SYLLABUS FOR PH.D ENTRANCE TEST:

RESEARCH METHODOLOGY

1. Foundations of Research

Meaning and importance of research; Objectives; Motivation; and Significance of research; Exploring the concepts of theory; Empiricism, Deductive, and Inductive reasoning; Features of the scientific method; and Familiarization with research terminology- Concepts, Constructs, Definitions, and Variables; Overview of the research process.

2. Research Problem Identification and Formulation

Defining and developing a research problem; Importance of problem definition and the role of literature review in this process; Distinguishing between research questions, Investigative questions, and Measurement issues; Introduction to hypothesis formulation—Characteristics of a good hypothesis, Null vs. Alternative hypotheses, and the Logic and Significance of hypothesis testing.

3. Qualitative and Quantitative Research

Introduction to qualitative and quantitative research approaches; Concepts such as measurement, Causality, Generalization, and Replication; Analyze qualitative and quantitative data; Ethical considerations; and integrate both approaches for comprehensive research outcomes.

4. Research Design & Ethics

Understanding the concept and relevance of research design; Features of an effective design; Types of research designs; Research ethics committees/institutional review board – Roles and Importance; Intellectual Property rights – Commercialization, Royalty; Reproduction of published material – Citation and acknowledgement; Plagiarism.

5. Data Analysis and Measurement

Implementing the research plan; Types of data; Sources of data; Observing, and gathering data; Techniques for data collection and Testing hypotheses; Generalizing findings, and interpreting results; Understanding what is measured in research; Issues in measurement, including reliability and validity; Levels of measurement:

6. Sampling Techniques

Key concepts: Population, Sample, Sampling error, Sampling frame, Sample size, and Non-response; Traits of a good sample; Overview of probability sampling methods.

7. Research Writing

Structure and format of a research paper, Scientific reports, and Theses; Types of reports, Importance of clear layout, Structure, and Language; Use of visuals, Illustrations, and Tables; Proper citation practices—Bibliography, Referencing, and Footnotes; Preparing and Delivering oral presentations using visual aids; Emphasis on effective communication; Understanding impact factors, Ethical issues in publishing, including plagiarism and self-plagiarism.

8. Research Tools and Techniques

Introduction to research tools: Reference managers (e.g., Zotero, Mendeley); Paper formatting tools (e.g., LaTeX, MS Office); Plagiarism detection software

9. Reasoning and Mental Ability

Topics include: Analogy, Classification, Series completion, Coding-decoding, Blood relations, Direction sense, Logical sequence of words, Number & alphabet series, Venn diagram-based reasoning, Mathematical and arithmetical reasoning, Cause and effect, Seating arrangements, Missing character problems, Number ranking and sequence tests, Eligibility tests, Comprehension, Logical reasoning (statements & assumptions, conclusions, actions), Classification of figures, Cube and dice problems, Pattern completion, arithmetic reasoning, mathematical operations, Problems on ages, Calendar and clock problems, Simplification and approximation, Number series.

DEPT. OF MECHANICAL ENGG.

Mechanical Engg, Heat Transfer, Fluid Mechanics, Thermodynamics, Solid Mechanics, Manufacturing Engg., Machine Design, Applied Mechanics, Material Science, Theory of Machine, Heat Transfer.

DEPT. OF APPLIED CHEMISTRY, ENERGY AND ENVIRONMENT.

1. Specialilzation : Applied Chemistry

The syllabus for the PhD entrance examination in Chemistry is as per GATE/CSIR.

2. Specialilzation : Energy and Environment

Fundamentals of Energy systems: various forms of energy, solar, wind, ocean, geothermal, nuclear, biomass, chemical etc., Energy conversion processes, various equipment for energy conversion, combustion basics, concept of calorific value for fuels. Basics of thermal engineering: laws of thermodynamics, thermodynamic cycles, properties of working fluid, Open and closed systems, basics of heat transfer, and different modes of heat transfer. Hydrogen energy and fuel cell basics: technology, applications, benefits and challenges. Applications of solar, wind, ocean, and geothermal energy: solar photovoltaic, wind turbine, wave and tidal energy generators, thermal powerplant with renewable energy sources, and electrical equipment in energy conversion. Biofuel generation from biomass: technology, influencing factors, benefits and challenges.

