Pandit Deendayal Energy University

Syllabus for Written Aptitude Test for Ph.D. Admission January 2023

Contents

Research Aptitude

- Definition of research
- Concepts and types of research
- Ethics in Research including Plagiarism
- Qualities of a competent Researcher
- Purpose and Scope of Research in Engineering Education (inter-disciplinary)
- Steps in conducting research
- Selection of Research problem
- Literature review
- Defining research Problem
- Hypothesis and its type
- Functions of Hypothesis
- Sampling techniques
- Measurement and Scaling techniques
- Data collection techniques and methods
- Analysis of Quantitative and Qualitative Data (including Basic Statistical parameters)
- Citation and Reference Styles
- Research report and thesis writing

Suggested Reading**:**

1) Kothari, C. R. (2004) Research methodology: Methods and techniques
2) Kumar, Ranjit (2014): Research methodology: A step by step guide for Beginners
3) Thiel, D. V. (2014) Research methods for Engineers, Cambridge University press
4) Gregory, Ian (2003) Ethics in Research

School of Petroleum Management

Management

Energy & Infrastructure Sector Management (Hydrocarbon/Renewables/Power/Marine/ Climate Change/Carbon Finance etc. and related areas), Management accounting, marketing, organizational behavior, human resource management, financial management, operations management, managerial economics, strategy, research methodology, information technology, quantitative methods and general management.

School of Petroleum Technology

Petroleum Engineering

Unit - I: Petroleum Exploration

Source, reservoir, migration, trap and seal. Lead, Play and Prospect. Geochemical Analysis. Gravity methods. Electrical methods. Seismic methods, Acquisition, Processing and Interpretation, Attribute Analysis. Resistivity methods. Formation evaluation using standardwireline logs.

Unit - II: Reservoir Engineering

Petro physical properties. Darcy's law.Rock fluid interactions. Fluid and rock properties. Phase behavior of hydrocarbon system. Reservoir drive mechanism. Reserve determination (volumetric, material balance, decline curve, P/Z method).Flow in porous media. Fluid Coning.Reservoir Pressure measurements and maintenance. Well test analysis. Static and dynamic modeling.

Unit - III: Drilling Engineering

Well planning. Drilling Rigs. Mud Hydraulics. Casing Practices. Drill String. Bits and their classification. Drilling problems and remedies. Drilling fluids. Safety, Health and Environment, HAZOP and HAZID. Drilling Waste Management. Cementing Techniques. Directional Survey. Dog-log severity. Advance drilling methods – ERD, horizontal drilling, multilateral drilling.

Unit - IV: Production Engineering

Well Equipments. Well head assembly. Packers. Tubing Strings. Well completion – techniques and design. Well Activation. Swabbing. Well Perforation. Well Stimulation. Artificial Lift Techniques. Production Optimization Techniques, Nodal Analysis. Storage and Transportation, Storage Tanks, Pumps and Compressors. Separation of Oil and Gas. GGS. Oil and Gas Metering and Processing.

School of Liberal Studies

Economics

Developmental Economics, Microeconomics, Macroeconomics, Indian Economics, Basic Statistics, Basic Econometrics, Other allied areas.

Psychology

Clinical Psychology, Applied Psychology, Industrial Psychology, Social Psychology, Environmental Psychology, Cognitive Psychology, Human Development, Health, Other allied areas.

English

Indian English Literature and Contemporary Fiction in India, American Literature, Research Method, Comparative Literature, Trends in Contemporary Literature, 20th Century British Literature, Communication Theories and Applications, Other allied areas.

Public Policy and Administration

Governance (Good Governance, E-Governance) and allied areas, Service Delivery, Public Private Partnerships, Public Health, Rural and Urban Development, Disaster Management, Police and Security Studies, Personnel Administration, Policy evaluation.

Political Science-International Relations

Political theory, Political Thought, Comparative politics, Theories and approaches of International Relations, Foreign policy, Diplomacy and war, Energy politics, Political economy, Geopolitics, Nuclear policy, Armament & disarmament, Peace and conflict, socio-economic and political dynamics, Institutions and regimes, Environment and climate change politics, Global security, and the allied areas.

Mass Communication

Journalism, Development communication, Advertising, Public Relation, Corporate, Communication, Films (popular and documentary), Media literacy, Social Media, Media education and allied areas.

Business Administration

Banking, Insurance, Finance, Capital Market, Marketing, Other allied areas.

Commerce

Commerce, Accounting, Taxation, Other allied areas.

School of Technology

Mechanical Engg.

Fluid Mechanics: Fluid properties; fluid statics, manometry, buoyancy, forces on submerged bodies, stability of floating bodies; control-volume analysis of mass, momentum and energy; fluid acceleration; differential equations of continuity and momentum; Bernoulli's equation; dimensional analysis; viscous flow of incompressible fluids, boundary layer, elementary turbulent flow, flow through pipes, head losses in pipes, bends and fittings.

Heat-Transfer: Modes of heat transfer; one dimensional heat conduction, resistance concept and electrical analogy, heat transfer through fins; unsteady heat conduction, lumped parameter system, Heisler's charts; thermal boundary layer, dimensionless parameters in free and forced convective heat transfer, heat transfer correlations for flow over flat plates and through pipes, effect of turbulence; heat exchanger performance, LMTD and NTU methods; radiative heat transfer, Stefan-Boltzmann law, Wien's displacement law, black and grey surfaces, view factors, radiation network analysis.

Thermodynamics: Thermodynamic systems and processes; properties of pure substances, behaviour of ideal and real gases; zeroth and first laws of thermodynamics, calculation of work and heat in various processes; second law of thermodynamics; thermodynamic property charts and tables, availability and irreversibility; thermodynamic relations.

