Engineering Science Ph.D.

in

Nuclear Engineering / Nuclear Science and Technology

Syllabus for Written Test

Institute for Plasma Research

2019

1. BASIC CONCEPTS IN NUCLEAR PHYSICS:

Nuclear constituents – charge, mass, shape, and size of nucleus, Binding energy, packing fraction, nuclear magnetic moment, saturation and short range nuclear forces, *Radioactivity* – Laws of radioactive decay, half life, mean life, specific activity, partial radioactive decay, successive disintegration, α decay: Barrier penetration, β decay: Fermi theory, selection rules, parity non-conservation, γ decay of excited states. *Nuclear models* – single particle shell model, evidence and limitations of shell model, liquid drop model : Introduction, assumptions, semi-empirical mass formula

2. NUCLEAR DETECTORS, ACCELERATORS AND REACTORS

Types of detectors, Geiger-Mueller counter, Scintillation counter, classification of accelerators, Cyclotron, Betatron. *Nuclear Reactor* – Basic principle, classification, constituent parts, Heterogeneous reactor, Swimming pool reactor, Breeder reactor, Heavy water cooled and moderated CANDU type reactors, Gas cooled reactors. General considerations about reactor physics, engineering requirements- Description of the neutron distribution: fluxes, currents, and sources-Nuclear data, cross sections, and reaction rates- Basic scheme of nuclear system modeling methods-Deterministic modeling of nuclear systems-Neutron balance (conservation) equations. Spent fuel - light water reactor, light water reactor MOX, fast reactor MOX Radiotoxicity of fission products -Advanced conditioning of minor actinides-Transmutation of minor actinides. Thermal Parameter-sources and distribution of thermal loads in nuclear Power reactor- Conservation equation and their applications to nuclear power systems - Nuclear reactor materials and applications-Nuclear imaging-Nuclear waste management.

3. FUNDAMENTALS OF NUCLEAR SYSTEMS

Characteristics of the fission reaction, neutron moderation, practical fission fuels-Reactor power, fuel burn up, and fuel consumption-Neutron chain-reacting systems-Homogeneous and heterogeneous cores, reflectors-Reactor kinetics and dynamics, reactivity feedback- Core composition changes during reactor operation, nuclear system lifetime. Theories of Nuclear reactions, Conservation laws, Q-value equation, Nuclear fission, explanation on the basis of liquid drop model, energy available from fission, Nuclear chain reaction, Nuclear fusion.

4. NEUTRON MODERATION

Neutron moderation in infinite homogeneous media- Moderation without absorption Moderation with infinitely massive absorber- Moderation with real materials Neutron moderation in finite homogeneous media-Continuous slowing down theory Moderation without absorption, fast non-leakage probability- Moderation with absorption, resonance-escape probability

5. NUCLEAR REACTOR DESIGN AND APPLICATIONS

Nuclear reactor analysis and design, neutronics and thermo hydraulics coupling- Computational analysis capabilities for Generation IV systems, Introduction - fission in nature; the fission process - natural fission - fundamentals of fission reactor: fission chain reaction, prerequisites for a reactor - choice of moderator - feed back mechanism - reactor control - decay heat - fission products and transuranics - reactors types. Introduction to fuel fabrication - design and consideration -uranium fortification – conversion – magnox – fuel – oxides - oxide fuel assembly - enrichment of uranium: gaseous diffusion - centrifuge enrichment - laser enrichment - re-enrichment of reprocessed uranium. Nuclear power reactors -Nuclear reactor analysis - Reactor physics and thermodynamics coupling and safety and to either develop new designs or to assess existing or proposed designs based upon fundamental understanding of reactor physics. Hot channel, hop spot factors, statistical methods, Overall hot channel factor, Applications of hot channel factors, Determination of reactor core characteristics (thermal – hydraulic analysis), Thermal design limits and safety margins, Figures of merit for core thermal performance