Fundamentals of Environment: atmosphere and its properties, soil, air, and water pollution. Wastewater treatment technologies, Desalination, CO_2 capture, Solid waste management, hazardous waste management and Environmental Impact Assessment. Concept of sustainability and sustainable development.

DEPT. OF ELECTRONICS ENGINEERING

Time and frequency domain analysis of linear circuits: Laplace transform. Continuous-time signals: Fourier series and Fourier transform, sampling theorem and applications. DTFT, DFT, z-transform. LTI systems: definition and properties, causality, stability, impulse response, convolution.
Energy bands in intrinsic and extrinsic semiconductors, equilibrium carrier concentration, direct and indirect band-gap semiconductors. Carrier transport: Diffusion current, drift current, mobility and resistivity. P-N junction, Zener diode, BJT, MOS capacitor, LED, photo diode and solar cell.

Clipping, clamping and rectifiers. BJT and MOSFET amplifiers: biasing, ac coupling, small signal analysis, frequency response. Op-amp circuits: Amplifiers, summers, differentiators, integrators, active filters, and oscillators.

Binary, integer and floating-point-numbers. Combinatorial circuits: Boolean algebra, minimization of functions using Boolean identities and Karnaugh map, logic gates, arithmetic circuits, code converters.

Auto correlation and power spectral density, properties of white noise, filtering of random signals through LTI systems.

Amplitude modulation and demodulation, angle modulation and demodulation, spectra of AM and FM, super heterodyne receivers. Information theory: entropy, mutual information and channel capacity theorem.

Digital communications: PCM, DPCM, digital modulation schemes (ASK, PSK, FSK), bandwidth, inter-symbol interference, SNR and BER. Fundamentals of error correction.

Maxwell's equations, Differential and integral forms and their interpretation, boundary conditions, wave equation, Poynting vector.

DEPT. OF COMPUTER SECIENCE & ENGINEERING

- **Discrete Mathematics**: Propositional and first-order logic, sets, relations, functions, partial orders, lattices, monoids, groups, graphs (connectivity, matching, coloring), combinatorics (counting, recurrence relations, generating functions).
- **Linear Algebra**: Matrices, determinants, systems of linear equations, eigenvalues and eigenvectors, LU decomposition.
- **Probability and Statistics**: Random variables, probability distributions (uniform, normal, exponential, Poisson, binomial), mean, median, mode, standard deviation, conditional probability, Bayes' theorem.
- **Digital Logic**: Boolean algebra, combinational and sequential circuits, minimization techniques, number representations, computer arithmetic (fixed and floating point).
- **Computer Organization and Architecture**: Machine instructions and addressing modes, ALU, data-path and control unit, instruction pipelining and hazards, memory hierarchy (cache, main memory, secondary storage), I/O interface (interrupt and DMA modes).
- **Programming and Data Structures**: Programming in C, recursion, arrays, stacks, queues, linked lists, trees, binary search trees, binary heaps, graphs. Object-Oriented Programming: Classes, inheritance, and polymorphism
- **Algorithms**: Searching, sorting, hashing, asymptotic worst-case time and space complexity, algorithm design techniques (greedy, dynamic programming, divide-and-conquer), graph algorithms (traversal, minimum spanning trees, shortest paths).
- **Theory of Computation**: Regular expressions and finite automata, context-free grammars and push-down automata, regular and context-free languages, pumping lemma, Turing machines, decidability and undecidability.
- **Compiler Design**: Lexical analysis, parsing, syntax-directed translation, runtime environments, intermediate code generation, local optimization, data flow analyses (constant propagation, liveness analysis, common subexpression elimination).
- **Operating Systems**: System calls, processes, threads, inter-process communication, concurrency and synchronization, deadlocks, CPU and I/O scheduling, memory management and virtual memory, file systems, disk management.
- **Databases**: Entity-Relationship (ER) model, relational model, integrity constraints, normalization, file organization, indexing, transactions, concurrency control.
- **Computer Networks**: Concepts of networking, OSI and TCP/IP models, network protocols, data link layer, network layer, transport layer, application layer, network security

- **Artificial Intelligence**: Search algorithms: BFS, DFS, A*. Knowledge representation: propositional and first-order logic, Planning, reasoning under uncertainty
- **Machine Learning**: Supervised learning: linear regression, logistic regression, decision trees, SVMs. Unsupervised learning: k-means clustering, hierarchical clustering. Model evaluation: cross-validation, confusion matrix, ROC curves
- **Cyber Security**: Secure communication, cryptography, and network security

