

Research Fellowship

1. COMPUTER SCIENCE AND INFORMATION TECHNOLOGY

Basic Discrete Mathematics: Counting principles, linear recurrence, mathematical induction, equation sets, relations and function, predicate and propositional logic.

Digital Logic:

Logic functions, Minimization, Design and synthesis of combinational and sequential circuits; Number representation and computer arithmetic (fixed and floating point).

Computer Organization and Architecture:

Machine instructions and addressing modes, ALU and data-path, CPU control design, Memory interface, I/O interface (Interrupt and DMA mode), Instruction pipelining, Cache and main memory, Secondary storage.

Programming and Data Structures:

Programming in C; Functions, Recursion, Parameter passing, Scope, Binding; Abstract data types, Arrays, Stacks, Queues, Linked Lists, Trees, Binary search trees, Binary heaps.

Algorithms:

Analysis, Asymptotic notation, Notions of space and time complexity, Worst and average case analysis; Design: Greedy approach, Dynamic programming, Divide-and conquer; Tree and graph traversals, Connected components, Spanning trees, Shortest paths; Hashing, Sorting, Searching. Asymptotic analysis (best, worst, average cases) of time and space, upper and lower bounds, Basic concepts of complexity classes P, NP, NP-hard, NP-complete.

Operating System:

Processes, Threads, Inter-process communication, Concurrency, Synchronization, Deadlock, CPU scheduling, Memory management and virtual memory, File systems.

Databases:

ER-model, Relational model (relational algebra, tuple calculus), Database design (integrity constraints, normal forms), Query languages (SQL), File structures (sequential files, indexing, B and B+ trees), Transactions and concurrency control.

Information Systems and Software Engineering:

information gathering, requirement and feasibility analysis, data flow diagrams, process specifications, input/output design, process life cycle, planning and managing the project, design, coding, testing, implementation, maintenance.

2. ELECTRICAL SCIENCES

Electric Circuits and Fields:

Node and mesh analysis, transient response of dc and ac networks, sinusoidal steady-state analysis, resonance, basic filter concepts, ideal current and voltage sources, Thevenin's, Norton's and Superposition and Maximum Power Transfer theorems, two port networks, three phase circuits, measurement of power in three phase circuits, Gauss Theorem, electric field and potential due to point, line, plane and spherical charge distributions, Ampere's and Biot-Savart's laws, inductance, dielectrics, capacitance.

Electrical Machines: Magnetic circuits

Magnetic circuits, Single phase transformer- equivalent circuit, phasor diagram, tests, regulation and efficiency, Three phase transformers- connections, parallel operation, auto-transformer; energy conversion principles, DC Machines- types, starting and speed control of dc motors, Three phase induction motors- principles, types, performance characteristics, starting and speed control, Single phase induction motors, synchronous machines performance, regulation and parallel operation of synchronous machine operating as generators, starting and speed control of synchronous motors and its applications, servo and stepper motors.

Power Systems:

Basic power generation concepts, transmission line models and performance, cable performance, insulation, corona and radio interference, Distribution systems, per-unit quantities, bus impedance and admittance matrices, load flow, voltage and frequency control, power factor correction; unbalanced analysis, symmetrical components, basic concepts of protection and stability; Introduction to HVDC systems.

Control Systems:

Principles of feedback control, transfer function, block diagrams, steady state errors, Routh and Nyquist techniques, Bode plots, Root loci, Lag, Lead and Lead-lag compensation; proportional, PI, PID controllers, state space model, state transition matrix, controllability and observability.

Power Electronics and Drives:

Semiconductor Power devices - power diodes, power transistors, thyristors, triacs, GTOs, MOSFETs, IGBTs - their characteristics and basic triggering circuits; diode rectifiers, thyristor based line commutated ac to dc converters, dc to dc converters - buck, boost, buck-boost, buck, flyback, forward, push-pull converters, single phase and three phase dc to ac inverters and related pulse width modulation techniques, stability of electric drives; speed control issues of dc motors, induction motors and synchronous motors.

3. ELECTRONICS

Analog Circuits and Systems:

Electronic devices: characteristics and small-signal equivalent circuits of diodes, BJTs and MOSFETs. Diode circuits: clipping, clamping and rectifier. Biasing and bias stability of BJT and FET amplifiers. Amplifiers: single and multi-stage, differential and operational, feedback, and power. Frequency response of amplifiers. Op-amp circuits: voltage-to-current and current-to-

voltage converters, active filters, sinusoidal oscillators, wave-shaping circuits, effect of practical parameters (input bias current, input offset voltage, open loop gain, input resistance, CMRR). Electronic measurements: voltage, current, impedance, time, phase, frequency measurements, oscilloscope.

Digital Circuits and Systems:

Boolean algebra and minimization of Boolean functions. Logic gates, TTL and CMOS IC families. Combinatorial circuits: arithmetic circuits, code converters, multiplexers and decoders. Sequential circuits: latches and flip-flops, counters and shift-registers. Sample-and-hold circuits, ADCs, DACs. Microprocessors and microcontrollers: number systems, 8085 and 8051 architecture, memory, I/O interfacing, Serial and parallel communication.

Signals and Systems:

Linear time invariant systems: impulse response, transfer function and frequency response of first- and second order systems, convolution. Random signals and noise: probability, random variables, probability density function, autocorrelation, power spectral density. Sampling theorem, Discrete-time systems: impulse and frequency response, IIR and FIR filters.

Communications:

Amplitude and angle modulation and demodulation, frequency and time division multiplexing. Pulse code modulation, amplitude shift keying, frequency shift keying and pulse shift keying for digital modulation. Bandwidth and SNR calculations. Information theory and channel capacity.