6. FAST REACTORS

Fast reactor principles-Design considerations: materials, neutronics, heat transfer, and systems-Fast reactors for actinide transmutation-Safety of fast reactors-Fast reactor fuels-Fast reactor structural materials-Commercialization of fast reactors-Fast reactor database-Code systems for fast reactor studies. Hybrid system principles-Size of hybrid systems-Practical systems-Evaluation of hybrid systems-Accelerator driven systems

– international trends in research and Development-Fusion-driven systems

7. LASER TECHNOLOGY & APPLICATIONS

Ultrashort pulse generation; amplification of femtosecond laser pulses, Ti:Sapphire technology and OPCPA amplifiers; pulse diagnostics; future PetaWatt and ExaWatt laser systems, Electrons in relativistic light fields; introduction into plasma physics; absorption processes; electron acceleration; bubble acceleration; ion acceleration mechanisms. Monoenergetic electron acceleration with lasers, Bremsstrahlung generation and applications in nuclear physics; ion acceleration and applications in accelerator physics; medical applications, strong field quantum electro- dynamics with intense laser fields. Coulomb collisions and transport processes, Motion of charged particles in magnetic fields: plasma confinement schemes. MHD models: simple equilibrium and stability analysis, Two-fluid hydrodynamic plasma models: wave propagation in a magnetic field; Introduces kinetic theory; Vlasov plasma model: electron plasma waves and Landau damping.

8. PLASMA INTERACTIONS

Comprehensive theory of electromagnetic waves in magnetized plasma, Wave propagation in cold and hot plasmas; Energy flow, Absorption by Landau and cyclotron damping and by transit time magnetic pumping (TTMP); Wave propagation in inhomogenous plasma; WKB theory, mode conversion, connection formulae, and Budden tunneling; Applications to RF plasma heating, wave propagation in the ionosphere and laser-plasma interactions.

9. OPERATIONAL FEATURES OF NUCLEAR REACTOR SYSTEM – RELVANCE OF SAFETY

Purpose, Scope, Relevant Legislation, Safety Analysis Objectives and requirements, Responsibility, Events to be Analyzed, Identifying Events, Scope of Events, Classification of Events, Acceptance Criteria , Normal Operation, Anticipated Operational Occurrences and Design Basis Accidents , Beyond Design Basis Accidents, Acceptance Criteria for AOOs and DBAs, Safety Analysis Methods and Assumptions, General, Analysis Method, Analysis Data, Analysis Assumptions, Conservatism in Analysis, Safety Analysis Documentation, Safety Analysis Review and Update, Review of Safety Analysis. Engineered Safety Features, Containment, Passive Containment Cooling System, Containment Isolation System, Passive Core Cooling System, Main Control Room Emergency Habitability System, Fission Product Control. Reactor physics, Fuel, Fuel element temperatures, Gas pressure inside sheath, Fuel behavior in accidents, Over power, dry out, Low coolant flow, Loss of coolant, Heat transport system, Fuel channels. Temperature Excursion/Temperature Runaway, Safe Design and Operating Guidelines, Stability Criteria, Catalyst Loading and Preparations, General Emergency Guidelines

10. PROPERTIES OF MATTER AND SOUND

Hooke's law – Twisting couple on a cylinder – Shafts – Torsion pendulum – Bending of beams – Bending moment – Uniform bending and non-uniform bending – I shape girder. Shock waves – Mach number (simple problems) – Ultrasonic production (magnetostriction and piezoelectric methods) and application – Acoustics of buildings – Sources and impacts of noise – Sound level meter – Control of noise pollution.

11. ELECTROMAGNETISM AND MICROWAVES

Divergence, curl and gradient – Maxwell's equations – Wave equation for electromagnetic waves – Propagation in free space – Poynting vector – Rectangular and circular wave guides. Microwaves - Properties and applications – Generation by magnetron and reflex klystron oscillator – Traveling wave tube – Biological effects.