DEPT. OF APPLIED PHYSICS

1. Electromagnetic: Theory Solutions of electrostatic and magnetostatic problems including boundary value problems; method of images; separation of variables; dielectrics and conductors; magnetic materials; multipole expansion; Maxwell's equations; scalar and vector potentials; Coulomb and Lorentz gauges; electromagnetic waves in free space, non-conducting and conducting media; reflection and transmission at normal and oblique incidences; polarization of electromagnetic waves; Poynting vector, Poynting theorem, energy and momentum of electromagnetic waves; radiation from a moving charge.

2. Quantum Mechanics: Postulates of quantum mechanics; uncertainty principle; Schrodinger equation; Dirac Bra-Ket notation, linear vectors and operators in Hilbert space; one dimensional potentials: step potential, finite rectangular well, tunneling from a potential barrier, particle in a box, harmonic oscillator; two and three dimensional systems: concept of degeneracy; hydrogen atom; angular momentum and spin; addition of angular momenta; variational method and WKB approximation, time independent perturbation theory; elementary scattering theory, Born approximation; symmetries in quantum mechanical systems.

3. Atomic and Molecular Physics: Spectra of one-and many-electron atoms; spin-orbit interaction: LS and jj couplings; fine and hyperfine structures; Zeeman and Stark effects; electric dipole transitions and selection rules; rotational and vibrational spectra of diatomic molecules; electronic transitions in diatomic molecules, Franck-Condon principle; Raman effect; EPR, NMR, ESR, X-ray spectra; lasers: Einstein coefficients, population inversion, two and three level systems

4. Solid State Physics: Elements of crystallography; diffraction methods for structure determination; bonding in solids; lattice vibrations and thermal properties of solids; free electron theory; band theory of solids: nearly free electron and tight binding models; metals, semiconductors and insulators; conductivity, mobility and effective mass; Optical properties of solids; Kramer's-Kronig relation, intra- and inter-band transitions; dielectric properties of solid; dielectric function, polarizability, ferroelectricity; magnetic properties of solids; dia, para, ferro, antiferro and ferri-magnetism, domains and magnetic

anisotropy; superconductivity: Type-I and Type II superconductors, Meissner effect, London equation, BCS Theory, flux quantization.

5. Electronics: Electron and hole statistics in intrinsic and extrinsic semiconductors; metal- semiconductor junctions; Ohmic and rectifying contacts; PN diodes, bipolar junction transistors, field effect transistors; negative and positive feedback circuits; oscillators, operational amplifiers, active filters; basics of digital logic circuits, combinational and sequential circuits, flip-flops, timers, counters, registers, A/D and D/A conversion.

DEPT. OF APPLIED MATHEMATICS

Calculus: Functions of two or more variables, continuity, directional derivatives, partial derivatives, total derivative, maxima and minima, saddle point, method of Lagrange's multipliers; Double and Triple integrals and their applications to area, volume and surface area; Vector Calculus: gradient, divergence and curl, Line integrals and Surface integrals, Green's theorem, Stokes' theorem, and Gauss divergence theorem.

Linear Algebra: Finite dimensional vector spaces over real or complex fields; Linear transformations and their matrix representations, rank and nullity; systems of linear equations, characteristic polynomial, eigen values and eigen vectors, diagonalization, minimal polynomial, Cayley-Hamilton Theorem, Finite dimensional inner product spaces, Gram-Schmidt orthonormalization process, symmetric, skew-symmetric, Hermitian, skew-Hermitian, normal, orthogonal and unitary matrices; diagonalization by a unitary matrix, Jordan canonical form; bilinear and quadratic forms.

Real Analysis: Metric spaces, connectedness, compactness, completeness; Sequences and series of functions, uniform convergence, Ascoli-Arzela theorem; Weierstrass approximation theorem; contraction mapping principle, Power series; Differentiation of functions of several variables, Inverse and Implicit function theorems; Lebesgue measure on the real line, measurable functions; Lebesgue integral, Fatou's lemma, monotone convergence theorem, dominated convergence theorem.

