. , Earthquake Hazard Analysis: Issues and Insights, Columbia University Press
18. Agarwal P. and Shrikhande M., Earthquake Resistant Design of Structures, Prentice Hall of India 2006
19. Grey M. and Spaeth K., The Bioterrorism Sourcebook, McGraw Hill 2006
20. Yousef A. K., et.al., Biology, Pathogenicity, Epidemiology, and Biodefense, WileyBlackwell 2007
21. Luther E. L., GeorgeKorch, Biological Weapons Defense: Infectious Diseases and Counter bioterrorism, Humana Press 2004
22. NDMA Publications on disaster management

CF – 509 SAFETY MANAGEMENT AND SHE LEGISLATION

UNIT I CONCEPTS AND TECHNIQUES

History of Safety movement –Evolution of modern safety concept- general concepts of management – planning for safety for optimization of productivity -productivity, quality and safety-line and staff functions for safety-budgeting for safety, safety policy, job safety analysis, safety survey, safety inspection, safety sampling, evaluation of performance of supervisors on safety.

UNIT II ACCIDENT INVESTIGATION AND REPORTING

Concept of an accident, reportable and non reportable accidents, reporting to statutory authorities – principles of accident prevention – accident investigation and analysis – records for accidents, departmental accident reports, documentation of accidents – unsafe act and condition – domino sequence – supervisory role – role of safety committee –cost of accident.

UNIT III SAFETY PERFORMANCE MONITORING

Recommended practices for compiling and measuring work injury experience – permanent total disabilities, permanent partial disabilities, temporary total disabilities - Calculation of accident indices, frequency rate, severity rate, frequency severity incidence, incident rate, accident rate, safety score, safety activity rate – problems.

UNIT IV SAFETY EDUCATION AND TRAINING

Importance of training-identification of training needs-training methods – programmes, seminars, conferences, competitions – method of promoting safe practice - motivation – communication - role of government agencies and private consulting agencies in safety training – creating awareness, awards, celebrations, safety posters, safety displays, safety pledge, safety incentive scheme, safety campaign – Domestic Safety and Training.

UNIT VI SHE LEGISLATIONS

(A) FACTORIES ACT – 1948

Statutory authorities – inspecting staff, health, safety, provisions relating to hazardous processes, welfare, working hours, employment of young persons – special provisions – penalties and procedures-Tamilnadu Factories Rules 1950 under Safety and health chapters of Factories Act 1948

(B) ENVIRONMENT ACT – 1986

General powers of the central government, prevention, control and abatement of environmental pollution-Biomedical waste (Management and handling Rules, 1989-The noise pollution (Regulation and control) Rules, 2000-The Batteries (Management and Handling Rules) 2001-No Objection certificate from statutory authorities like pollution control board. Air Act 1981 and Water Act 1974: Central and state boards for the prevention and control of air pollution-powers and functions of boards – prevention and control of air pollution and water pollution – fund – accounts and audit, penalties and procedures.

(C) CHEMICAL RULES 1989

Definitions – duties of authorities – responsibilities of occupier – notification of major accidents – information to be furnished – preparation of offsite and onsite plans – list of hazardous and toxic chemicals – safety reports – safety data sheets.

(D) OTHER ACTS AND RULES

Indian Boiler Act 1923, static and mobile pressure vessel rules (SMPV), motor vehicle rules, mines act 1952, workman compensation act, rules – electricity act and rules – hazardous wastes (management and handling) rules, 1989, with amendments in 2000- the building and other construction workers act 1996., Petroleum rules, Gas cyclinder rules-Explosives Act 1983-Pesticides Act

(E) INTERNATIONAL ACTS AND STANDARDS

Occupational Safety and Health act of USA (The Williames-Steiger Act of 1970) – Helath and safety work act (HASAWA 1974, UK) – OSHAS 18000 – ISO 14000 – American National Standards Institute (ANSI).

