# *Vardhman Mahaveer Open University, Kota*
# *M.Sc. Physics Entrance Test Syllabus*
# *Admission Session July 2021*

## *Mathematical Physics*

Vector algebra, vector Calculus, gradient of scalar field and its geometrical interpretation, divergence and curl of a vector field, line, surface and volume integral, multiple integrals, flux of vector field, Divergence theorem, Green's theorem, Stokes' theorem. Algebra of complex numbers.

Curvilinear coordinate systems, Del, Divergence, Curl and Laplacian operators in curvilinear coordinate systems. Dirac-Delta function and its properties. Fourier series, computation of Fourier coefficients

Transformation of covariant, contravariant and mixed tensor, addition, multiplication and contraction of tensors, quotient law, pseudo tensor, metric tensor, transformation of tensors.

Matrices: Matrices algebra, types of matrices (null, diagonal, scalar and unit, upper-triangular and lower-triangular), transpose of a matrix, symmetric and skew-symmetric matrices, Hermitian and skew-hermitian matrices, singular and non singular matrices, unitary matrices, conjugate of matrix

Adjoint of a matrix, inverse of a matrix by adjoint method, trace of a matrix, eigen-values and eigenvectors, Cayley- Hamiliton theorem, diagonalization of matrices,

First order equations and linear second order differential equations with constant coefficients, the second order linear differential equation with variable coefficient and singular points, series solution method and its application in the Bessel's, Hermite's, Legendre's and Laguerre's differential equations, Basic properties like orthogonality, recurrence relations, graphical representation and generating function of Bessel, Hermite, Legendre, Laguerre and associated Legendre functions.

Technique of separation of variables and its application to following boundary value problems: Laplace equation in three dimension Cartesian coordinate system-line charge between two earthed parallel plates, wave equation in spherical polar coordinates the vibration of circular membrane, diffusion equation in two dimensional Cartesian coordinate system-heat conduction in thin rectangular plate, Laplace equation in spherical coordinate system-Electric Potential about a spherical surface.

Four vector formulation, energy-momentum four vectors, relativistic equation of motion, orthogonality of four forces and four velocities, transformation of four wave vector, longitudinal and transverse Doppler's effect.

Electromagnetic field tensor, transformation of four potentials, four currents, electric and magnetic field between two inertial frames of reference, Lorentz force, equation of continuity, conservation of charge, tensor description of Maxwell's equations.

## *Mechanics and General Properties of Matter*

Newton's laws of motion and applications, velocity and acceleration in cartesian, polar and cylindrical coordinate systems, inertial frame of references, motion and rest, Galilean transformations-transformation of displacement, velocity and acceleration, Special theory of relativity, Lorentz transformation and rotation in space-time, time like and space like vectors, energy-mass relation, length contraction, time dilation, relativistic velocity addition theorem.

Rotating frame of references, transformation of velocity and acceleration between rotating frames, Coriolis and centrifugal forces, effects of Coriolis and centrifugal forces due to Earth's rotation, Foucault's pendulum.

Conservation Laws: Conservative forces and non-conservative forces, potential energy, gravitational potential, electric potential, conservation of energy, center of mass and motion of center of mass of a system of particles, two particle system and reduced mass, conservation of linear momentum in Lab and CM system, elastic and inelastic collisions, collision of two bodies in one, two and three dimensions, slowing down of neutrons in a moderator, motion of a system with varying mass.

Dynamics of rigid body and motion under central forces: rotational motion of a body, moment of inertia, parallel and perpendicular axes theorem, inertia tensor, kinetic energy of rotation and concept of principal axes, angular momentum of a system, conservation angular momentum, precessional motion of a spinning top and spin precession in constant magnetic field, gravitational law and field, potential due to a spherical body, gravitational self energy, motion under central forces, general solution under gravitational interaction, cases of elliptical and circular orbits, scattering of charged particles by heavy nucleus, planetary motion, Kepler's laws.