12. OPTICS

Principles and Lummer-Brodhun photometer. Lasers: Principles and characteristics – Types of lasers (CO_2, excimer, NdYAG, GaAs, free electron) – Holographic mass storage. Optical Fiber: Principles – Physical structure and types – Optical fiber communication. Photo elasticity: Theory and applications.

13. CRYSTAL PHYSICS AND CRYOGENICS

Crystal Physics: Crystal directions – Planes and Miller indices – Basic symmetry elements,Translational symmetry elements – Reciprocal lattice – Diamond and HCP crystal structure – Imperfections in crystals. *Cryogenics:* Methods of liquefaction of gases (cascade process, Linde's process, and adiabatic demagnetization process) – Measurement of cryogenic temperatures.

14. ENERGY PHYSICS

Introduction to non-conventional energy sources – Solar cells – Thermoelectric power generators –Thermionic power generator – Magneto hydrodynamic power generator – Fuel cells (H2O2) – Solid state batteries (Lithium) – Low voltage and high voltage nuclear cells – Thermocouple based nuclear cell – Ultra capacitors.

15. APPLICATION OF RADIOISOTOPES

Nuclear systematics - naturally occurring radioactive isotopes and series - instrumental techniques for detection and measurement of radioactivity - radioactive methods for prospecting and assaying of mineral (radioactive and non-radioactive) deposits - applications of radioactivity and radon in prospecting for oil and hydrocarbon deposits - applications of radiometric studies to paleoseismology-Radioisotopes and applications in industry and medicine.

16. NUCLEAR FUSION

Fusion power generation, concept of cross section, mean free path and collision frequency. Radiation losses. fusion reactor energy, system energy balance, plasma heating, Lawson criterion. Nature of plasma, plasma charectristics, magnetic configuration and particle orbit, plasma as magneto hydrodynamic (MHD) fluid. MHD macroscopic eqillibrium and stabilities. MHD relaxation confinement. Open magnetic confinement – magnetic and kinetic pressure, magnetic flux surfaces, magnetic mirrors, instabilities in mirror fields. Classical mirror confinement. Closed magnetic systems-Torroidal fields, Tokamak features, particle trapping. Tokamaks-devices, equilibrium, beta limit of elongated plasma, impurity control, scrap- off layer and divertor, boot strap current, neoclassical tearing mode. Reversed field pinch(RFP) stellarator- configuration, relaxation, confinement, Oscillating field device, stellarator- helical field, stelarator devices, neoclassical diffusion in helical field, confinement of stellarator system.

17. REACTOR HEAT GENERATION & HEAT REMOVAL

Energy release and deposition, Heat generation parameters, Neutron flux distributions and power profiles in reactor cores, Power peaking factors, Heat generation in the structure, Reactor shutdown heat generation. Heat transfer via thermal conduction, Thermal properties of fuel materials, Radial steady-state temperature distribution in fresh fuel and restructured fuel elements, Heat transfer via convection in single-phase coolants, Radial heat transfer from fuel element to coolant, Hydraulic flow in heated channels, heat transfer coefficients, Axial steady-state temperature distribution in fuel elements, Boiling heat transfer in nuclear reactors, Pressure drop through primary coolant loop, Heat removal and pumping power.

18. DESIGNS OF NUCLEAR POWER PLANTS

Pressurized Water reactors, Boiling water reactors, gas-cooled reactors, heavy water reactors, liquid metal-cooled fast reactors, Temperature coefficients of reactivity, reactivity feedback, Loss-of-cooling accidents, Reactivity insertion accidents, Containment pressurization process, Response of a PWR pressurizer to load changes, Nuclear Power Plant control

19. DETECTION AND MEASUREMENT OF RADIOACTIVITY

Ionization chamber, Geiger- Muller,proportional, scintillation counters, Wilson cloud chamber, Health physics instrumentation-Film badges, Pocket ion chambers, portable counters and survey meters, Accelerators: Van de Graff and cyclotron.