REFERENCES

1. Heinrich H.W. “Industrial Accident Prevention” McGraw-Hill Company, New York, 1980.
2. Krishnan N.V. “Safety Management in Industry” Jaico Publishing House, Bombay,1997.
3. Lees, F.P., “Loss Prevention in Process Industries” Butterworth publications, London, 1990.
4. John Ridley, “Safety at Work”, Butterworth and Co., London, 1983.\
5. Dan Petersen, “Techniques of Safety Management”, McGraw-Hill Company, Tokyo, 1981.
6. Relevant India Acts and Rules, Government of India.
7. Relevant Indian Standards and Specifications, BIS, New Delhi.
8. Blake R.B., “Industrial Safety” Prentice Hall, Inc., New Jersey, 1973.
9. “Safety and Good House Keeping”, N.P.C., New Delhi, 1985.
10. “Accident Prevention Manual for Industrial Operations”, N.S.C.Chicago, 1982.
11. The Factories Act 1948
12. The Environment Act (Protection) 1986
13. Water (Prevention and control of pollution) act 1974.
14. Air (Prevention and control of pollution) act 1981.
15. The Indian boilers act 1923.
16. The Mines Act 1952.
17. The manufacture, storage and import of hazardous chemical rules 1989.

MS/CF – 510 :RISK AND HAZARD ASSESSMENT

UNIT I : HAZARD, RISK ISSUES AND HAZARD ASSESSMENT

Introduction, hazard, hazard monitoring-risk issue, group or societal risk, individual risk, voluntary and involuntary risk, social benefits Vs technological risk, approaches for establishing risk acceptance levels, Risk estimation, Hazard assessment, procedure, methodology; safety audit, checklist analysis, what-if analysis, safety review, preliminary hazard analysis (PHA), human error analysis, hazard operability studies (HAZOP),safety warning systems.

UNIT II : COMPUTER AIDED INSTRUMENTS

Applications of Advanced Equipment and Instruments, Thermo Calorimetry, Differential Scanning Calorimeter(DSC), Thermo Gravimetric Analyser(TGA), Accelerated Rate Calorimeter(ARC), Reactive Calorimeter(RC), Reaction System Screening Tool(RSST) - Principles of operations, Controlling parameters, Applications, advantages, Explosive Testing, Deflagration Test, Detonation Test, Ignition Test, Minimum ignition energy Test, Sensitiveness Test, Impact Sensitiveness Test(BAM) and Friction Sensitiveness Test (BAM), Shock Sensitiveness Test, Card Gap Test.

UNIT III : RISK ANALYSIS QUANTIFICATION AND SOFTWARES

Fault Tree Analysis and Event Tree Analysis, Logic symbols, methodology, minimal cut set ranking - fire explo ion and toxicity index(FETI), various indices - Hazard analysis(HAZAN)-Failure Mode and Effect Analysis(FMEA)- Basic concepts of Reliability- Software on Risk analysis, CISCON, FETI, HAMGARS modules on Heat radiation, Pool fire, Jet, Explosion. Reliability softwares on FMEA for mechanical and electrical systems.

UNIT IV :CONSEQUENCES ANALYSIS

Logics of consequences analysis- Estimation- Hazard identification based on the properties of chemicals- Chemical inventory analysis- identification of hazardous processes- Estimation of source term, Gas or vapour release, liquid release, two phase release- Heat radiation effects, BLEVE, Pool fires and Jet fire- Gas/vapour dispersion- Explosion, UVCE and Flash fire, Explosion effects and confined explosion- Toxic effects- Plotting the damage distances on plot plant/layout.