Applications: Power Engineering: Air and gas compressors; vapour and gas power cycles, concepts of regeneration and reheat. I.C. Engines: Air-standard Otto, Diesel and dual cycles. Refrigeration and air-conditioning: Vapour and gas refrigeration and heat pump cycles; properties of moist air, psychrometric chart, basic psychrometric processes. Turbomachinery: Impulse and reaction principles, velocity diagrams, Pelton-wheel, Francis and Kaplan turbines.

Engineering Materials and Metallurgy: Structure and properties of engineering materials, phase diagrams, heat treatment, stress-strain diagrams for engineering materials, TTT diagrams, SEM, TEM, XRD.

Casting, Forming and Joining Processes: Different types of castings, design of patterns, moulds and cores; solidification and cooling; riser and gating design. Plastic deformation and yield criteria; fundamentals of hot and cold working processes; load estimation for bulk (forging, rolling, extrusion, drawing) and sheet (shearing, deep drawing, bending) metal forming processes; principles of powder metallurgy. Principles of welding, brazing, soldering and adhesive bonding.

Machining and Machine Tool Operations: Mechanics of machining; basic machine tools; single and multi-point cutting tools, tool geometry and materials, tool life and wear; economic of machining; principles of non-traditional machining processes; principles of work holding, design of jigs and fixtures.

Metrology and Inspection: Limits, fits and tolerances; linear and angular measurements; comparators; gauge design; interferometry; form and finish measurement; alignment and testing methods; tolerance analysis in manufacturing and assembly.

Computer Integrated Manufacturing: Basic concepts of CAD/CAM and their integration tools.

Engineering Mechanics: Free body diagrams and equilibrium; trusses and frames; virtual work; kinematics and dynamics of particles and of rigid bodies in plane motion, including impulse and momentum (linear and angular) and energy formulations; impact.

Strength of Materials: Stress and strain, stress-strain relationship and elastic constants, Mohr's circle for plane stress and plane strain, thin cylinders; shear force and bending moment diagrams; bending and shear stresses; deflection of beams; torsion of circular shafts; Euler's theory of columns; strain energy methods; thermal stresses.

Theory of Machines: Displacement, velocity and acceleration analysis of plane mechanisms; dynamic analysis of slider-crank mechanism; gear trains; flywheels.

Vibrations: Free and forced vibration of single degree of freedom systems; effect of damping; vibration isolation; resonance, critical speeds of shafts.

Design: Design for static and dynamic loading; failure theories; fatigue strength and the S-N diagram; principles of the design of machine elements such as bolted, riveted and welded joints, shafts, spur gears, rolling and sliding contact bearings, brakes and clutches.

Electrical Engg.

Basic of electrical Engineering , Basic of Electronics, Measurement, Instrumentation, Control Systems, Network analysis, Power System, High Voltage Engineering, Switchgear & Protection, Renewable Energy Engineering, Power Electronics & Drives, Microprocessor & Micro controllers, Electrical Machines, Electrical Machine Design, Power System Operation & Control, Power System Stability, Advances in Power System, Commissioning of Electrical Equipments.

Civil Engg.

Geotechnical and Foundation Engineering; Structural Engineering; Construction Management; Hydraulics and Environmental Engineering; Hydrology and Water Resources Engineering; Transportation Engineering; Surveying; Concrete Technology; Building materials; Construction Technology

Computer Engg.

Unit – I: Engineering Mathematics

Discrete Mathematics: Propositional and first order logic. Sets, relations, functions, partial orders and lattices, Groups, Graphs: connectivity, matching, coloring. Combinatorics: counting, recurrence relations, generating functions. Linear Algebra: Matrices, determinants, system of linear equations, eigenvalues and eigenvectors, LU decomposition. Calculus: Limits, continuity and differentiability. Maxima and Minima. Mean value theorem. Integration. Probability: Random variables. Uniform, normal, exponential, poisson and binomial distributions. Mean, median, mode and standard deviation. Conditional probability and Bayes theorem.

Unit – II: Computer Architecture and Networks

Digital Logic: Boolean algebra. Combinational and sequential circuits. Minimization. Number representations and computer arithmetic (fixed and floating point). Computer Organization: Machine instructions and addressing modes. ALU, data-path and control unit. Instruction pipelining. Memory hierarchy: cache, main memory and secondary storage; I/O interface (interrupt and DMA mode). Computer Networks: Concept of layering. LAN technologies (Ethernet). Flow and error control techniques, switching. IPv4/IPv6, routers and routing algorithms (distance vector, link state). TCP/UDP and sockets, congestion control. Application layer protocols (DNS, SMTP, POP, FTP, HTTP). Basics of Wi-Fi. Network security: authentication, basics of public key and private key cryptography, digital signatures and certificates, firewalls.

Unit – III: System Software

Operating System: Processes, threads, inter-process communication, concurrency and synchronization. Deadlock. CPU scheduling. Memory management and virtual memory. File systems. Theory of Computation: Regular expressions and finite automata. Context-free grammars and push-down automata. Regular and context-free languages, pumping lemma. Turing machines and undecidability. Compiler Design: Lexical analysis, parsing, syntax-directed translation. Runtime environments. Intermediate code generation.

Unit – IV: Algorithms and Artificial Intelligence

Programming in C/C++. Data structures and Algorithms: Linear and nonlinear data structures, Searching, sorting, hashing. time and space complexity analysis. Algorithm design techniques: greedy, dynamic programming and divide-and-conquer. Graph search, minimum spanning trees, shortest paths. Databases: ER-model. Relational model: relational algebra, tuple calculus, SQL. Integrity constraints, normal forms. File organization, indexing (e.g., B and B+ trees). Transactions and concurrency control. Artificial Intelligence: knowledge representation, Supervised and Unsupervised Learning, Kernel methods, reinforcement learning, Evolutionary computing and evaluation techniques.