Complex Analysis: Functions of a complex variable: continuity, differentiability, analytic functions, harmonic functions; Complex integration: Cauchy's integral theorem and formula; Liouville's theorem, maximum modulus principle, Morera's theorem; zeros and singularities; Power series, radius of convergence, Taylor's series

and Laurent's series; Residue theorem and applications for evaluating real integrals; Rouche's theorem, Argument principle, Schwarz lemma; Conformal mappings, Mobius transformations.

Ordinary Differential Equations: First order ordinary differential equations, existence and uniqueness theorems for initial value problems, linear ordinary differential equations of higher order with constant coefficients; Second order linear ordinary differential equations with variable coefficients; Cauchy-Euler equation, method of Laplace transforms for solving ordinary differential equations, series solutions (power series, Frobenius method); Legendre and Bessel functions and their orthogonal properties; Systems of linear first order ordinary differential equations, Sturm's oscillation and separation theorems, Sturm-Liouville eigenvalue problems, Planar autonomous systems of ordinary differential equations: Stability of stationary points for linear systems with constant coefficients, Linearized stability, Lyapunov functions.

Numerical Analysis: Systems of linear equations: Direct methods (Gaussian elimination, LU decomposition, Cholesky factorization), Iterative methods (Gauss-Seidel and Jacobi) and their convergence for diagonally dominant coefficient matrices; Numerical solutions of nonlinear equations: bisection method, secant method, Newton-Raphson method, fixed point iteration; Interpolation: Lagrange and Newton forms of interpolating polynomial, Error in polynomial interpolation of a function; Numerical differentiation and error, Numerical integration: Trapezoidal and Simpson rules, Newton-Cotes integration formulas, composite rules, mathematical errors involved in numerical integration formulae; Numerical solution of initial value problems for ordinary differential equations: Methods of Euler, Runge-Kutta method of order 2.

Partial Differential Equations: Method of characteristics for first order linear and quasilinear partial differential equations; Second order partial differential equations in two independent variables: classification and canonical forms, method of separation of variables for Laplace equation in Cartesian and polar coordinates, heat and wave equations in one space variable; Wave equation: Cauchy problem and d'Alembert formula, domains of dependence and influence, nonhomogeneous wave equation; Heat equation: Cauchy problem; Laplace and Fourier transform methods.

Linear Programming: Linear programming models, convex sets, extreme points; Basic feasible solution, graphical method, simplex method, two phase methods, revised

simplex method ; Infeasible and unbounded linear programming models, alternate optima; Duality theory, weak duality and strong duality; Balanced and unbalanced transportation problems, Initial basic feasible solution of balanced transportation problems (least cost method, north-west corner rule, Vogel's approximation method); Optimal solution, modified distribution method; Solving assignment problems, Hungarian method.

Probability and Statistics: Counting (permutation and combinations), probability axioms, Sample space, events, independent events, mutually exclusive events, marginal, conditional and joint probability, Bayes Theorem, conditional expectation and variance, mean, median, mode and standard deviation, correlation, and covariance, random variables, discrete random variables and probability mass functions, uniform, Bernoulli, binomial distribution, Continuous random variables and probability distribution function, uniform, exponential, Poisson, normal, standard normal, t-distribution, chi-squared distributions, cumulative distribution function, Conditional PDF, Central limit theorem, confidence interval, z-test, t-test, chi-squared test.

Machine Learning: (i) Supervised Learning: regression and classification problems, simple linear regression, multiple linear regression, ridge regression, logistic regression, k-nearest neighbour, naive Bayes classifier, linear discriminant analysis, support vector machine, decision trees, bias variance trade-off, cross-validation methods such as leave-one-out (LOO) cross-validation, k-folds cross-validation, multi-layer perceptron, feed-forward neural network; (ii) Unsupervised Learning: clustering algorithms, k-means/k-medoid, hierarchical clustering, top-down, bottom-up: single linkage, multiple-linkage, dimensionality reduction, principal component analysis, LU decomposition, singular value decomposition.

DEPT. OF METALLURGICAL AND MATERIALS ENGINEERING

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,

2. Crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids: metallic crystal structure

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 equilibria in ceramic crystals, Phase equilibria in ceramics, Industrial application of ceramics and ceramic coatings, mechanical properties of ceramics.

4. Dielectrics: Dielectric strength, Loss factor. Equivalent circuit description of linear dielectrics, Power factor, Dielectric polarisation, Polarisation mechanisms, Applications. Refractories: Classification of Refractories, Applications.