UNIT V : CREDIBILITY OF RISK ASSESSMENT TECHNIQUES

Past accident analysis as information sources for Hazard analysis and consequences analysis of chemical accident, Mexico disaster, Flixborough, Bhopal, Seveso, Pasadena, Feyzindisaster(1966),Port Hudson disaster- convey report, hazard assessment of non-nuclear installation- Rijnmond report, risk analysis of size potentially Hazardous Industrial objects- Rasmussen masses report,Reactor safety study of Nuclear power plant

REFERENCES

1. Loss Prevention in Process Industries-Frank P. Less Butterworth-Hein UK 1990 (Vol.I, II and III)
2. Methodologies for Risk and Safety Assessment in Chemical Process Industries, Commonwealth Science Council, UK
3. Course Material Intensive Training Programme on Consequence Analysis, by Process Safety Centre, Indian Institute of Chemical Technology, Tarnaka and CLRI, Chennai.
4. ILO- Major Hazard control- A practical Manual, ILO, Geneva, 1988.
5. Brown, D.B. System analysis and Design for safety, Prentice Hall, 1976.
6. Hazop and Hazom, by Trevor AKlett, Institute of Chemical Engineering.
7. Quantitative Risk assessment in Chemical Industries, Institute of Chemical Industries, Centre for Chemical process safety.
8. Guidelines for Hazard Evaluation Procedures, Centre for Chemical Process safety, AICHE 1992.

CF – 511 ACCIDENT INVESTIGATION & REPORTING: CASE STUDIES

UNIT I

Concept of an accident, reportable and non-reportable accidents, unsafe act and condition principles of accident prevention,

UNIT II

Supervisory role- Role of safety committee – Accident causation models - Cost of accident.

UNIT III

Overall accident investigation process - Response to accidents, India reporting requirement, Planning document, Planning matrix,

UNIT IV

Investigators Kit, functions of investigator, four types of evidences, Records of accidents, accident reports.

CF – 512 : ELECTIVE II

(A) HUMAN FACTORS AND BEHAVIOUR BASED SAFETY

UNIT I ERGONOMICS AND ANATOMY

Introduction to ergonomics: The focus of ergonomics**,** ergonomics and its areas of application in the work system, a brief history of ergonomics, attempts to humanize work, modern ergonomics, future directions for ergonomics Anatomy, Posture and Body Mechanics: Some basic body mechanics, anatomy of the sprine and pelvis related to posture, posture stability and posture adaptation, low back pain, risk factors for musculoskeletal disorders in the workplace, behavioural aspects of posture, effectiveness and cost effectiveness, research directions

UNIT II HUMAN BEHAVIOR

Individual differences, Factors contributing to personality, Fitting the man to the job, Influence of difference on safety, Method of measuring characteristics, Accident Proneness. Motivation, Complexity of Motivation, Job satisfaction. Management theories of motivation, Job enrichment theory. Frustration and Conflicts, Reaction to frustration, Emotion and Frustration. Attitudes-Determination of attitudes, Changing attitudes Learning, Principles of Learning, Forgetting, Motivational requirements.

UNIT III ANTHROPOMETRY AND WORK DESIGN FOR STANDING AND SEATED WORKS

Designing for a population of users, percentile, sources of human variability, anthropometry and its uses in ergonomics, principals of applied anthropometry in ergonomics, application of anthropometry in design, design for everyone, anthropometry and personal space, effectiveness and cost effectiveness. Fundamental aspects of standing and sitting, an ergonomics approach to work station design, design for standing workers, design for seated workers, work surface design, visual display units, guidelines for design of static work**,** effectiveness and cost effectiveness, research directions

UNIT IV MAN - MACHINE SYSTEM AND REPETITIVE WORKS AND MANUAL HANDLING TASK

Applications of human factors engineering, man as a sensor, man as information processor, man as controller – Man vs Machine.

Ergonomics interventions in Repetitive works, handle design, key board design- measures for preventing in work related musculoskeletal disorders (WMSDs), reduction and controlling, training Anatomy and biomechanics of manual handling, prevention of manual handling injuries in the work place, design of manual handling tasks, carrying, postural stability

UNIT V HUMAN SKILL AND PERFORMANCE AND DISPLAY, CONTROLS AND VIRTUAL ENVIRONMENTS

A general information-processing model of the users, cognitive system, problem solving, effectiveness.Principles for the design of visual displays- auditory displays- design of controls-combining displays and controls- virtual (synthetic) environments, research issues.