20. INTERACTION OF RADIATION WITH MATTER

Primary radiation – Chemical Process, Direct interaction of radiation with matter, ionization, excitation, neutron impact. Basic reactions involving active species produced in the primary act, and Radiation dosimetry. Selection of radioisotopes as tracer-Application of radioisotopes as tracersanalytical,-physico- chemical,

medical, agriculture and industrial applications-Neutron activation analysis- Radiometric titrations and isotope dilution techniques-.Radiopharmaceutical, radioimmunoassay and radiation sterilization. The relationship between load and resistance offered by material through equilibrium compatibility and material property.

21. NUCLEAR MATERIAL

Structure of a power plant, Requirements of reactor materials-fuel materials- plutonium, uranium and thorium and their alloys and compound core materials-beryllium, graphite control and shielding materials- magnesium and its alloys, alluminium and its alloys-Coolant used in reactors radiation embrittlement- corrosion reactor materials-Mechanical properties of materials. Radiation, Fission, reactor and reactor elements, characteristics of fission materials-Density – Melting point- Electrical and thermal conductivity-Fission cross section-Coolants- Cladding materials- Moderators-Heat exchanger-Arrestor.

22. MAGNETIC, DIELECTRIC AND MODERN ENGINEERING MATERIALS

Magnetic materials: Ferrites and garnets – Magnetic bubbles and their applications – Giant Magneto Resistance (GMR) – Colossal Magneto Resistance (CMR). *Dielectric materials:* Various polarization mechanisms in dielectrics (elementary ideas) and their frequency and temperature dependence – Dielectric loss – Piezo electric and ferro electric materials and their applications. *Modern engineering materials:* Shape memory alloys – Metallic glasses – Advanced ceramics and composites.

23. NANO MATERIALS AND NANOTECHNOLOGY

Basic concepts of Nano science and technology – Quantum wire – Quantum well – Quantum dot – Properties and technological advantages of Nano materials – Carbon Nanotubes and applications – Material processing by Sol – Gel method, Chemical Vapour deposition and Physical Vapour deposition – Microwave Synthesis of materials – Principles of SEM, TEM and AFM .

24. MECHANICAL PROPERTIES OF MATERIALS

Stress Strain diagram for different engineering materials – Engineering and true stress strain diagram – Ductile and brittle material – Tensile strength – Hardness – Impact strength – Fatigue – Creep – Fracture (Types and Ductile to brittle transition) – Factors affecting mechanical properties. Yield criteria for Ductile materials under plane stress-Fracture criteria for Brittle materials under plane stress- Introduction to fracture mechanics-Repeated loading: Fatigue: Introduction to Fatigue-Fatigue materials – Factors affecting mechanical properties.

25. STRESSES, PRINCIPLE STRESSES, STRAIN ENERGY

Basic definations: Stress-Strain-Shear-Poison's ratio- 1D Hook's law and constitutive equation for elastic behaviour-Examples of various stress states 2D and 3D multiaxial stress states -Principal stresses: Theory principle stresses-Calculations of Octahedral and maximum shear stress, Stress-Strain Temperature relations-Stress– Strain diagram for different engineering materials - Strain Energy: Strain energy density-Stress concentration.

26. SHAFTS, BEAMS & COLUMNS

Shafts- Plastic Deformation in circular Shafts - Thin-Walled Hollow shafts *Beams:* Deflection of beams, Deformation of a beam under Transverse loading-Direct Determination of the elastic curve from the Load distribution-Method of Superposition-Application of Superposition to statically indeterminate Beams. *Columns:* Introduction-Stability of Structures-Euler's Formula for Pin-ended columns-Extension of Euler's formula to columns with other end condition-Eccentric loading: The Secant formula Design of column under a centric load- Design of column under an Eccentric load. Boundary and initial value problems - Transverse vibrations of elastic string with fixed ends – Fourier series.

