

Ph.D. Written Test Syllabus

Mechanical Engineering

APPLIED MECHANICS AND DESIGN

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.

FLUID MECHANICS AND THERMAL SCIENCES

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

Heat-Transfer: Modes of heat transfer; one dimensional heat conduction, resistance concept, electrical analogy, unsteady heat conduction, fins; dimensionless parameters in free and forced convective heat transfer, various correlations for heat transfer in flow over flat plates and through pipes; thermal boundary layer; effect of turbulence; radiative heat transfer, black and grey surfaces, shape factors, network analysis; heat exchanger performance, LMTD and NTU methods.

Thermodynamics: Zeroth, First and Second laws of thermodynamics; thermodynamic system and processes; Carnot cycle, irreversibility and availability; behaviour of ideal and real gases, properties of pure substances, calculation of work and heat in ideal processes; analysis of thermodynamic cycles related to energy conversion.

Applications: *Power Engineering:* Steam Tables, Rankine, Brayton cycles with regeneration and reheat. *I.C. Engines:* air-standard Otto, Diesel cycles. *Refrigeration and air-conditioning:* Vapour refrigeration cycle, heat pumps, gas refrigeration, Reverse Brayton cycle; moist air: psychrometric chart, basic psychrometric processes. *Turbomachinery:* Pelton-wheel, Francis and Kaplan turbines — impulse and reaction principles, velocity diagrams.

MANUFACTURING AND INDUSTRIAL ENGINEERING

Engineering Materials: Structure and properties of engineering materials, heat treatment, stress-strain diagrams for engineering materials.

Metal Casting: Design of patterns, moulds and cores; solidification and cooling; riser and gating design, design considerations.

Forming: 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.

Joining: Physics of welding, brazing and soldering; adhesive bonding; design considerations in welding.

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

Production Planning and Control: Forecasting models, aggregate production planning, scheduling, materials requirement planning.

Inventory Control: Deterministic and probabilistic models; safety stock inventory control systems.

Operations Research: Linear programming, simplex and duplex method, transportation, assignment, network flow models, simple queuing models, PERT and CPM.

**Syllabus for Written Test for PhD Civil Engineering
(2018-19 Admissions)**

Type: MCQ – 50 Questions

Time: 1 hour

Total Marks: 50

Note: The paper will consist of two sections.

1. Section A: General Aptitude - 30 Marks (COMPULSORY)
2. Section B: Civil Engineering Discipline - 20 Marks.

Section B will have following 4 sub-sections specialization specific, candidate shall attempt any ONE SUB-SECTION of his/her choice.

Section A

General Aptitude Verbal ability, numerical ability, reasoning, engineering mathematics.

Section B

1. Structural Engineering

Engineering mechanics, solid mechanics, structural analysis, design of RCC structures, design of steel structures, structural dynamics, construction materials.

2. Geotechnical Engineering

Index and engineering properties of soils, slope stability, subsurface exploration, shallow improvement techniques. Foundations, deep foundations, earth retaining structures, ground improvement techniques.

3. Water Resources Engineering

Fluid Mechanics, hydrology, open channel flow

4. Transportation Engineering

Traffic engineering, urban transport planning, highway materials, pavement design, pavement evaluation.

Electrical Engineering

Section 1. (compulsory , 30 Marks)

Electric Circuits

Network graph, KCL, KVL, Node and Mesh analysis, Transient response of dc and ac networks, Sinusoidal steady-state analysis, Resonance, Passive filters, Ideal current and voltage sources, Thevenin's theorem, Norton's theorem, Superposition theorem, Maximum power transfer theorem, Two-port networks, Three phase circuits, Power and power factor in ac circuits.

Electromagnetic Fields

Coulomb's Law, Electric Field Intensity, Electric Flux Density, Gauss's Law, Divergence, Electric field and potential due to point, line, plane and spherical charge distributions, Effect of dielectric medium, Capacitance of simple configurations, Biot-Savart's law, Ampere's law, Curl, Faraday's law, Lorentz force, Inductance, Magnetomotive force, Reluctance, Magnetic circuits, Self and Mutual inductance of simple configurations.

Signals and Systems

Representation of continuous and discrete-time signals, Shifting and scaling operations, Linear Time Invariant and Causal systems, Fourier series representation of continuous periodic signals, Sampling theorem, Applications of Fourier Transform, Laplace Transform and z-Transform.

Analog and Digital Electronics

Characteristics of diodes, BJT, MOSFET; Simple diode circuits: clipping, clamping, rectifiers; Amplifiers: Biasing, Equivalent circuit and Frequency response; Oscillators and Feedback amplifiers; Operational amplifiers: Characteristics and applications; Simple active filters, VCOs and Timers, Combinational and Sequential logic circuits, Multiplexer, Demultiplexer, Schmitt trigger, Sample and hold circuits, A/D and D/A converters, 8085 Microprocessor: Architecture, Programming and Interfacing.

Control Systems

Mathematical modelling and representation of systems, Feedback principle, transfer function, Block diagrams and Signal flow graphs, Transient and Steady-state analysis of linear time invariant systems, Routh-Hurwitz and Nyquist criteria, Bode plots, Root loci, Stability analysis, Lag, Lead and Lead-Lag compensators; P, PI and PID controllers; State 3 space model, State transition matrix.