Information & Communication Technology

Unit – I : - Engineering Mathematics

Discrete Mathematics: Propositional and first order logic. Sets, relations, functions, partial orders and lattices. Groups. Graphs: connectivity, matching, coloring. Combinatorics: counting, recurrence relations, generating functions. Linear Algebra: Matrices, determinants, system of linear equations, eigenvalues and eigenvectors, LU decomposition. Calculus: Limits, continuity and differentiability. Maxima and Minima. Mean value theorem. Integration. Probability: Random variables. Uniform, normal, exponential, poisson and binomial distributions. Mean, median, mode and standard deviation. Conditional probability and Bayes theorem.

Unit II: Communication and Signal Processing:

Analog and Digital Communication: AM, FM and PM Modulation and Demodulation, AM & FM Receivers, Noise Characteristics, Digital Baseband Modulation and demodulation: PCM, DM, DPCM, ADM, SDM, Digital Carrier Modulation and Demodulation: ASK, FSK, MSK & PSK

Techniques, Digital Receiver Characteristics, Synchronisation, Noise Performance. Information Theory and Coding: Probability Theory, Random Process, Source Coding, Line Coding Techniques, Channel Coding Techniques, Error Detection and Correction Codes.Signals and Systems: Analysis of Continuous and Discrete Time Signals and Systems: Laplace, Fourier & Z-Transform, Frequency Analysis, Digital Filter Structures, Design of Digital Filters, Concept of Feedback in Linear Systems, Applications to Speech and Image Processing.

Unit III: RF Engineering:

Electromagnetics: Divergence & Curl, Maxwell's Equations, Propagation of EM Waves, Plane Waves, Wave Impedance, Wave Equation, Poynting Theorem. Reflection & Refraction of Plane Waves, Group and Phase Velocity, skin depth, wave equation and solution for waveguide, modes in waveguide, S-Parameters and Scattering Matrix. Transmission Line: Characteristic Impedance, Reflection Coefficient, Standing Wave Ratio, Impedance Matching.Wave Propagation: Modes of Wave Propagation, Basics of Radar, range Equation, Blind Speed, Types of Radar, Radar Display, MTI Radar, pulse Radar, Unambiguous Range.Antenna: Antennas Concepts and Terminology, wire antenna, antenna Array, Microstrip Antenna, Smart Antenna.

Unit IV: Computing and Embedded Systems:

Digital Systems: Number Systems, Boolean Algebra, Combinational & Sequential Circuits, ADC and DAC, Memory Units.Computer Organization and Architecture: Machine Instructions and Addressing Modes. ALU, Data-path and Control Unit, Instruction pipelining, Memory hierarchy: cache, main memory and secondary storage.Microprocessor and Microcontroller: Architecture, Programming and Interfacing Concepts for 80X86 and ARM, Bus Communication Protocols, Serial and Parallel Communication, Network Communication, Interfacing to Analog World and Signal Conditioning.Embedded Systems: Design Aspects, Software aspects of Embedded Systems, Real Time Operating Systems for Embedded Systems, Embedded Programming, Scheduler, Multitasking, Threading Concepts and Implementation, Concept of IoT.

Chemical Engg.

Engineering Mathematics:

Linear Algebra: Matrix algebra, systems of linear equations, eigen values and eigenvectors. Calculus: functions of single variable, limit, continuity and differentiability, taylor series, mean value Theorems, evaluation of definite and improper integrals, partial derivatives, total derivative, maxima And minima, gradient, divergence and curl, vector identities, directional derivatives, line, surface and Volume integrals, stokes, gauss and green’s theorems.

Differential equations: First order equations (linear and nonlinear), higher order linear differential Equations with constant coefficients, cauchy’s and euler’s equations, initial and boundary value Problems, laplace transforms, solutions of one dimensional heat and wave equations and laplace Equation.

Complex variables: Complex number, polar form of complex number, triangle inequality.

Probability and statistics: Definitions of probability and sampling theorems, conditional probability, mean, median, mode and standard deviation, random variables, poisson, normal and binomial distributions, linear regression analysis.

Numerical methods: Numerical solutions of linear and non-linear algebraic equations. Integration by trapezoidal and simpson's rule. single and multi-step methods for numerical solution of differential equations.

Process Calculations and Thermodynamics:

Steady and unsteady state mass and energy balances including multiphase, multi-component, reacting and non-reacting systems. use of tie components; recycle, bypass and purge calculations; gibb's phase rule and degree of freedom analysis. first and second laws of thermodynamics. applications of first law to close and open systems. second law and entropy. thermodynamic properties of pure substances: equation of state and residual properties, properties of mixtures: partial molar properties, fugacity, excess properties and activity coefficients; phase equilibria: predicting vle of systems; chemical reaction equilibrium.

Fluid Mechanics and Mechanical Operations

Fluid statics, newtonian and non-newtonian fluids, shell-balances including differential form of bernoulli equation and energy balance, macroscopic friction factors, dimensional analysis and similitude, flow through pipeline systems, flow meters, pumps and compressors, elementary boundary layer theory, flow past immersed bodies including packed and fluidized beds, turbulent flow: fluctuating velocity, universal velocity profile and pressure drop. particle size and shape, particle size distribution, size reduction and classification of solid particles; free and hindered settling; centrifuge and cyclones; thickening and classification, filtration, agitation and mixing; conveying of solids.

Heat Transfer

Steady and unsteady heat conduction, convection and radiation, thermal boundary layer and heat transfer coefficients, boiling, condensation and evaporation; types of heat exchangers and evaporators and their process calculations. design of double pipe, shell and tube heat exchangers, and single and multiple effect evaporators.

Mass Transfer

Fick's laws, molecular diffusion in fluids, mass transfer coefficients, film, penetration and surface renewal theories; momentum, heat and mass transfer analogies; stage-wise and continuous contacting and stage efficiencies; htu & ntu concepts; design and operation of equipment for distillation, absorption, leaching, liquid-liquid extraction, drying, humidification, dehumidification and adsorption.