Hooke's law, Young's modulus, bulk modulus and modulus of rigidity, Poisson's ratio, relation between various elastic constants, torsion of a cylinder, bending of beam, Searle's method

Kinematics of moving fluids, equation of continuity, Euler's equation, Bernoulli's theorem, viscous fluids, stream line and turbulent flow, Poiseuille's law, capillary tube flow, Reynold's number, Stoke's law, surface tension and surface energy, molecular interpretation of surface tension, pressure on a curved liquid surface, wetting.

## *Waves and Oscillations*

Differential equation for simple harmonic oscillator and its general solution, superposition of two or more simple harmonic oscillators, Lissajous figures, oscillations in a potential well, examples of harmonic motion - mass on a spring, torsional oscillators, LC circuit, energy of the oscillator, damping, viscous and solid friction damping, damped harmonic oscillator, power dissipation.

Forced harmonic oscillator with viscous damping, frequency response, phase relation, quality factor, resonance, electrical oscillation, anharmonic oscillator, simple pendulum as an example.

Equation of motion of two coupled simple harmonic oscillators, normal modes, motion in mixed modes, transient behavior, effect of coupling in mechanical systems, electrically coupled circuits, frequency response, reflected impedance, effect of coupling and resistive load.

Dynamics of number of oscillators with near-neighbour interactions, equation of motion for one dimensional monoatomic and diatomic lattices, acoustic and optical mode, dispersion relations, concept of group and phase velocities.

Wave motion and its parameters, traveling and stationary waves, energy density and energy transmission in waves, sound waves in media, Doppler effect, properties and uses of ultrasonic waves, reverberation time, Sabine's formula.

## *Electricity & Magnetism*

Coulomb's law, Gauss's law, electric field and potential, electrostatic boundary conditions, Solution of Laplace's equation for simple cases, conductors, capacitors, electric potential-gradient of a scalar function, line integral of a vector field, potential difference and potential function, potential energy of a system, energy required to build a uniformly charged sphere, classical radius of an electron, potential and field of an arbitrary charge distribution at rest, potential and field due to a short dipole, concept of multi poles, monopole, dipole and quadruple potentials and field, work done on a charge in an electrostatic field, torque on a dipole in a uniform electric field and its energy

Measurement of charge in motion, invariance of charge, electric field measured in different frames of reference, field of a point charge moving with constant velocity, force on a moving charge, interaction between a moving charge and other moving charges, magnetic field, Ampere's circuital law with applications, Ampere's law in differential form, vector potential, field of a current carrying conductor, Biot-Savart law.

Electric field in matter: atomic and molecular dipoles, permanent dipole moment, dielectrics, polarizability, polarization vector, volume and surface charges, electrostatic energy, capacity of parallel plate capacitor with partially or completely filled dielectric, electric displacement, electrostatic energy of charge distribution in dielectric, Lorentz local

field and Clausius Mossotti relation, potential and field due to a polarized sphere, dielectric sphere in a uniform field, field of charge in a dielectric medium and Gauss's law, electric susceptibility and atomic polarizability, polarization in changing fields.

Electrostatic field - conductors in electric field, Boundary conditions for potential and field at dielectric surface, uniqueness theorem, method of images and its applications for system of a point charge near a grounded conducting plane, Poisson's and Laplace's equations in cartesian, cylindrical and spherical polar coordinates, solutions of Laplace' equations in cartesian coordinates, potential at a point inside a rectangular box

Bohr magneton, electron spin and magnetic moment, magnetic susceptibility, magnetic field due to magnetized matter, electromagnetic induction, Faraday's law of electromagnetic induction, Lenz's law, self and mutual inductance, alternating currents, simple DC and AC circuits with R, L and C components, charging, discharging of condenser through resistance, rise and decay of current in LR circuit, decay constant, transient in LCR circuit, series and parallel resonance, Q-factor and sharpness of resonance.