27. FLUID FLOW

Fundamental Concepts, Fluid Motion, Viscosity Hydrostatics and Manometry, Force on Submerged Surfaces, *Systems and control volumes:* Mass, Momentum Balance, Angular Momentum and Energy Balance and Example, Application of Control Volume Balance to 1-D Systems: 1-D Mass, Momentum and Energy

Balances, Application. *Kinematics:* Momentum Equation, Incompressible In viscid flow: Pressure and Measurement, Energy and Bernoulli Equations Dimensional Analysis: Flow Similarity and Scaling Internal, *Laminar flow:* Laminar Pipe Flow, Flow in Pipes and Bends. Calculation of Head Lass - Friction Factor: Minor Losses and Non-circular Ducts, Solution of Pipe Flow problem, Flow Measurement Boundary Layer Introduction (2-D cases) - Fluid Drag, *Turbo machinery Analysis:* Turbo machinery Performance, Pump One Dimensional Compressible Flow: Isentropic Flow, Flow with Friction Introduction to Two-Phase Flow, Applications in Nuclear Safety.

28. THERMODYNAMICS

Macroscopic vs Microscopic aspects – Thermodynamic system and surrounding – Forms of energy– Properties of a system – State and equilibrium– Quasi static process– Zeroth law of Thermodynamics -Heat and work-Internal energy-Indicator Diagrams work done in Isothermal and adiabatic processes-First law of thermodynamics-significance and applications of first law of thermodynamics-Reversible and irreversible process-Carnot's theorem-Carnot's engine, efficiency. Second law of thermodynamics-Thermodynamic scale of temperature-Entropy concept- entropy changes in reversible and irreversible processes-Entropy of universe-Entropy-Temperature diagrams-Thermodynamic potentials -Clausius theorem – Clausius inequality – Entropy principle – Property diagrams involving entropy – Entropy change of Ideal gases – Entropy generation in a closed system – Entropy generation in an open system – Third law of Thermodynamics – Introduction to availability in non-flow and flow Process. *Thermodynamic relations:* Maxwell's equations – Clapeyron equation – General relations for dh, du, ds, Cp and Cv – Joule Thomson coefficient. Gas Mixtures – Dalton's law of partial pressures – P-v-T behaviour of gas mixtures– Property calculations.

29. HEAT AND MASS TRANSFER

Introduction- General Equation of Heat Conduction- 1-D and 2-D steady conduction –analytical approach-Unsteady conduction- Numerical approach to conduction problems-Introduction to convection: Conservation equations for mass-momentum and energy-Internal and external laminar forced convection- Natural convection- Effect of turbulence on convective heat transfer- Heat Exchangers – basic principles and design-Introduction to Radiation- Spectral and directional nature of surface radiation- Kirchhoff's law and gray surface approximation. One dimensional heat equation - Steady and transient states – problems. Two dimensional heat equation – Steady state heat flow equation – Laplace Equation Cartesian form – Laplace equation in polar form – heat flow in circular plates including annulus - Fourier series solution. The Plane Wall -An Alternative Conduction Analysis -Radial Systems- Conduction with Thermal Energy Generation- Heat Transfer from Extended Surfaces- the Bio heat Equation. Alternative Approaches-The Method of Separation of Variables-The Conduction Shape Factor and the Dimensionless Conduction - Heat Rate Finite- Difference Equations-Solving the Finite-Difference Equations. The Lumped Capacitance Method-Validity of the Lumped Capacitance Method- General Lumped Capacitance Analysis- Spatial Effects-The Plane Wall with Convection-Radial Systems with Convection- The Semi-Infinite Solid - Objects with Constant Surface Temperatures or Surface Heat Fluxes- Periodic Heating- Finite-Difference Methods. The Convection Boundary Layers- Local and Average Convection Coefficients- Laminar and Turbulent Flow- The Boundary Layer Equations. Boiling and Condensation, Heat Exchanges, Radiation: Processes and Properties, Radiation Exchange between Surfaces, Diffusion Mass Transfer.