Chemical Reaction Engineering

Theories of reaction rates; kinetics of homogeneous reactions, interpretation of kinetic data, single and multiple reactions in ideal reactors, non-ideal reactors; residence time distribution, single parameter model; non-isothermal reactors; kinetics of heterogeneous catalytic reactions; diffusion

effects in catalysis.

Instrumentation and Process Control

Measurement of process variables; sensors, transducers and their dynamics, process modeling and linearization, transfer functions and dynamic responses of various systems, systems with inverse response, process reaction curve, controller modes (p, pi, and pid); control valves; analysis of closed loop systems including stability, frequency response, controller tuning, cascade and feed forward control.

Plant Design and Economics

Principles of process economics and cost estimation including depreciation and total annualized cost, cost indices, rate of return, payback period, discounted cash flow, optimization in process design and sizing of chemical engineering equipments such as compressors, heat exchangers, multistage contactors.

Chemistry

Inorganic Chemistry

1. Chemical periodicity
2. Structure and bonding in homo- and heteronuclear molecules, including shapes of molecules (VSEPR Theory).
3. Concepts of acids and bases, Hard-Soft acid base concept, Non-aqueous solvents.
4. Main group elements and their compounds: Allotropy, synthesis, structure and bonding, industrial importance of the compounds.
5. Transition elements and coordination compounds: structure, bonding theories, spectral and magnetic properties, reaction mechanisms.
6. Inner transition elements: spectral and magnetic properties, redox chemistry, analytical applications.
7. Organometallic compounds: synthesis, bonding and structure, and reactivity. Organometallics in homogeneous catalysis.
8. Cages and metal clusters.
9. Analytical chemistry – separation, spectroscopic, electro- and thermoanalytical methods.
10. Bioinorganic chemistry: photosystems, porphyrins, metalloenzymes, oxygen transport, electron-transfer reactions; nitrogen fixation, metal complexes in medicine.
11. Characterisation of inorganic compounds by IR, Raman, NMR, EPR, Mössbauer, UV-vis, NQR, MS, electron spectroscopy and microscopic techniques.
12. Nuclear chemistry: nuclear reactions, fission and fusion, radio-analytical techniques and activation analysis.

Physical Chemistry:

1. Basic principles of quantum mechanics: Postulates; operator algebra; exactly- solvable systems: particle – in – a – box, harmonic oscillator and the hydrogen atom, including shapes of atomic orbitals; orbital and spin angular momenta; tunneling.
2. Approximate methods of quantum mechanics: Variational principle; perturbation theory up to second order in energy; applications.

3. Atomic structure and spectroscopy; term symbols; many-electron systems and antisymmetry principle.
4. Chemical bonding in diatomics; elementary concepts of MO and VB theories; Huckel theory for conjugated π-electron systems.
5. Chemical applications of group theory; symmetry elements; point groups; character tables; selection rules.
6. Molecular spectroscopy: Rotational and vibrational spectra of diatomic molecules; electronic spectra; IR and Raman activities – selection rules; basic principles of magnetic resonance.
7. Chemical thermodynamics : Laws, state and path functions and their applications; thermodynamic description of various types of processes; Maxwell's relations; spontaneity and equilibria; temperature and pressure dependence of thermodynamic quantities; Le Chatelier principle; elementary description of phase transitions; phase equilibria and phase rule; thermodynamics of ideal and non-ideal gases, and solutions.
8. Statistical thermodynamics: Boltzmann distribution; kinetic theory of gases; partition functions and their relation to thermodynamic quantities – calculations for model systems.
9. Electrochemistry: Nernst equation, redox systems, electrochemical cells; Debye – Huckel theory; electrolytic conductance – Kohlrausch's law and its applications; ionic equilibria; conductometric and potentiometric titrations.
10. Chemical kinetics : Empirical rate laws and temperature dependence; complex reactions; steady state approximation; determination of reaction mechanisms; collision and transition state theories of rate constants; unimolecular reactions; enzyme kinetics; salt effects; homogeneous catalysis; photochemical reactions.
11. Colloids and surfaces: Stability and properties of colloids; isotherms and surface area; heterogeneous catalysis.
12. Solid state: Crystal structures; Bragg's law and applications; band structure of solids.
13. Polymer chemistry: Molar masses; kinetics of polymerization.
14. Data analysis: Mean and standard deviation; absolute and relative errors; linear regression; covariance and correlation coefficient.

Organic Chemistry

1. IUPAC nomenclature of organic molecules including regio- and stereoisomers.
2. Principles of stereochemistry: Configurational and conformational isomerism in acyclic and cyclic compounds; stereogenicity, stereoselectivity, enantioselectivity, diastereoselectivity and asymmetric induction.
3. Aromaticity : Benzenoid and non-benzenoid compounds – generation and reactions.
4. Organic reactive intermediates: Generation, stability and reactivity of carbocations, carbanions, free radicals, carbenes, benzynes and nitrenes.
5. Organic reaction mechanisms involving addition, elimination and substitution reactions with electrophilic, nucleophilic or radical species. Determination of reaction pathways.
6. Common named reactions and rearrangements – applications in organic synthesis.
7. Organic transformations and reagents: Functional group interconversion including oxidations and reductions; common catalysts and reagents (organic, inorganic, organometallic and enzymatic). Chemo, regio and stereoselective transformations.
8. Concepts in organic synthesis: Retrosynthesis, disconnection, synthons, linear and convergent synthesis, umpolung of reactivity and protecting groups.
9. Asymmetric synthesis: Chiral auxiliaries, methods of asymmetric induction – substrate, reagent and catalyst controlled reactions; determination of enantiomeric and diastereomeric excess; enantio-discrimination. Resolution – optical and kinetic.