REFERENCES

1. Introduction to Ergonomics, R.S. Bridger, Taylor and Francis
2. Ergonomic design for organizational effectiveness, Michael O'Neill
3. Human factors in engineering and design, MARK S.SANDERS
4. The Ergonomics manual, Dan Mc Leod, Philip Jacobs and Nancy Larson

(B) : AVIATION FIRE SAFETY

UNIT ICATEGORISATION OF AIRPORT AND HALIPAD

1. Categorisation of Airports and level of Fire Protection. Concept of critical area &requirement of extinguishing agents. Organisation of rescue and Fire Fighting services at Airports.

2. Categorisation of Heliports and level of Fire Protection. Other Rescue &fire fighting facilities at Heliports.

UNIT II AIRCRAFT CONSTRUCTION,AIRCRAFT ENGINES AND FUEL HAZARDS

1.Structural features of Aircrafts, Materials used in Aircraft construction & their hazards. Aircraft Access and Exits.
2. Types of Aircraft Engines and Hazards associated with each type.
3. Types of Aviation fuels used and their fire hazards.

UNIT IIIEMERGENCY PLANNING & PROCEDURES

Preplanning for Emergencies, Categorization of Emergencies at Airports, Emergency organizations and procedure for responding to the emergency.

UNIT IV AIRCRAFT FIRE FIGHTING AND RESCUE PROCEDURE

Aircraft Fires, Fire Fighting at Aerodromes, Positioning of appliances and methods of attack.
Ground incidents and low speed accidents.Effects of water on hot brake and wheel assemblies. Foaming of Runway.
Aircraft rescue tactics and evacuation procedure. Rescue Equipment. Personal Protection Equipment.

UNIT V HAZARDS OF MILTARY AIRCRAFT

Types and Construction of Military Aircrafts. Auxiliary Fuel Tanks, Auxiliary Power Plants. Fuel System, Compressed gases. Problems in dealing with Fire Accidents involving Aircrafts carrying Ammunition/Explosives. Symbols of hazardous materials carried in Aircrafts.
Rescue from Military Aircraft :Main entrance door, Emergency exits. Parachute and Catching Escapes panels, Canopies – Breaking through Prospex, Ejection Seats.

UNIT VI POST ACCIDENT MANAGEMENT

Introduction and Significance, Removal of bodies, Movement of wreckage, Preservation of evidence etc.

UNIT VII FIRE PROTECTION OF AIRPORT TERMINAL BUILDINGSAND HANGARS

1. Fire hazards associated with Airport Terminal Buildings and Fire safety Arrangements. Problems faced during fire fighting.
2. Classification of Hangars, Fire Hazards and Fire Safety arrangements.

UNIT VII CRASH FIRE TENDER DRILLS
(PRACTICALS)

Manning a Crash Fire Tender-

- working with a Monitor on approach to Crashed Aircraft.
- Working twin Monitors on approach.
- Working on Monitor and two sidelines.
- Getting two sidelines to work on Crashed Aircraft.

Replenishing the water tank of Air Crash Fire Tender from:

- Water Tender
- Water Bowser
- Airport Hydrants

Fire Pumps (Supporting Appliances)

UNIT VIII RESCUE FROM CRASHED AIRCRAFT

Standard Drills using different rescue techniques &equipment.

REFERENCES :

1. ICAO standards
2. Hand book by NFPA

(C) :EXPLOSIVE SAFETY

UNIT I PROPERTIES OF EXPLOSIVE CHEMICALS

Fire properties – potassium nitrate (KN03), potassium chlorate (KCl03), barium nitrate (BaNO3), calcium nitrate (CaNO3), Sulphur (S), Phosphorous (P), antimony (Sb), Pyro Aluminum (A1) powder- Reactions-metal powders, Borax, ammonia (NH3) – Strontium Nitrate, Sodium Nitrate, Potassium per chloride. Fire and explosion, impact and friction sensitivity.

UNIT II STATIC CHARGE AND DUST

Concept-prevention-earthing-copper plates-dress materials-static charge meter lightning, Causeseffects- hazards in fire works factories-lightning arrestor:concept-installation-earth pit-maintenanceresistance- legal requirements-case studies.