Maxwell's equations, electromagnetic waves in isotropic medium, properties of electromagnetic waves, reflection and refraction at a dielectric interface, transmission and reflection coefficients (normal incidence only), energy density, radiation pressure, momentum and Poynting vector, radiation resistance of free space, spectrum of electromagnetic waves.

## *Optics*

Formation of images, sign convention, position of object and its image formed by refraction on spherical surfaces, lateral, axial and angular magnification, Abbe's sine condition, aplantic points, deviation produced by thin lenses, equivalent focal length, combination of two thin lenses, Aberrations: chromatic, achromatic combination of lenses, spherical, method of reducing aberrations.

Superposition of waves from two point sources, necessity of coherence, spatial & temporal coherence, shape of interference fringes, intensity distribution in space, Fresnel's biprism experiment, Interference by division of amplitude, Interference in thin films, color of thin films in transmission and reflection, Newton's rings, Michelson's interferometer, fringes of different shapes, Determination of $\lambda$ and $\Delta\lambda$ with Michelson's interferometer.

Fraunhofer diffraction: by a single slit, circular aperture, two parallel slits, plane diffraction grating, transmission and reflection gratings, dispersion by grating, resolving power, Rayleigh's criterion of resolution, resolving power of a grating, resolving power of a telescope, Fresnel's diffraction: half-period zones, Fresnel's diffraction by a circular aperture, Straight edge and thin slit, Zone plate.

Polarized light, production and analysis of plane, circularly and elliptically polarized light, Huygen's theory of double refraction using Fresnel's ellipsoidal surfaces, quarter and half wave plates, optical activity, specific rotation, Fresnel's explanation for optical rotation, Biquartz and half shade polarimeters.

Spontaneous and stimulated emission, Einstein's A and B coefficients, Laser Criterion, condition for amplification, population inversion, methods of optical pumping, He-Ne laser, ruby lasers, holography, construction of hologram and reconstruction of the image, basic characteristics of the optical fiber, total internal reflection, acceptance angle, acceptance cone, numerical aperture.

## *Thermal Physics and Statistical Physics*

General thermodynamical interaction, dependence of the number of states of external parameters, general relations in equilibrium, infinitesimal quasistatic process, entropy of an ideal gas, equilibrium of an isolated system, equilibrium of a system in contact with reservoir (Gibb's free energy), laws of thermodynamics, Zeroth law and concept of thermal equilibrium, first law and its consequences, isothermal and adiabatic processes, reversible, irreversible and quasi-static processes, second law and entropy

Equilibrium between phases, Clausius-Clapeyron equation, triple point, vapor in equilibrium with liquid or solid, equilibrium conditions for a system of fixed volume in contact with heat reservoir (Helmholtz free energy), for a system at constant pressure in contact with a heat reservoir (enthalpy), Maxwell's relations.

Second law of thermodynamics, Clausius and Kelvin's statements, partition function (Z), mean energy of an ideal gas and mean pressure, heat engine and efficiency of the engine, Carnot's cycle, thermodynamical scale as an absolute scale.

Production of low temperatures and applications, Joule Thomson expansion and J.T. coefficients for ideal gas, Van-der Waal's gas, temperature inversion, regenerative cooling, cooling by adiabatic expansion and demagnetization, liquid He, He–I and He-II, superfluidity, quest for absolute zero, Nernst heat theorem.

Elements of kinetic theory of gases, velocity distribution and equipartition of energy, ideal gas, Van-der-Waals gas and equation of state, mean free path, Maxwell' Boltzmann's statistics, distribution of molecular velocities, energy distribution function, most probable, average & r.m.s. velocities, specific heat of gases, classical theory of specific heat capacity, specific heat of solids, Einstein's and Debye's Model.

Classical statistics: phase space, micro and macro states, thermodynamic probability, entropy and probability-monoatomic ideal gas, Entropy of mixing, Ensembles: canonical, micro canonical and grand canonical.