10. Pericyclic reactions – electrocyclisation, cycloaddition, sigmatropic rearrangements and other related concerted reactions. Principles and applications of photochemical reactions in organic chemistry.
11. Synthesis and reactivity of common heterocyclic compounds containing one or two heteroatoms (O, N, S).
12. Chemistry of natural products: Carbohydrates, proteins and peptides, fatty acids, nucleic acids, terpenes, steroids and alkaloids. Biogenesis of terpenoids and alkaloids.
13. Structure determination of organic compounds by IR, UV-Vis, 1H & 13C NMR and Mass spectroscopic techniques.

Interdisciplinary Topics

1. Chemistry in nanoscience and technology.
2. Catalysis and green chemistry.
3. Medicinal chemistry.
4. Supramolecular chemistry.
5. Environmental chemistry

Physics

Mathematical Methods of Physics

Dimensional analysis. Vector algebra and vector calculus. Linear algebra, matrices, Cayley – Hamilton Theorem. Eigenvalues and eigenvectors. Linear ordinary differential equations of first & second order, Special functions (Hermite, Bessel, Laguerre and Legendre functions). Fourier series, Fourier and Laplace transforms. Elements of complex analysis, analytic functions; Taylor & Laurent series; poles, residues and evaluation of integrals. Elementary probability theory, random variables, binomial, Poisson and normal distributions. Central limit theorem.

Classical Mechanics

Newton's laws. Dynamical systems, Phase space dynamics, stability analysis. Central force motions.Two body Collisions – scattering in laboratory and Centre of mass frames. Rigid body dynamics – moment of inertia tensor. Non – inertial frames and pseudoforces. Variational principle. Generalized coordinates. Lagrangian and Hamiltonian formalism and equations of motion. Conservation laws and cyclic coordinates. Periodic motion: small oscillations, normal modes. Special theory of relativity – Lorentz transformations,relativistic kinematics and mass – energy equivalence.

Electromagnetic Theory

Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems. Magnetostatics : Biot – Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces. Scalar and vector potentials, gauge invariance. Electromagnetic waves in free space. Dielectrics and conductors. Reflection and refraction, polarization, Fresnel's law, interference, coherence, and diffraction. Dynamics of charged particles in static and uniform electromagnetic fields.

Quantum Mechanics

Wave – particle duality. Schrödinger equation (time – dependent and time – independent). Eigenvalue problems (particle in a box, harmonic oscillator, etc.). Tunneling through a barrier. Wave – function in coordinate and momentum representations. Commutators and Heisenberg uncertainty principle. Dirac notation for state vectors. Motion in a central potential : orbital angular momentum, angular momentum algebra, spin, addition of angular momenta; Hydrogen atom. Stern – Gerlach experiment. Time – independent perturbation theory and applications. Variational method. Time dependent perturbation theory and Fermi's golden rule, selection rules. Identical particles, Pauli exclusion principle, spin – statistics connection.

Thermodynamic and Statistical Physics

Laws of thermodynamics and their consequences. Thermodynamic potentials, Maxwell relations, chemical potential, phase equilibria. Phase space, micro – and macro-states. Micro – canonical, canonical and grand – canonical ensembles and partition functions. Free energy and its connection with thermodynamic quantities. Classical and quantum statistics. Ideal Bose and Fermi gases. Principle of detailed balance. Blackbody radiation and Planck's distribution law.

Electronics and Experimental Methods

Semiconductor devices (diodes, junctions, transistors, field effect devices, homo – and hetero – junction devices), device structure, device characteristics, frequency dependence and applications. Opto – electronic devices (solar cells, photo -detectors, LEDs). Operational amplifiers and their applications. Digital techniques and applications (registers, counters, comparators and similar circuits). A / D and D / A converters. Microprocessor and microcontroller basics.

Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Least squares fitting.

Mathematical Methods of Physics

Green's function. Partial differential equations (Laplace, wave and heat equations in two and three dimensions). Elements of computational techniques: root of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule, Solution of first order differential equation using Runge Kutta method. Finite difference methods. Tensors. Introductory group theory : SU(2), O(3).

Classical Mechanics

Dynamical systems, Phase space dynamics, stability analysis. Poisson brackets and canonical transformations. Symmetry, invariance and Noether's theorem. Hamilton – Jacobi theory.

Electromagnetic Theory

Dispersion relations in plasma. Lorentz invariance of Maxwell's equation. Transmission lines and wave guides. Radiation – from moving charges and dipoles and retarded potentials.

IQuantum Mechanics

Spin – orbit coupling, fine structure. WKB approximation. Elementary theory of scattering : phase shifts, partial waves, Born approximation. Relativistic quantum mechanics: Klein-Gordon and Dirac equations. Semi – classical theory of radiation.

Thermodynamic and Statistical Physics

First – and second – order phase transitions. Diamagnetism, paramagnetism, and ferromagnetism. Ising model. Bose – Einstein condensation. Diffusion equation. Random walk and Brownian motion. Introduction to nonequilibrium processes.

Electronics and Experimental Methods

Linear and nonlinear curve fitting, chi-square test. Transducers (Temperature, pressure / vacuum, magnetic fields, vibration, optical, and particle detectors). Measurement and control. Signal conditioning and recovery. Impedance matching, amplification (Op – amp based, instrumentation amp, feedback), filtering and noise reduction, shielding and grounding. Fourier transforms, lock-in detector, box-car integrator, modulation techniques. High frequency devices (including generators and detectors).

Atomic & Molecular Physics

Quantum states of an electron in an atom. Electron spin. Spectrum of helium and alkali atom. Relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectrum lines, LS & JJ couplings. Zeeman, Paschen – Bach & Stark effects. Electron spin resonance. Nuclear magnetic resonance, chemical shift. Frank-Condon principle. Born – Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Lasers : spontaneous and stimulated emission, Einstein A & B coefficients. Optical pumping, population inversion, rate equation. Modes of resonators and coherence length.