Section 2. (attempt any one section, 20 Marks)

1. Power Systems, Electrical Machines and Drives

Power generation concepts, ac and dc transmission concepts, Models and performance of transmission lines and cables, Series and shunt compensation, Electric field distribution and insulators, Distribution systems, Per-unit quantities, Bus admittance matrix, Gauss-Seidel and Newton-Raphson load flow methods, Voltage and Frequency control, Power factor correction, Symmetrical components, Symmetrical and unsymmetrical fault analysis, Principles of over-current, differential and distance protection; Circuit breakers, System stability concepts, Equal area criterion.

1-ph and 3-ph transformers, autotransformers, instrument transformers, principles of electromechanical energy conversion, forces and torques in magnetic field system, field energy and coenergy, DC machines, alternators, synchronous motor, 1-ph and 3-ph induction motors, special machines, test methods, design of machines, power semiconductor devices, drive and protection circuits, different types of converters and performance parameters, applications of converters, harmonics and mitigation.

2. Signal Processing and communications

Introduction to continuous and Discrete-time signal and Sequence, introduction to system and its properties: Linearity, time invariance and causality, Analysis of A LTI System:(a) impulse response, Convolution sum convolution integral (b) differential equation and Difference equation(c) transform domain considerations. Z-transform, Applications of transforms to discrete and continuous time system analysis, Transfer function, block diagram representation. Fourier Series and Fourier Transform (FT), Discrete-time FT (DTFT), Discrete FT (DFT), fast Fourier transform (FFT). Sampling theorem, Design of Digital filters:(a) FIR, and (b) IIR Introduction to spectral estimation. AM, FM and PCM. Sampling theorem.

3. Semiconductor theory and IC Fabrication

Energy bands in intrinsic and extrinsic silicon; Carrier transport: diffusion current, drift current, mobility and resistivity; Generation and recombination of carriers; exciton theory, Poisson and continuity equations; crystal structure, crystalline and amorphous semiconductors, compound semiconductors, P-N junction, homojunction and heterojunction, MOS capacitor, LED, photo diode, phototransistors and solar cells; Integrated circuit fabrication process: oxidation, diffusion, ion implantation, photolithography and twin-tub CMOS process.

Physics

1. 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. 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: $SU(2)$, $O(3)$.

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

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

4. 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. 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.

5. 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. 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.

6. 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, 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).

7. 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.

8. 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.

9. 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.

Economics

A) Microeconomics: 1. Demand and Supply Analysis 2. Theory of Production and Cost 3. Welfare Economics

B) Macroeconomics: 1. Measuring value of Economic Activity (National Income Accounting). 2. Theory of employment, Consumption, Output, Inflation, Money and Finance 3. Financial and Capital Market 4. Economic Growth and Development 5. International Economics 7. Balance of Payments 8. Global Institutions

C) Public Finance: 1. Theories of taxation, Theories of public expenditure and Theory of public debt management. 2. Environmental Economics 4. State, Market and Planning

D) Indian Economy: 1. History of development and planning. 2. Budgeting and Fiscal Policy 3. Poverty, Unemployment and Human Development 4. Agriculture and Rural Development Strategies. 5. Foreign trade and Foreign Investment 15

E) Research Methodology, Basic Statistics, Econometrics, Logical Reasoning and Data

Interpretation: 1. Primary and Secondary Research. 2. Techniques of data collection- Qualitative and Quantitative. 3. Presentation and analysis 4. Econometric and Statistical tools for social research

F) Current Affairs related to Infrastructure development in India.

Chemistry

Periodic table, periodic properties.

Chemical bonding, hybridization, Valence bond and molecular orbital theories.

Concepts of acids and bases.

Coordination compounds and organometallic compounds

Solid state chemistry: Crystal structures; Bragg's law and applications.

Nuclear chemistry, nuclear fission and fusion, nuclear reactor.

Chemical thermodynamics, laws of thermodynamics, energy, entropy, free energy, state and path functions, spontaneity and equilibria.

Phase transitions and phase rule. One and two components systems.

Electrochemistry: Nernst equation, redox systems, electrodes, electrochemical cells; ionic equilibria; pH and buffer solutions. Conductometric and potentiometric titrations.

Chemical kinetics, rate laws and temperature dependence of rate; complex reactions; steady state approximation; collision and transition state theories, unimolecular reactions.

Adsorption, adsorption isotherms, colloids.

Homogeneous and heterogeneous catalysis; Enzyme kinetics;

Photo chemical reactions and quantum yield.

IUPAC nomenclature of organic molecules,

Aromaticity, heterocyclic compounds.

Basic reaction mechanisms, Named reactions. Isomerism, stereochemistry.

Natural products, Drugs and pharmaceuticals.

Polymer chemistry, Polymerization reactions, MW of polymers and their determination,

Nanomaterials,

Environmental impact of chemicals and green chemistry.

Chromatography, theory, classification, applications.

Basic molecular spectroscopy, microwave, IR and UV-Visible spectroscopy. NMR spectroscopy. Instrumentation. Applications.

Thermal methods of analysis: DTA, TG, DSC

Data analysis: Mean and standard deviation; absolute and relative errors; linear regression; covariance and correlation coefficient