5. Glass: Definition of glass, Basic concepts of glass structure, Different types of glasses, Application of glasses.

6. Simple and composite systems, phase, Internal energy, Enthalpy, Entropy, Gibbs Free energy, Specific heat, Laws of thermodynamics, Reversible and Irreversible processes, adiabatic work interaction.

7. 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.

8. Diffusion in idea, nonideal, substitutional and interstitial solid solutions, The kirkendall effect, Darken’s equations, Fick’s First law, Fick’s second law, Self-diffusion in pure metals, temperature dependence of diffusion coefficient, diffusion along grain boundaries and free surfaces.

9. Phase rule, Phase diagram, Isomorphous ally systems, The lever rule, Equilibrium heating and cooling of an isomorphous alloy, Microstructure, Thermodynamics of solutions, Phase equilibrium in single and multi-phase systems. Eutectic, Fe-FeC diagram. Miscibility gaps.

10. 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.

SCHOOL OF DEFENCE TECHNOLOGY AND MANAGEMENT

INTRODUCTION TO TECHNOLOGY MANAGEMENT

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. Understanding the Dynamics of Technology & Product development Environment, Technology Search Mechanisms, Technology Assessment Models, Technology selection criteria. Technology Planning, Acquisition and Exploitation of Technology, Managing risk in high technology, Transfer of tech from lab to land.

R&D AND INNOVATION MANAGEMENT

Definition and significance of R&D in the technology sector, R&D Categories and Organizational Structures- Differentiating between basic research, applied research, and development. Definition and types of innovation, Innovation models, Steps of innovation management, technological innovation process, technology innovation management planning, technological innovation management strategies, technology forecasting, and Incubators, types of IPR, Patents, and Copyrights in India

PROJECT MANAGEMENT

Project Management Foundation, Project lifecycle, Project Management Success Organization: The Strategy, Governance, structures, processes, standards, regulations, Scope Management: Requirements, Work Breakdown Structure, Scope Creep.

Schedule Management: Project Network Diagram (Activity on Node diagram), Estimation, Critical Path Method & Network analysis, Schedule compression (Crashing, Fast tracking), Cost Management, Contingency, Cost breakdown structure, Direct & Indirect cost, Earned Value Management (EVM)

Risk & Opportunity Management, Procurement Management, Quality Management in PM.

Resource Management, Change Management, Milestone trend chart, Relationships and engagement, Leadership & Teamwork.

STRATEGIC MANAGEMENT FOR TECHNOLOGY

Introduction to Strategic Management of Technology **:** Strategic Management Process; Challenge of Globalization; Strategic Planning in India; Corporate Governance; Board of Directors; Role and functions of Top Management, Industry and Environmental Analysis: Analyzing industry structure for technology opportunities, Understanding market failures and disruptions, Forecasting technological change,

Technology Strategy Formulation: Situation Analysis and Business Strategy, Corporate Strategy, Functional Strategy.

DATA ANALYSIS IN MANAGEMENT – I

Types of data: qualitative and quantitative, Measures of central tendency: mean, median, mode, Measures of variability: range, variance, standard deviation. Frequency distributions and histograms. Basic concepts of probability - Probability distributions and rules of probability. Sampling theory, Sampling distributions and the Central Limit Theorem, Confidence Intervals, Hypothesis testing - Null and alternative hypotheses, Type I and Type II errors, Z-test and t-test for Paired and independent samples hypothesis testing.

DEVELOPING HUMAN CAPITAL IN TECHNOLOGY-INTENSIVE ORGANIZATIONS

Personnel Management & HRM, *Balanced Scorecard* - History, perspectives, BSC & Strategy, *Competency Management* - Concept, need, competence & competency framework.

Human Capital Management: elements, significance, *Management of change* - The nature of change, Eight steps to successful change, Change strategies, Change resistance, *Effective communication, Effective leadership, Emotional Intelligence, HR Analytics* - Introduction, HR Analytics issues and metrices.

LEADERSHIP & ORGANISATIONAL BEHAVIOUR

Introduction to Organizational Behaviour, definition, importance, scope, fundamental concepts of OB, different models of OB: Autocratic, custodian, supportive, collegial, SOBC.