30. MANUFACTURING PROCESSES

Sheet Metal Work: Introduction – Equipments – Tools and accessories – Various processes (applications, advantages / disadvantages). Welding: Types – Equipments – Tools and accessories – Techniques employed (applications, advantages / disadvantages (gas and arc welding only)) – Gas cutting – Brazing and soldering. Lathe Practice: Types - Description of main components – Cutting tools – Work holding devices – Basic operations. Simple Problems. Drilling Practice: Introduction – Types – Description – Tools. Simple Problems.

31. MECHANICS

Rigid body mechanics – Statics of particles – vectorial representation of forces – resolution and composition of forces – coplanar and space – equivalent system of forces – free body diagram- types of support and reactions – stable equilibrium – moments and couples – equilibrium in two – three dimensions – examples. Dynamics of particles – displacement, velocity, acceleration – relationship – relative and curvilinear motion - Newton's law -impulse and momentum (simple problems only).

32. PROPERTIES OF SURFACE AND SOLIDS

Determination of areas and volumes – first moment of area and the centroid of sections – rectangle, circle, triangle, T section, I section, Angle section, hollow sections by using standard formula – second and product moments of plane, area for rectangle, triangle, circle, T, I, Angle sections, hollow sections by standard formula – parallel and perpendicular axis theorem, polar moment of inertia – mass moment of inertia for rectangular, prism, sphere – (simple problems only).

33. FLUID PROPERTIES

Importance and Application of fluid mechanics – Fluid properties – Density, Viscosity, Vapour Pressure, Bulk Modulus of Elasticity, Surface Tension, Capillarity – Pascal's Law – Law of Hydrostatics. Velocity and Acceleration – Classification of Flow – Co-efficient of discharge-Continuity Equation – Streamline, Streakline, Pathline – Potential Function and Stream Function – Flow Net Analysis. Control Volume. Euler Equation – Bernoullie's Equation – Darcey's Equation – Momentum Principle – Free and Forced Vortex motion - Hagen-Poisuilli's – Laminar and Turbulent Flows – Reynold's Experiment – Moody Chart – Friction factor – Major and Minor Losses – Pipes in Series and Parallel- Centrifugal blower, Air compressor.

34. DRAWINGS

Projection of straight lines, projection of solids – auxiliary projections, Sections of solids and development of surfaces, Conversion of projections: Orthographic projection, isometric projection of regular solids combination of solids.

35. POWER GENERATION

Thermodynamic analysis of Conventional Power Plants- Advanced Power Cycles-Overview of Nuclear power plant-Radio activity- Cross sections- Fission process-reaction rates, diffusion theory- elastic scattering and slowing down-criticality calculations- critical heat flux- power reactors, nuclear safety. Steam Turbine - Superheater, reheater and Intercoolers in Gas-Turbine power plants- Hydro power plants - turbine characteristics.

36. ENERGY

Sources: Renewable and non-renewable (various types, characteristics, advantages/disadvantages). Power Generation: External and internal combustion engines - Hydro and nuclear power plants (layouts, element/component description, advantages, disadvantages, applications). Simple Problems.

37. ELECTRICAL MACHINES

Definition of mmf, flux and reluctance, leakage flux, fringing, magnetic materials and B-H relationship. Problems involving simple magnetic circuits, Faraday's laws, induced emfs and inductances, brief idea on Hysteresis and eddy currents. Working principle, construction and applications of DC machines and AC machines (1-phase transformers, 3-phase induction motors, single phase induction motors – split phase, capacitor start and capacitor start & run motors).