Dust: size-desirable, non-respirable-biologicalbarriers-hazards-personal protective equipment, pollution prevention.

UNIT III PROCESS SAFETY

Safe-quantity, mixing-filling-fuse cutting – fuse fixing – finishing – drying at various stages-packingstorage- hand tools-materials, layout: building-distances- factories act – explosive act and rules – fire prevention and control – risk related fireworks industries.

UNIT IV MATERIAL HANDLING

Manual handling – wheel barrows-trucks-bullock carts-cycles-automobiles-fuse handling – paper caps handling-nitric acid handling in snake eggs manufacture-handling the mix in this factory-material movement-godown-waste pit.

UNIT V TRANSPORTATION:

Packing-magazine-design of vehicles for explosive transports loading into automobiles-transport restrictions-case studies-overhead power lines-driver habits-intermediate parking-fire extinguishers, loose chemicals handling and transport.

UNIT VI WASTE CONTROL AND USER SAFETY

Concepts of wastes – Wastes in fire works-Disposal-Spillages-storage of residues.

Consumer anxietyhazards in display-methods in other countries-fires, burns and scalds-sales outlets-restrictions-role of fire service.

REFERENCES

1. K.N.Ghosh, “Principles of fireworks”, H.Khatsuria, Sivakasi, 1987.
2. “Proceedings of National seminar on Fireworks Safety-1999”, MSEC-1999.
3. “Seminar on explosives”, Dept.of of explosives.
4. J.A.Purkiss, “Fireworks-Fire Safety Engineering”
5. Bill of once, “Fireworks Safety manual”
6. “Goeff, “Dust Explosion prevention, Part 1”
7. A.Chelladurai, “Fireworks related accidents”
8. A.Chelladurai, “Fireworks principles and practice”
9. A.Chelladurai, “History of the fireworks in India” Brock, “History of fireworks”

CF – 513 : PRACTICALS – FIRE SAFETY

UNIT I: FIRST AUD FIRE EXTINGUISHER DRILL
UNIT II : PUMP DRILL AND HYDRANT DRILL WITH HOSES AND ALL TYPES OF BRANCHES AND FOAM MAKING EQUIPMENT
UNIT III : FIRE TENDER DRILL
UNIT IV : UNIT IV BA SET DRILL
UNIT V: INTRODUCTION AND OPERATION OF DISASTER MANAGEMENT EQUIPMENT

CF - 514 :SAFETY IN PROCESSING INDUSTRIES

UNIT I SAFETY IN WELDING AND GAS CUTTING

Gas welding and oxygen cutting, resistances welding, arc welding and cutting, common hazards, personal protective equipment, training, safety precautions in brazing, soldering and metalizing –explosive welding, selection, care and maintenance of the associated equipment and instruments – safety in generation, distribution and handling of industrial gases-colour coding – flashback arrestor – leak detection-pipe line safety-storage and handling of gas cylinders.

UNIT II SAFETY IN COLD FARMING AND HOT WORKING OF METALS

Cold working, power presses, point of operation safe guarding, auxiliary mechanisms, feeding and cutting mechanism, hand or foot-operated presses, power press electric controls, power press set up and die removal, inspection and maintenance-metal sheers-press brakes, Hot working safety in forging, hot rolling mill operation, safe guards in hot rolling mills – hot bending ofpipes , hazards and control measures.Safety in gas furnace operation, cupola, crucibles, ovens, foundry health hazards, work environment, material handling in foundries, foundry production cleaning and finishing foundry processes.

UNIT III SAFETY IN FINISHING, INSPECTION AND TESTING

Heat treatment operations, electro plating, paint shops, sand and shot blasting, safety in inspection and testing, dynamic balancing, hydro testing, valves, boiler drums and headers, pressure vessels, air leak test, steam testing, safety in radiography, personal monitoring devices, radiation hazards, engineering and administrative controls, Indian Boilers Regulation.Health and welfare measures in engineering industry-pollution control in engineering industry industrial waste disposal.