Personality, Perception, Learning, Attitudes, Emotions, Motivation, Interpersonal Behaviour at Work, Communication, Organizational culture, Decision Making, Group Dynamics, Teams and conflict management, Fundamentals of Leadership

TOTAL QUALITY MANAGEMENT

Introduction to TQM, Customer satisfaction, Continuous Improvement, Quality, Productivity and Flexibility, Approaches and philosophies of TQM, Quality Awards, 7 QC Tools, OC curve.

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.

Quality Teams, Leadership, delegation; empowerment and motivation; role of communication in Total Quality, Quality Circles; Kaizen and Innovation; Quality Information Systems, ISO 9000 series of Quality Standards; Introduction to Six Sigma.

DATA ANALYSIS IN MANAGEMENT– II

Regression Analysis- linear and multiple regression, Interpretation of regression coefficients. Correlation Analysis- Multiple and Partial correlations, Chi-square test, Non-parametric tests, Analysis of Variance (ANOVA)- One-way ANOVA, Two-way ANOVA. Factor Analysis, Time Series Components-Trends, seasonality, and cyclical patterns, Decomposition of time series data, Time Series Models averages and exponential smoothing, and Qualitative forecasting methods.

LOGISTICS AND SUPPLY CHAIN MANAGEMENT

Concept and objectives of logistics management and supply chain management (SCM), Push-pull supply chains, Supply chain integration, Uncertainties in supply chain, supply chain drivers. Sourcing and Procurement, Vendor managed inventory (VMI); Purchasing, Computer-based systems/EDI, Stores management.

Introduction of inventory system, EOQ model, ABC-VED Analysis, Risk pooling and postponement strategies, Lean, Agile and Leagile supply chain, Different distribution strategies in supply chain, warehousing and cross- locking, Network planning and design, 3PL and 4PL.

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.

KNOWLEDGE MANAGEMENT

Concepts of Knowledge, Knowledge Management, Knowledge Management Strategy, Knowledge Management Cycle, Capturing Tacit Knowledge, Knowledge transfer and sharing, Design the KM Team, Managing KM, Evaluation of KM effectiveness, KM in Indian organizations, Knowledge portals

ARTIFICIAL INTELLIGENCE (AI) IN MANAGEMENT

Data and models, AI modelling framework, Classification, Regression, Decision trees, Ensemble learning, Clustering, Association rules, Reinforcement learning, and Natural Language processing, Deep Learning -ANN, CNN. AI adoption and valuation- Phases of AI deployment, AI investment and valuation, AI strategy, Policy, and Risk management- strategy formulation, Principles of human-AI work policy, and Risk with AI

DEPT. OF AEROSPACE ENGINEERING AND AUTONOMOUS SYSTEMS

Specialization: Aerospace Engineering

Aerodynamics

Basic Fluid Mechanics, Airfoil nomenclature; Aerodynamic coefficients: lift, drag and moment; Kutta-Joukoswki theorem; Thin airfoil theory, Kutta condition, starting vortex; Finite wing theory: Induced drag, Prandtl lifting line theory; Critical and drag divergence Mach number. Compressible Flows: Basic concepts of compressibility, One-dimensional compressible flows, Isentropic flows, Fanno flow, Rayleigh flow; Normal and oblique shocks, Prandtl-Meyer flow; Flow through nozzles and diffusers.

Flight Mechanics

Basics of Atmosphere, Airplane (fixed wing aircraft) configuration and various parts. Pressure altitude; equivalent, calibrated, indicated air speeds; Primary flight instruments: Altimeter, ASI, VSI, Turn-bank indicator. Angle of attack, sideslip; Roll, pitch & yaw controls. Aerodynamic forces and moments. Airplane Performance: Drag polar; take-off and landing; steady climb and descent; absolute and service ceiling; range and endurance, load factor, turning flight, V-n diagram. Winds: head, tail and cross winds. Basics of static stability and dynamic stability.

Structures

Stress and strain: Three-dimensional transformations, Mohr’s circle, principal stresses, Three-dimensional Hooke's law, Plane stress and strain. Failure theories: Maximum stress, Tresca von Mises. Strain energy. Castigliano’s principles. Statically determinate and indeterminate trusses and beams. Elastic flexural buckling of columns. Flight Vehicle Structures: Characteristics of aircraft structures and materials. Torsion, bending and shear of thin-walled sections. Loads on aircraft. Structural Dynamics: Free and forced vibrations of undamped and damped SDOF systems. Free vibrations of undamped 2-DOF systems.