4. MATERIALS SCIENCE

Structure:

Atomic structure and bonding in materials. Crystal structure of materials, crystal systems, unit cells and space lattices, miller indices of planes and directions, packing geometry in metallic, ionic and covalent solids. Concept of amorphous, single and polycrystalline structures and their effect on properties of materials. Imperfections in crystalline solids and their role in influencing various properties.

Diffusion: Fick's laws and application of diffusion.

Metals and Alloys:

Solid solutions, solubility limit, phase rule, binary phase diagrams, intermediate phases, intermetallic compounds, iron-iron carbide phase diagram, heat treatment of steels, cold, hot working of metals, recovery, recrystallization and grain growth. Microstructure, properties and applications of ferrous and non-ferrous alloys.

Ceramics, Polymers, & Composites:

Structure, properties, processing and applications of ceramics. Classification, polymerization, structure and properties, processing and applications. Properties and applications of various composites.

Materials Characterization Tools:

X-ray diffraction, optical microscopy, scanning electron microscopy and transmission electron microscopy, differential thermal analysis, differential scanning calorimetry.

Materials Properties:

Stress-strain diagrams of metallic, ceramic and polymeric materials, modulus of elasticity, yield strength, tensile strength, toughness, elongation, plastic deformation, viscoelasticity, hardness, impact strength, creep, fatigue, ductile and brittle fracture.

Heat capacity, thermal conductivity, thermal expansion of materials. Concept of energy band diagram for materials - conductors, semiconductors and insulators, intrinsic and extrinsic semiconductors, dielectric properties. Origin of magnetism in metallic and ceramic materials, paramagnetism, diamagnetism, antiferro magnetism, ferromagnetism, ferrimagnetism, magnetic hysteresis.

Environmental Degradation:

Corrosion and oxidation of materials, prevention.

5. FLUID MECHANICS

Fluid Properties:

Relation between stress and strain rate for Newtonian fluids; Buoyancy, manometry, forces on submerged bodies.

Kinematics

Eulerian and Lagrangian description of fluid motion, strain rate and vorticity; concept of local and convective accelerations, steady and unsteady flows

Control Volume Based Analysis

Control volume analysis for mass, momentum and energy.

Differential equations of mass and momentum (Euler equation), Bernoulli's equation and its applications, Concept of fluid rotation.

Potential flow:

Vorticity, Stream function and Velocity potential function; Elementary flow fields and principles of superposition, potential flow past a circular cylinder.

Dimensional analysis:

Concept of geometric, kinematic and dynamic similarity, Non-dimensional numbers and their usage.

Viscous Flows

Navier-Stokes Equations; Exact Solutions; Couette Flow, Fully-developed pipe flow, Hydrodynamic lubrication, Basic ideas of Laminar and Turbulent flows, Prandtl-mixing length, Friction factor, Darcy-Weisbach relation, Simple pipe networks.

Boundary Layer

Qualitative ideas of boundary layer, Boundary Layer Equation; Separation, Streamlined and bluff bodies, drag and lift forces.

Measurements

Basic ideas of flow measurement using venturimeter, pitot-static tube and orifice plate.

6. SOLID MECHANICS

Equivalent force systems; free-body diagrams; equilibrium equations; analysis of determinate trusses and frames; friction; simple particle dynamics; plane kinematics and kinetics; work-energy and impulse-momentum principles;

Stresses and strains; principal stresses and strains; Mohr's circle; generalized Hooke's Law; thermal strain.

Axial, shear and bending moment diagrams; axial, shear and bending stresses; deflection of beams (symmetric bending); Torsion in circular shafts; thin walled pressure vessels. Energy methods (Castigliano's theorems) for analysis.

Combined axial, bending and torsional action; Theories of failure.

Buckling of columns.

Free vibration of single degree of freedom systems.

7. THERMODYNAMICS

Basic Concepts:

Continuum, macroscopic approach, thermodynamic system (closed and open or control volume); thermodynamic properties and equilibrium; state of a system, state diagram, path and process; different modes of work; Zeroth law of thermodynamics; concept of temperature; heat.

First Law of Thermodynamics:

Energy, enthalpy, specific heats, first law applied to closed systems and open systems (control volumes), steady and unsteady flow analysis.

Second Law of Thermodynamics:

Kelvin-Planck and Clausius statements, reversible and irreversible processes, Carnot theorems, thermodynamic temperature scale, Clausius inequality and concept of entropy, principle of increase of entropy, entropy balance for closed and open systems, exergy (availability) and irreversibility, non-flow and flow exergy.

Properties of Pure Substances:

Thermodynamic properties of pure substances in solid, liquid and vapor phases, P-V-T behaviour of simple compressible substances, phase rule, thermodynamic property tables and charts, ideal and real gases, equations of state, compressibility chart.

Thermodynamic Relations:

T-ds relations, Maxwell equations, Joule-Thomson coefficient, coefficient of volume expansion, adiabatic and isothermal compressibilities, Clapeyron equation.

Thermodynamic cycles:

Carnot vapour power cycle; simple Rankine cycle, reheat and regenerative Rankine cycle; Air standard cycles: Otto cycle, Diesel cycle, simple Brayton cycle, Brayton cycle with regeneration, reheat and intercooling; vapour-compression refrigeration cycle.

Ideal Gas Mixtures:

Dalton's and Amagat's laws, calculations of properties (internal energy, enthalpy, entropy), air-water vapour mixtures and simple thermodynamic processes involving them.