UNITIV SAFETY IN PROCESS DESIGN AND PRESSURE SYSTEM DESIGN

Design process, conceptual design and detail design, assessment, inherently safer design-chemical reactor, types, batch reactors, reaction hazard evaluation, assessment, reactor safety, operating conditions, unit operations and equipment, utilities.Pressure system, pressure vessel design, standards and codes- pipe works and valves- heat exchangers- process machinery-over pressure protection, pressure relief devices and design, fire relief, vacuum and thermal relief, special situations, disposal- flare and vent systems- failures in pressure system.

UNIT V PLANT COMMISSIONING INSPECTION AND OPERATIONS

Commissioning phases and organization, pre-commissioning documents, process commissioning, commissioning problems, post commissioning documentation

Plant inspection, pressure vessel, pressure piping system, non-destructive testing, pressure testing, leak testing and monitoring- plant monitoring, performance monitoring, condition, vibration, corrosion, acoustic emission-pipe line inspection.

Operating discipline, operating procedure and inspection, format, emergency procedures- hand over and permit system- start up and shut down operation, refinery units- operation of fired heaters, driers, storage- operating activities and hazards- trip systems- exposure of personnel

UNIT VI PLANT MAINTENANCE, MODIFICATION AND EMERGENCY PLANNING

Management of maintenance, hazards- preparation for maintenance, isolation, purging, cleaning, confined spaces, permit system- maintenance equipment- hot works- tank cleaning, repair and demolition- online repairs- maintenance of protective devices- modification of plant, problems controls of modifications. Emergency planning, disaster planning, onsite emergency-offsite emergency.

REFERENCES

1. “Accident Prevention Manual” – NSC, Chicago, 1982.
2. “Occupational safety Manual” BHEL, Trichy, 1988.
3. “Safety Management by John V. Grimaldi and Rollin H. Simonds, All India Travelers Book seller,New Delhi, 1989.
4. “Safety in Industry” N.V. Krishnan JaicoPublishery House, 1996.
5. Indian Boiler acts and Regulations, Government of India.
6. Safety in the use of wood working machines, HMSO, UK 1992.
7. Health and Safety in welding and Allied processes, welding Institute, UK, High Tech. Publishing Ltd., London, 1989.

MS/CF – 515 : QUALITY AND RELIABILITY ENGINEERING

UNIT I : RELIABILITY CONCEPT

Reliability function – failure rate – mean time between failures (MTBF) – mean time to failure (MTTF), A priori and a posteriori concept - mortality curve – useful life – availability – maintainability – system effectiveness.

UNIT II : FAILURE DATA ANALYSIS

Time to failure distributions – Exponential, normal, Gamma, Weibull, ranking of data – probability plotting techniques – Hazard plotting.

UNIT III : RELIABILITY PREDICTION MODELS

Series and parallel systems – RBD approach – Standby systems – m/n configuration – Application of Bayes' theorem – cut and tie set method – Markov analysis – Fault Tree Analysis – limitations.

UNIT IV : QUALITY MANAGEMENT

Introduction to Quality-Principles and prescription-Needs, Requirements and Expectations-The Stakeholders-Defining Quality-The characteristics of Quality

UNIT V : AN OVERVIEW OF TOTAL QUALITY MANAGEMENT

Evolution of Quality, Definition, TQM concepts, The Deming Philosophy, Quality Gurus, TQM Principles, TQM organisation

REFERENCES

1. Srinath L.S, "Reliability Engineering", Affiliated East-West Press Pvt Ltd, New Delhi, 1998.
2. Modarres, "Reliability and Risk analysis", Maral Dekker Inc.1993.
3. John Davidson, "The Reliability of Mechanical system" published by the Institution of Mechanical Engineers, London, 1988.
4. Smith C.O. "Introduction to Reliability in Design", McGraw Hill, London, 1976.
5. A I Endres, "Implementing Juran's Road Map for Quality Leadership: Benchmarks and Results",Wiley,2000
6. James W.Gairfield-Sonn, "Corporate Culture and the Quality organisation", Quorum Books,2001
7. Jiju Antony, David Preece, "Understanding, Managing and Implementing Quality: Frameworks, Techniques and cases", Routledge, 2002

ELECTIVE _ III

(A) : SAFETY IN HYDROCARBON INDUSTRIES

UNIT I

Simplified flow diagrams of a typical refinery – distillation unit, catalytic cracker, reformer, treatingunit (hydro forming, gas purification, Sulphur recovery, lubricating oil unit) Simplified flowdiagrams of Petrochemical Industry – steam cracking, butadiene extraction, ethane recovery, butylrubber polymerization.