Condensed Matter Physics

Bravais lattices. Reciprocal lattice. Diffraction and the structure factor. Bonding of solids. Elastic properties, phonons, lattice specific heat. Free electron theory and electronic specific heat. Response and relaxation phenomena. Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power. Electron motion in a periodic potential, band theory of solids: metals, insulators and semiconductors. Superconductivity : type – I and type – II superconductors. Josephson junctions. Superfluidity. Defects and dislocations. Ordered phases of matter : translational and orientational order, kinds of liquid crystalline order. Quasi crystals.

Nuclear and Particle Physics

Basic nuclear properties : size, shape and charge distribution, spin and parity. Binding energy, semi – empirical mass formula, liquid drop model. Nature of the nuclear force, form of nucleon – nucleon potential, charge -independence and charge-symmetry of nuclear forces. Deuteron problem. Evidence of shell structure, single – particle shell model, its validity and limitations. Rotational spectra. Elementary ideas of alpha, beta and gamma decays and their selection rules. Fission and

fusion. Nuclear reactions, reaction mechanism, compound nuclei and direct reactions.

Classification of fundamental forces. Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gellmann-Nishijima formula. Quark model, baryons and mesons. C, P, and T invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction. Relativistic kinematics.

Mathematics

UNIT – 1

Analysis: Elementary set theory, finite, countable and uncountable sets, Real number system as a complete ordered field, Archimedean property, supremum, infimum. Sequences and series, convergence, limsup, liminf. Bolzano Weierstrass theorem, Heine Borel theorem. Continuity, uniform continuity, differentiability, mean value theorem. Sequences and series of functions, uniform convergence. Riemann sums and Riemann integral, Improper Integrals. Monotonic functions, types of discontinuity, functions of bounded variation, Lebesgue measure, Lebesgue integral. Functions of several variables, directional derivative, partial derivative, derivative as a linear transformation, inverse and implicit function theorems. Metric spaces, compactness, connectedness. Normed linear Spaces. Spaces of continuous functions as examples.

Linear Algebra: Vector spaces, subspaces, linear dependence, basis, dimension, algebra of linear transformations. Algebra of matrices, rank and determinant of matrices, linear equations. igenvalues and eigenvectors, Cayley-Hamilton theorem. Matrix representation of linear transformations. Change of basis, canonical forms, diagonal forms, triangular forms, Jordan forms. Inner product spaces, orthonormal basis. Quadratic forms, reduction and classification of quadratic forms

UNIT – 2

Complex Analysis: Algebra of complex numbers, the complex plane, polynomials, power series, transcendental functions such as exponential, trigonometric and hyperbolic functions. Analytic functions, Cauchy-Riemann equations.Contour integral, Cauchy's theorem, Cauchy's integral formula, Liouville's theorem, Maximum modulus principle, Schwarz lemma, Open mapping theorem. Taylor series, Laurent series, calculus of residues. Conformal mappings, Mobius transformations.

Algebra: Permutations, combinations, pigeon-hole principle, inclusion-exclusion principle, derangements. Fundamental theorem of arithmetic, divisibility in Z, congruences, Chinese Remainder Theorem, Euler's Ø- function, primitive roots. Groups, subgroups, normal subgroups, quotient groups, homomorphisms, cyclic groups, permutation groups, Cayley's theorem, class equations, Sylow theorems. Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain. Polynomial rings and irreducibility criteria. Fields, finite fields, field extensions, Galois Theory.

Topology: basis, dense sets, subspace and product topology, separation axioms, connectedness and compactness.

UNIT – 3

Ordinary Differential Equations (ODEs): Existence and uniqueness of solutions of initial value problems for first order ordinary differential equations, singular solutions of first order ODEs, system of first order ODEs. General theory of homogenous and non-homogeneous linear ODEs, variation of parameters, Sturm-Liouville boundary value problem, Green's function.

Partial Differential Equations (PDEs):

Lagrange and Charpit methods for solving first order PDEs, Cauchy problem for first order PDEs. Classification of second order PDEs, General solution of higher order PDEs with constant coefficients, Method of separation of variables for Laplace, Heat and Wave equations.

Numerical Analysis:

Numerical solutions of algebraic equations, Method of iteration and Newton-Raphson method, Rate of convergence, Solution of systems of linear algebraic equations using Gauss elimination and Gauss-Seidel methods, Finite differences, Lagrange, Hermite and spline interpolation, Numerical Differentiation and Integration, Numerical solutions of ODEs using Picard, Euler, modified Euler and Runge-Kutta methods.

Calculus of Variations:

Variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema. Variational methods for boundary value problems in ordinary and partial differential equations.

Linear Integral Equations:

Linear integral equation of the first and second kind of Fredholm and Volterra type, Solutions with separable kernels. Characteristic numbers and eigenfunctions, resolvent kernel.

Classical Mechanics:

Generalized coordinates, Lagrange's equations, Hamilton's canonical equations, Hamilton's principle and principle of least action, Two-dimensional motion of rigid bodies, Euler's dynamical equations for the motion of a rigid body about an axis, theory of small oscillations.

UNIT – 4

Descriptive statistics, exploratory data analysis Sample space, discrete probability, independent events, Bayes theorem. Random variables and distribution functions (univariate and multivariate); expectation and moments. Independent random variables, marginal and conditional distributions. Characteristic functions. Probability inequalities (Tchebyshef, Markov, Jensen). Modes of convergence, weak and strong laws of large numbers, Central Limit theorems (i.i.d. case). Markov chains with finite and countable state space, classification of states, limiting behaviour of n-step transition probabilities, stationary distribution, Poisson and birth-and-death processes. Standard discrete and continuous univariate distributions. sampling distributions, standard errors and asymptotic distributions, distribution of order statistics and range.