38. AC & DC CIRCUITS

Circuit parameters, Ohms law, Kirchhoff's law. Average and RMS values, concept of phasor representation. RLC series circuits and series resonance, RLC parallel circuits (includes simple problems in DC & AC circuits) Introduction to three phase systems – types of connections, relationship between line and phase values. (qualitative treatment only)

39. ELECTRONIC AND PHOTONIC MATERIALS

Electronic materials: Importance of Classical and Quantum free electron theory of metals – Fermi energy and Fermi Dirac distribution function – Variation of Fermi level with temperature in intrinsic and extrinsic semiconductors – Hall effect – Dilute Magnetic Semiconductors (DMS) and their applications – High temperature Superconductivity. Photonic materials: LED and LCD materials – Photo conducting materials –

Nonlinear optical materials (elementary ideas) and their applications.

40. ELECTRONIC COMPONENTS AND DEVICES

Passive components: Resistors- Inductors and Capacitors and their types. *Semiconductor:* Energy band diagram- Intrinsic and Extrinsic semiconductors- PN junction diodes and Zener diodes – characteristics. *Transistors:* PNP and NPN transistors – theory of operation – Transistor configurations – characteristics – comparison. *Special semiconductor devices:* FET – SCR – LED – V I characteristics – applications. *Rectifiers:* Half wave and full wave rectifier – capacitive filter – wave forms – ripple factor – regulation characteristics.

41. TRANSDUCERS AND MEASURING INSTRUMENTS

Transducers: General features and classification of transducers, Resistive Transducers – Potentiometer, Unbonded strain gauge-Bonded strain gauge-Load cell, Inductive transducers – Differential output transducers – LVDT, Flow transducers, Temperature Transducers – Thermistors, Thermocouple and pyrometers. *Chemical and optical transducer:* Bio sensors - Ion exchange membrane electrodes- oxygen electrodes- CO2 electrodes enzyme electrode - construction - ISFET for glucose, urea etc. Electrolytic sensors - optical sensor - fiber optic sensors. Ion sensor, cation and anion sensor, liquid and solid ion exchange membrane electrodes, enzyme electrodes, molecular electrode, photo acoustic sensor, PPG sensors, biomedical applications. *Measuring Instruments:* Basic principles and classification of instruments, Moving coil and Moving iron instruments, CRO – Principle of operation. *Force, pressure and motion measurement:* Various transducers capable of measuring low pressure and force, its measuring system, external and catheter tip transducers, transducer to measure single movement and differential movement, velocity transducers, seismic pick-up, accelerometer, biomedical applications. *Temperature and pressure measurement:* Different Transduction principles - Temperature transducers - thermo resistive transducers, thermoelectric, chemical thermometry. Displacement transducers - potentiometer - resistive strain gauges - inductive displacement - capacitive displacement transducer. Pressure transducer - indirect method - measurement of blood pressure using sphygmomanometer -instrument based on Korotkoff sound, strain gauge and LVDT transducers, capacitive and piezo electric type, catheter tip transducers - measurement of intracranial pressure – cathetertip-implantabletype. *Flow measurement:*Flow measurement transducer -Electro magnetic flow meters and ultrasonic blood flow meters - Fibre optic flow transducers & transducers for light . Transducer to measure a velocity, magnitude and direction flow, various methods of measuring the parameter, invivo and invitro type of measurements

42. DIGITAL ELECTRONICS & LINEAR ICs

Digital Fundamentals: Number systems – Boolean Theorems – DeMorgan's Theorem - Logic gates – Implementation of Boolean Expression using Gates. *Integrated Circuits:* IC fabrication – Monolithic Technique- Function of Operational Amplifier

43. MATRICES

Characteristic equation – Eigen values and eigen vectors of a real matrix – Properties of eigen values – Caley-Hamilton theorem – Orthogonal reduction of a symmetric matrix to diagonal form – Orthogonal matrices – Reduction of quadratic form to canonical form by orthogonal transformations.