UNIT II

Potential fire hazards in petroleum and petrochemical industries (ignition by local sources, spark,flame, hot surface, ignition of oil mists and fumes.). Storage tank farms of petroleum andpetrochemical industries – Identification of Hazards, Type of Tanks, Design, Layout, Fire preventionmeasures including lightning protection. Fire protection arrangements in large tank farms, Designconcepts of various fixed fire protection systems like Foam- Water Systems, Halogen & DCPsystems. Lock out procedures. Salient features of codes / standards: NFPA, API, OISD and SHELL.

UNIT III

Fire protection facilities in Oil Refineries, Depots & Terminals- Transportation of petroleum andpetrochemical products (safety considerations, statutory considerations). Design and Constructionrequirements for cross country hydrocarbon pipelines. Liquefied Petroleum Gas (LPG) Bottling PlantOperations. Design Philosophies. Operating Practices- Safety and Fire

Protection in bottling plants.Internal Safety Audits in (Procedures and Checklist) Transportation of Bulk Petroleum Products.Storage and Handling of Bulk Liquefied Petroleum Gas.

UNIT IV

On- Shore and off- shore drilling. Classification of wells. Drilling method. Rotary drilling. Drillingequipment. Ground and offshore structures for drilling. Offshore platforms and drilling vessels.Drilling mud – functions, classification and properties. Blow-off, well kicks, Blow out preventer.Shallow gas. Directional drilling. Well killing procedure. Emergency shut down, Methods of Rescue& Fire Fighting.

References:

1. Frank P Lees :Loss prevention in Process Industries – Vol. I, II & III, Butter worth – Heinemann Publishing Company, UK.
2. Manual of Fireman ship – Vol. I to XIII, HMSO, London.
3. Fire Protection Hand book.
4. OISD guidelines.

(B) : SAFETY IN POWDER HANDLING

UNIT I : INTRODUCTION

Powder classification-physical, chemical and other properties-metal powders-other non-metallic powders-handling methods-manual, mechanical, automatic-charges on powders-charge distribution charging of powders.

UNIT II : METAL POWDERS AND CHARACTERIZATION

Atomization, types – milling – electro deposition – spray drying, Production of iron powder, Aluminium powder, Titanium – screening and cleaning of metals – Explosivity and pyrophoricity – toxicity, Particle size and size distribution – measurement, types and significance – particle shape analysis, methods, surface area, density, porosity, flowrate – testing.Metal powders, applications as fuel, solid propellants, explosives, pyrotechnics.

UNIT III : DUST EXPLOSION

Industrial dust, dust explosion accidents – explosibility characteristics, minimum explosive concentration, minimum ignition energy, explosion pressure characteristics, maximum permissible oxygen concentration- explosibility tests, Hartmann vertical tube apparatus, horizontal tube apparatus, inflammatory apparatus, Godbert and Greenward furnace. Explosibility classification – Hybrid test – gas mixtures – Dust ignition sources – Dust explosion prevention – Dust explosion protection – Dust explosion venting, vent coefficient, various methods of design – venting of ducts and pipes – dust fire.

UNIT IV : DUST HANDLING PLANTS AND ELECTRO STATIC HAZARDS

Grinding mills, conveyors, bucket elevators, dust separators, dust filters, cyclones, driers, spray driers, silos, grain elevators, typical applications, hazards.

Electrostatic charges-energy released-type of discharge-spark-carona-insulating powders-propagating brush discharge-discharge in bulk lightning hazards in powder coating-electroplating.