Propulsion

Basics of Thermodynamics, boundary layers, heat transfer, combustion and thermo chemistry. Aerothermodynamics of Aircraft Engines: Thrust, efficiency, range. Brayton cycle. Engine Performance: ramjet, turbojet, turbofan, turboprop and turboshaft engines. After burners. Turbomachinery: Axial compressors: Angular momentum, work and compression, characteristic performance of a single axial compressor stage, efficiency of the compressor and degree of reaction, multi-staging.

Centrifugal Compressor: Stage dynamics, inducer, impeller and diffuser. Axial Turbines: Stage performance. Rockets: Thrust equation and specific impulse, rocket

performance. Multi-staging. Chemical rockets. Performance of solid and liquid propellant rockets.

Navigation, Guidance & Control:

Basics of Navigation, INS, GPS, Accelerometers, Gyros, Radar, Flight control system. Types of Guidance; Active, semi-active and passive guidance, PN guidance, Basics of Advance Guidance Schemes, Basics of Path Planning. Basics of Control System, Laplace transform, open and closed loop systems, transfer function and state space model, Mathematical Modeling of systems, standard test signals, time domain analysis of first and second order systems, Time domain specifications, Stability check of systems. Frequency domain analysis of system, frequency domain specifications, Bode plot, polar plot, Nyquist criteria systems, stability analysis using Nyquist plots, gain margin, phase margin. root locus technique, PID Controller, compensators, Nonlinear Control, Robust Control, Optimal Control.

Specialization: Robotics

Introduction to Robotics

Robot classification, Types and components of Robot Anatomy, Robot Terminology-Links, joints, DOF, Specification of a robot, work volume, work space, work object, Robot geometrical configuration & Selection of Robots, Control Resolution & Spatial Resolution, Applications in industry.
Robot work cell, Kinematic systems, spatial descriptions: Position, orientation and frames, Coordinate frames, Mapping between frames (D-H method and DH free notations), translations, rotations and transformations matrices and Homogeneous Transformation Matrix, serial and parallel manipulators.
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.
Inverse Kinematics of Serial and parallel manipulators-geometric method, Analytical method, velocity, velocity propagation, Jacobian, acceleration, Jacobian-force relationship, Robot Dynamics, Inertia properties.
Trajectory Planning Definition, Introduction to Trajectory planning, General consideration in path description and Generation of motion.

Sensors, Actuators and Drives

Introduction to sensors & transducers, Sensors for Robots- Proximity sensors, Ultrasonic, magnetic, light sensors, speed measurement, GPS, LIDAR, IMU motion sensor, radar, gyroscope, FT sensor, Force sensor, shape memory alloy materials, smart sensing, applications. Principle of operation of actuators, control methods for industrial applications. 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

Automatic control system

Automatic Control System: definition and types, performance specifications, Design process, Block diagrams, Laplace transform and transient analysis, closed and open loop systems. Feedback and Feed forward control system, MIMO systems, state space analysis. Modeling of systems mechanical, electrical, hydraulic system block diagram representations, transfer functions. block diagram reduction techniques, signal flow graphs. Time response analysis, standard test signals, transient response for first and second order systems. Time domain specifications, Stability and Steady State Error. Frequency response analysis, frequency domain specifications, polar plots, nyquist criteria systems, stability analysis using nyquest plots, gain margin, phase margin. root locus technique. PID Controller

Introduction to Mechanisms

Physical Principles: Force and torque, motion, Newton's Law of motion, momentum and conservation of momentum, work, power and energy, material properties and selection, torque calculations and gearbox transmission mathematics for application. Machines and Mechanisms: Planar and spatial mechanisms, kinematics and dynamics of mechanisms, links, frames and kinematic chains. Kinematics: Basic kinematics of constrained rigid bodies, degrees of freedom of a rigid body. Basic Mechanisms: Straight line mechanisms, universal joint.

Introduction to Electronics Systems

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 and full wave rectifiers, filter circuits, regulated power supplies: introduction, characteristics, stabilization. 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.

SCHOOL OF QUANTUM TECHNOLOGY

Section 1: Mathematical Physics

Vector Calculus: Linear vector space: basis, orthogonality and completeness; matrices; similarity transformations, diagonalization, eigen values and eigen vectors; linear differential equations: second order linear differential equations and solutions involving special functions; complex analysis: Cauchy-Riemann conditions, Cauchy's theorem, singularities, residue theorem and applications; Laplace transform, Fourier analysis; elementary ideas about tensors: covariant and contravariant tensors.