Methods of estimation, properties of estimators, confidence intervals. Tests of hypotheses: most

powerful and uniformly most powerful tests, likelihood ratio tests. Analysis of discrete data and chi-square test of goodness of fit. Large sample tests. Simple nonparametric tests for one and two sample problems, rank correlation and test for independence. Elementary Bayesian inference. Gauss-Markov models, estimability of parameters, best linear unbiased estimators, confidence intervals, tests for linear hypotheses. Analysis of variance and covariance. Fixed, random and mixed effects models. Simple and multiple linear regression. Elementary regression diagnostics. Logistic regression. Multivariate normal distribution, Wishart distribution and their properties. Distribution of quadratic forms. Inference for parameters, partial and multiple correlation coefficients and related tests. Data reduction techniques: Principle component analysis, Discriminant analysis, Cluster analysis, Canonical correlation.

Simple random sampling, stratified sampling and systematic sampling. Probability proportional to size sampling. Ratio and regression methods. Completely randomized designs, randomized block designs and Latin-square designs. Connectedness and orthogonality of block designs, BIBD. 2K factorial experiments: confounding and construction. Hazard function and failure rates, censoring and life testing, series and parallel systems. Linear programming problem, simplex methods, duality. Elementary queuing and inventory models. Steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited waiting space, M/G/1.

Environmental Engg.

Mathematics

Concept of Error in Computation; Interpolation: Introduction of Finite differences, Operators, Newton Gregory Forward Interpolation Formula, Newton Gregory Backward Interpolation Formula, Gauss's Forward and Backward Interpolation Formula, Stirling's Central Difference Formula, Lagrange's Interpolation Formula for unevenly spaced data, Inverse Interpolation, Divided Differences, Properties of Divided Differences, Newton's Divided Difference Formula, Relation between Divided Differences and Ordinary Differences; Splines, Cubic Splines, Formulae for Derivatives, Newton-Cotes's Quadrature Formula, Trapezoidal rule, Simpson's one-third rule, Simpson's Three-Eighth rule, Weddle's rule, Romberg's method, Double Integration. Concept of Rate of Convergence; Numerical solution of Algebraic & Transcendental Equations: Introduction, Descarte's Sign rule, Newton-Raphson method, it's applications, Solution of non linear simultaneous equations, Newton-Raphson method for multiple roots, Horner's method, Lin-Bairstow's method or Method for Complex Root, Graeffe's root squaring method, Comparison of various methods. Numerical Solution of Ordinary and Partial Differential Equations: Picard's method, Taylor's method, Euler's method, Runge – Kutta method, Modified Euler's method, Predictor Corrector methods: Adam's method, Milne's method. Difference Quotients, Graphical representation, Classification of PDE's of 2nd order, Elliptic equations, Solutions of Laplace equation by Liebmann's, iteration method, Poisson's equation, Parabolic equation (One dimension heat equation),Bender-Schmidt method, Crank- Nicholson method.

Environmental Chemistry and Micro-biology

Water and Wastewater Characteristics, Principles of Analysis, Valency: Oxidation, State and Bonding, Colloids Redox potentials – Beer Lamberts Law : Instrumentation Techniques, Fundamentals of Process Kinetics: Reaction Rates, factors effecting, order of reactions, error analysis of environmental data. Concepts of Equilibrium Chemistry: Le,Chatlier's principle, Factor influencing equilibrium: Activity, Coefficient: Variations of the equilibrium relationship, Oxidation

Reduction reactions, Gas laws, acids and bases, buffers, solubility of salts, Lanmier Index, Lime soda process, degradation chemistry of food products, detergents, pesticides and hydro carbons. Prokaryotic, eukaryotic nucleic acids, Nutrition and growth conditions, Effect of environmental conditions, bacterial growth in terms of numbers and mass, growth curve, interpretation of curve, substrate limited growth, Monod's expression, substrate utilization and cell growth, effect of endogeneous metabolism, inhibition, effect of temperature, culturing of micro-organisms, application of growth and substrate removal kinetics to biological treatment. Distribution of microorganisms, indicator organisms, staining, coliforms - fecal coliforms, E.coli, Streptococcus fecalis, differentiation of coliforms, significance, MPN index, Aerobic, anaerobic and facultative, M.F. technique, standards, Microbiology of wastewater treatment processes such as activated sludge process, trickling filter, anaerobic processes. Introduction to Microbiology of Soil and Air and Industrial Microbiology, Introduction to algae for treatment of wastewater, Microbiology of bioremediation and solid waste treatment.

Air Pollution

Air pollutants, classification of air pollutants, properties of gaseous and particulate matter, effects of Air pollution on plants, animals, human health, Sources of Air pollution and emission inventory, Sampling and Analysis: Ambient air sampling, stack sampling, Air quality standards. Air pollution meteorology: Atmospheric energy balance, environmental lapse rates and atmospheric stability, winds, wind profiles, plume behaviour, convective current, turbulence, Dispersion of Air pollutants, Prediction of effective stack height - physics of plume rise, Holland's equation, Briggs equation, modifications of Gaussian dispersion models. Air quality monitoring, instrument, sampling frequency, sampling network design, Introduction to various air quality models – steady state, dynamic, continuous, discrete and empirical. Air pollution control devices, Air sampling and analysis, theory and equipment ambient and Stack sampling, monitoring of quality emission standards and Indoor air pollution, Control of Particulate matter: Dusts, fumes, smoke, samples, settling chambers, cyclones, spray towers, electrostatic precipitators, etc