UNIT V : DUST EVALUATION AND CONTROL

Evaluation, methodology, Quantitative, sampling, measurements – control approaches and strategies– control of dust sources, dust transmission – role of workers, PPE and work practice – House keeping – storage –labelling – warning sign – restricted areas - Environmental protections.Evaluation procedures and control measures for particulates (Respirable), Asbestos and other fibres, silica in coal mine - NIOSH guide to the selection and use of particulate respirators – case studies

REFERENCES

1. Martin Glor, "Electro Static Hazard in Powder Handling" Research studies Press Ltd.,UK, 1988.
2. Major hazard control-ILO Geneva, 1987.
3. Seminar on "Hazard recognition and prevention in the work place-airborne dust" Vol.I and SRMC, Chennai, 4/5, Sept.2000.
4. ASM Metals hand book, Ninth edition, Vol.7, Powder Metallurgy.

(C) SAFETY IN MARINE SYSTEMS

DOCK SAFETY

UNIT I : HISTORY OF SAFETY LEGISLATION

History of dock safety statues in India-background of present dock safety statues- dock workers (safety, health and welfare) act 1986 and the rules and regulations framed there under, few cases laws to interpret the terms used in the dock safety statues.
Responsibility of different agencies for safety, health and welfare involved in dock work –
Responsibilities of port authorities – dock labour board – owner of ship master, agent of ship – owner of lifting appliances and loose gear etc. – employers of dock workers like stevedores – clearing and forwarding agents – competent persons and dock worker. Forums for promoting safety and health in ports – Safety Committees and Advisory Committees. Their functions, training of dock workers.

UNIT II : WORKING ON BOARD THE SHIP

Types of cargo ships – working on board ships – Safety in handling of hatch beams – hatch covers including its marking, Mechanical operated hatch covers of different types and its safety features –safety in chipping and painting operations on board ships – safe means of accesses – safety in storage etc. – illumination of decks and in holds – hazards in working inside the hold of the ship and on decks – safety precautions needed – safety in use of transport equipment - internal combustible engines like fort-lift trucks-pay loaders etc. Working with electricity and electrical management – Storage – types, hazardous cargo.

UNIT III : LIFTING APPLIANCES

Different types of lifting appliances – construction, maintenance and use, various methods of rigging of derricks, safety in the use of container handling/lifting appliances like portainers, transtainer, top lift trucks and other containers – testing and examination of lifting appliances, portainers, transtainers, top lift trucks – derricks in different rigging etc.Use and care of synthetic and natural fibre ropes – wire rope chains, different types of slings and loose gears.

UNIT IV : TRANSPORT EQUIPMENT

The different types of equipment for transporting containers and safety in their use-safety in the use of self-loading container vehicles, container side lifter, fork lift truck, dock railways, conveyors and cranes.Safe use of special lift trucks inside containers – Testing, examination and inspection of containers – carriage of dangerous goods in containers and maintenance and certification of containers for safe operation

Handling of different types of cargo – loading and unloading of cargo identification of berths/walking for transfer operation of specific chemical from ship to shore and vice versa – restriction of loading and unloading operations.

UNIT V : EMERGENCY ACTION PLAN AND DOCK WORKERS (SHW) REGULATIONS

Emergency action Plans for fire and explosions - collapse of lifting appliances and buildings, sheds etc., - gas leakages and precautions concerning spillage of dangerous goods etc., - Preparation of onsite emergency plan and safety report.

Dock workers (SHW) rules and regulations 1990-related to lifting appliances, Container handling, loading and unloading, handling of hatch coverings and beams, Cargo handling, conveyors, dock railways, forklift.

REFERENCES

1. Safety and Health in Dock work, IInd Edition, ILO, 1992.
2. ”Dock Safety” Thane Belapur Industries Association, Mumbai.
3. Taylor D.A., “”Introduction to Marine Engineering”.
4. Srinivasan “Harbour, Dock and Tunnel Engineering”
5. Bindra SR “Course in Dock and Harbour Engineering.

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