Section 2: Classical Mechanics

Lagrangian Formulation: D'Alembert's principle, Euler-Lagrange equation, Hamilton's principle, calculus of variations; symmetry and conservation laws; central force motion: Kepler problem and Rutherford scattering; small oscillations: coupled oscillations and normal modes; rigid body dynamics: interia tensor, orthogonal transformations, Euler angles, Torque free motion of a symmetric top; Hamiltonian and Hamilton's equations of motion; Liouville's theorem; canonical transformations: action-angle variables, Poisson brackets, Hamilton-Jacobi equation. Special Theory of Relativity: Lorentz transformations, relativistic kinematics, mass-energy equivalence.

Section 3: Electromagnetic Theory

Solutions of electrostatic and magnetostatic problems including boundary value problems; method of images; separation of variables; dielectrics and conductors; magnetic materials; multipole expansion; Maxwell's equations; scalar and vector potentials; Coulomb and Lorentz gauges; electromagnetic waves in free space, non-conducting and conducting media; reflection and transmission at normal and oblique incidences; polarization of electromagnetic waves; Poynting vector, Poynting theorem, energy and momentum of electromagnetic waves; radiation from a moving charge.

Section 4: Quantum Mechanics

Postulates of quantum mechanics; uncertainty principle; Schrodinger equation; Dirac Bra-Ket

notation, linear vectors and operators in Hilbert space; one dimensional potentials: step potential, finite rectangular well, tunneling from a potential barrier, particle in a box, harmonic oscillator; two and three dimensional systems: concept of degeneracy; hydrogen atom; angular momentum and spin; addition of angular momenta; variational method and WKB approximation, time independent perturbation theory; elementary scattering theory, Born approximation; symmetries in quantum mechanical systems.

Section 5: Thermodynamics and Statistical Physics

Laws of thermodynamics; macrostates and microstates; phase space; ensembles; partition function, free energy, calculation of thermodynamic quantities; classical and quantum statistics; degenerate Fermi gas; black body radiation and Planck's distribution law; Bose-Einstein condensation; first and second order phase transitions, phase equilibria, critical point.

Section 6: Atomic and Molecular Physics

Spectra of one-and many-electron atoms; spin-orbit interaction: LS and jj couplings; fine and hyperfine structures; Zeeman and Stark effects; electric dipole transitions and selection rules; rotational and vibrational spectra of diatomic molecules; electronic transitions in diatomic molecules, Franck-Condon principle; Raman effect; EPR, NMR, ESR, X-ray spectra; lasers: Einstein coefficients, population inversion, two and three level systems.

Section 7: Solid State Physics

Elements of crystallography; diffraction methods for structure determination; bonding in solids; lattice vibrations and thermal properties of solids; free electron theory; band theory of solids: nearly free electron and tight binding models; metals, semiconductors and insulators; conductivity, mobility and effective mass; Optical properties of solids; Kramer's-Kronig relation, intra- and inter-band transitions; dielectric properties of solid; dielectric function, polarizability, ferroelectricity; magnetic properties of solids; dia, para, ferro, antiferro and ferri-magnetism, domains and magnetic anisotropy; superconductivity: Type-I and Type II superconductors, Meissner effect, London equation, BCS Theory, flux quantization.

Section 8: Electronics

Semiconductors in Equilibrium: Electron and hole statistics in intrinsic and extrinsic semiconductors; metal-semiconductor junctions; Ohmic and rectifying contacts; PN diodes, bipolar junction transistors, field effect transistors; negative and positive feedback circuits; oscillators, operational amplifiers, active filters; basics of digital logic circuits, combinational and sequential circuits, flip-flops, timers, counters, registers, A/D and D/A conversion.

Section 9: Nuclear and Particle Physics

Nuclear radii and charge distributions, nuclear binding energy, electric and magnetic moments; semi-empirical mass formula; nuclear models; liquid drop model, nuclear shell model; nuclear force and two nucleon problem; alpha decay, beta-decay, electromagnetic transitions in nuclei; Rutherford scattering, nuclear reactions, conservation laws; fission and fusion; particle accelerators and detectors; elementary particles; photons, baryons, mesons and leptons; quark model; conservation laws, isospin symmetry, charge conjugation, parity and time-reversal invariance.