Atmospheric Processes

Elements of Atmosphere and Physical Meteorology: Vertical temperature and pressure profile of atmosphere, atmospheric composition, scale height, solar and terrestrial radiation, transport of matter, energy and momentum in nature, wind, type of clouds and rain formation process. Conventional observational techniques, conventional measurement of pressure, temperature, humidity, wind, precipitation, visibility, Modern Observational Techniques: LIDARS, SODARS, RADARS, CTD, ARGO, Introduction of remote sensing from space. General Meteorology: Thermodynamics of dry and moist air: atmospheric stability and dry adiabatic lapse rate, saturated adiabatic lapse rate, pseudo adiabatic processes and equivalent potential temperature Clausius-Clapeyron (C-C) equation. Micrometeorology: Atmospheric fluid mechanics, turbulence, surface roughness and convective boundary layer. Satellite Meteorology: Introduction to satellite meteorology, weather satellite and orbits, satellite images, satellite winds, Data acquisition, data processing and applications, monitoring the global environment, Climate Change: Elements of weather and climate modeling, Basic equation and dynamics of atmosphere, Climate variability and climate change, Global warming and climate change, Elementary idea of Global climate models, Comparison of various IPCC reports, important findings of IPCC AR5, Impacts of climate change – Global and India.

Solid and Hazardous Waste Management

Types and Sources of solid wastes: Need for solid, hazardous and bio-medical waste management, Legislations on management and handling of municipal solid wastes, hazardous wastes and biomedical wastes. Waste generation rates, Composition, Hazardous Characteristics, TCLP tests, Waste sampling, Source reduction of wastes, Recycling and reuse. Handling and segregation of wastes at source: Storage and collection of municipal solid wastes, Analysis of collection systems: Need for transfer and transport, Transfer stations, labelling and handling of hazardous wastes, Waste processing: Processing technologies, biological and chemical conversion technologies Composting, Thermal conversion technologies, Energy recovery, Incineration, Solidification and stabilization of hazardous wastes, treatment of biomedical wastes. Disposal in landfills: site selection, design and operation of sanitary landfills, secure landfills and landfill bioreactors, Leachate and landfill gas management, Landfill closure and environmental monitoring, landfill remediation, Elements of integrated waste management. Hazardous Waste Management: Definition and identification of hazardous wastes, sources and characteristics, hazardous wastes in Municipal Waste, Hazardous waste regulations, minimization of Hazardous Waste, compatibility, handling and storage of hazardous waste, collection and transport, e-waste, sources, collection, treatment and reuse management, handling of nuclear waste, nuclear waste management.

Industrial Wastewater Management

Industrial wastes: Industrial waste source, Nature and characteristics, quantity and quality of industrial wastes and their impact on the environment, waste volume reduction, waste strength reduction, neutralization, removal of suspended and colloidal solids, removal of inorganic and organic dissolved solids, disposal of sludge solid treatment of cyanide waste, heavy metal and radio activity. Industrial Wastewater Treatment: Waste management Hierarchy, Source reduction techniques, Pollution Prevention of Assessment, Material balance, Evaluation of Pollution prevention options, Cost benefit analysis, payback period, Waste minimization Circles, Case Studies: Industrial manufacturing process description, wastewater characteristics, source reduction options and waste treatment flow sheet for Textiles, Tanneries, Pulp and paper, metal finishing, Oil Refining, Pharmaceuticals, Sugar and Distilleries. Wastewater Reuse And Residual Management: Individual and Common Effluent Treatment Plants, Joint treatment of industrial and domestic wastewater, Zero effluent discharge systems, Quality requirements for Wastewater reuse, Industrial reuse, Present status and issues, Disposal on water and land, Residuals of industrial wastewater treatment, Quantification and characteristics of Sludge Thickening, digestion, conditioning, dewatering and disposal of sludge, Management of RO rejects, wasteland reclamation techniques. Environmental audit: Environmental audit, objectives, types, features, planning of audits, Organisation of Auditing Programme, pre-visit data collection, Audit Protocol, Onsite Audit; Data Sampling, Inspections, Evaluation and presentation; Exit Interview; Audit Report Action Plan, Management of Audits, Waste Management Contractor Audits, Life Cycle Approach.).

Environmental Modelling

Introduction: Mathematical modelling and simulation, Defining systems and its components, Types of models and their applications. Models for Fate and Transport of Contaminants: Modelling of volatilization, chemical transformations, sorption/desorption, photochemical transformations, biological transformations. Brief review of mass, momentum and energy balance, advection, molecular diffusion, dispersion, their application in modelling of rivers, lakes, sediments, wetlands, subsurface flow and transport, air pollution modelling. Introduction to Soft Computing Techniques Fuzzy set theory and logic, Fuzzy MCDM and FRBS, simple applications in environmental engineering. Neural networks and Genetic algorithms. GIS Applications in Environmental

Engineering, introduction to GIS, concepts and data base structure, introduction to GIS software; Introduction to Remote Sensing; Applications in Environmental Engineering.

Water Treatment

Water cycle, quantity of water, Sources of water, water quality standards for potable and non- potable use, impact of water quality on human health, water usage rate, Design period and population forecast, Conventional Water Treatment, Specific Water Treatment like Water Softening, Ion Exchange, Electrodialysis, Membrane Technology: ultra filtration, nano filtration, Reverse Osmosis, Desalination, Defluoridation, Demineralization, Removal of colour, odour and heavy metals.

Solar Energy

Modes of solar energy conversion: Photovoltaic and thermal; Energy efficiency; Electromagnetic radiations and light; Characteristic of solar radiation; Solar collectors; Photon and its energy; Black body radiation; Fundamentals of thermodynamics; Entropy; Heat transfer; Specific heat; Kinetic theory of gases; Thin films and its methods of deposition; Plasma and its application in materials processing; Semiconductor and its fundamental properties; PN junction diodes and its energy diagram; Physical characterization techniques: XRD, SEM, IR-spectroscopy, AFM, XPS, Raman spectroscopy; Energy storage – SLA and Li ion battery technologies.