44. FUNCTIONS OF SEVERAL VARIABLES

Function of two variables – Partial derivatives – Total differential – Taylor's expansion – Maxima and Minima – Constrained Maxima and Minima by Lagrangean Multiplier method – Jacobians. *Ordinary differential equations:* Simultaneous first order linear equations with constant coefficients – Linear equations of second order with constant and variable coefficients – Homogeneous equation of Euler type – Equations reducible to homogeneous form. Two dimensional Random Variables – Marginal and conditional distributions – Transformation of Random Variables – central limit theorem – simple problems. Probability theory – Random Variables – Moments – Moment generating function – Binomial, Poisson, Geometric, Exponential, Normal distributions, functions of Random Variables, Chebyshev inequality.

45. INTEGRALS

Double integration in Cartesian and polar coordinates – Change of order of integration – Area as a double

integral – Triple integration in Cartesian coordinates. Line integral – Cauchy's integral theorem (without proof) – Cauchy's integral formulae (with proof) – application of Cauchy's integral formulae – Taylor's and Laurent's expansions (statements only) – Singularities – Poles and Residues – Cauchy's residue theorem (with proof) - Evaluation of line integrals.

46. LAPLACE TRANSFORMS

Transforms of simple functions – Basic operational properties – Transforms of derivatives and integrals – Initial and final value theorems – Inverse transforms – Convolution theorem – periodic functions – Applications of Laplace transforms for solving linear ordinary differential equations up to second order with constant coefficients only.

47. VECTOR CALCULUS

Gradient, divergence, curl – Solenoidal and irrotational fields – Vector identities (without proof) – Directional derivatives – Line, surface and volume integrals – Statements of Green's, Gauss divergence and Stroke's theorems only – Verification and applications to cubes and parallelopipeds only.

48. ANALYTIC FUNCTIONS

Definition of Analytic Function – Cauchy Riemann equations – Properties of analytic functions - Determination of harmonic conjugate – Milne-Thomson's method – Conformal mappings: 1/z, az az+b and bilinear transformation.

49. FOURIER SERIES

Dirichlet's conditions – General Fourier series – Half range Sine and Cosine series – Parseval's identity – Harmonic Analysis. Statement of Fourier integral theorem – Fourier transform pairs – Fourier Sine and Cosine transforms – Properties – Transforms of simple functions – Convolution theorem – Parseval's identity.

50. MODERN NUMERICAL METHODS

Method of Bisection – Method of False Position – Fixed point iterative Method - Newton's Method- Numerical differentiation using Newton's divided, forward and backward interpolation polynomials – Numerical Integration by Trapezoidal rule, Simpson's 1/3 and 3/8 rules.

51. COMPUTER PROGRAMMING FUNDAMENTALS

Computer Basics; Program Development Life Cycle: Flow Chart, Algorithm, Compilation and Execution; Introduction to C Language: program structure, variables, keywords, data types; Input / Output functions: scanf, printf; simple programs. *Unix:* Overview of Unix-Unix documentation-files, directories –Accounts and processes –Redirections and pipes – Shells – Editing texts-Dot files – Regular expressions – X Windows. *Matlab:* Familiarisation with MATLAB- control system tool box, MATLAB- SIMULINK tool box - Determination of step response for first order & second order system with unity feedback &calculations of control system specifications like time constant, % peak overshoot, settling time etc., from the response.- Simulation of step response & impulse response for type-0 , type-1 & type –2 system with unity feedback using MATLAB- Determination of root locus, BODE- Plot, NYQUIST- plot using MATLAB - control system toolbox for 2nd order system & determination of different control system specifications from the plot.

52. LINEAR PROGRAMMING

Introduction to Linear Programming – Formulation of the problem – Graphical method – Simplex method – Artificial variable techniques - Primal-dual problems – Dual Simplex method. *Advanced linear programming problems:* Integer programming problem - Cutting plane algorithm – Transportation models - Vogel's Approximation method – MODI method – Unbalanced transportation problem – Degeneracy in transportation models – Assignment models – Traveling salesman problem-Dynamic Programming problem.

NOTE: In addition to the above syllabus, the fundamental concepts in Physics, Chemistry and Mathematics are also included in the syllabus.