Quantum statistics: failures of classical statistics (black body radiation and various laws of distribution of radiation, qualitative discussion of Wien's and Rayleigh Jean's laws)

postulates of quantum statistics, indistinguishability of wave function and exchange degeneracy, a prior probability.

Bose-Einstein statistics: B-E distribution law, thermodynamic functions of a strongly degenerate Bose gas, Bose Einstein condensation, properties of liquid He, radiation as a photon gas and thermodynamic functions of photon gas

Fermi-Dirac Statistics: Fermi-Dirac distribution law, thermodynamic functions of degenerate Fermi gas, Fermi energy, electron gas in a metal, specific heat of metals.

## *Electronics*

Semiconductors, intrinsic and extrinsic semiconductors, variation of resistivity with temperature, charge density of semiconductors, generation and recombination of charges, diffusion, continuity equation, injected minority carrier charges, p-n junction, volt Ampere characteristic, temperature dependency, space charge, diffusion capacitance.

Rectification and power supply, half-wave, full wave and bridge rectifiers, ripple factor, efficiency and regulation, Filters-shunt capacitor, LC and RC filters regulation and stabilization, Zener diode, voltage multiplier.

Transistor and transistor Amplifiers: Notations and Volt-Ampere relations for bipolar junction transistor, concept of load line and operating point, hybrid parameters, field effect transistor and their circuit characteristics, analysis of transistor amplifiers using hybrid parameters and its frequency response, fixed and emitter bias, bias stability.

Concept of feedback, stabilization of gain by negative feedback, effect of feedback on output and input resistance, reduction of nonlinear distortion by negative feedback, voltage and current feedback circuits, frequency resonance, feedback requirements for oscillators, circuit requirement for oscillation, basic oscillators, Colpitt, Hartley, R-C coupled oscillators, Piezo-electric frequency control.

Operational Amplifier: Op-Amp basics, differential amplifier, DC level shifter, input and output impedances, input offset current, Applications : unit gain buffer, adder, subtractor, integrator and differentiator, comparator, idea of wave form generator, voltage regulator using integrated amplifiers, Boolean algebra, De Morgan's theorem, basic and universal logic gates.

## *Solid State Physics*

Crystal structure: symmetry elements in crystal, fundamental lattice systems and types, Miller indices and direction indices, spacing of planes in crystal lattice, crystal structures of simple cubic, face centered cubic structure, body centered cubic structure, hexagonal closed packed structure, diamond and Zinc blend structure, Pervoskite structure, reciprocal lattice, Brillouin zones.

Crystal bonding, ionic bond, binding energy of ionic crystal, determination of the repulsive exponent, covalent bonding, metallic bonding, molecular or Vander Waal's bonding, hydrogen bonding, crystal diffraction: Bragg's law, X-ray and neutron diffraction, rotating crystal and powder methods, Laue method.

Electrical and thermal properties of solids: phonon, lattice specific heat, classical, Einstein's and quantum theories of electrical and Thermal conductivity, Weidmann-Franz law, Fermi Dirac distribution function, density of states.

Semiconductor, Law of mass action, Calculation of impurity conductivity, Introduction of band structure, ellipsoidal energy surfaces in Si and Ge, Hall effect, recombination mechanism, excitons, photoconductivity, photo luminescence.

Band theory of solids: formation of bands, wave function in a periodic lattice and Bloch theorem, Kronig Penny model, effective mass of an electron moving in a crystal, physical origin of effective mass, difference between conductors, insulators, semiconductors.

## *Elementary Quantum Mechanics*

Failures of the classical mechanics, black body radiation and spectral distribution of energy, Planck's quantum hypothesis and average energy of Planck's oscillator, Planck's radiation law, photo electric effect, Compton effect, Wave-particle duality, de Broglie waves, Davisson-Germer experiment, group and phase velocities.

Uncertainty principle, its applications, concept of wave packet, phase velocity and group velocity, construction of one dimensional wave packet, momentum space representation of wave packet (Fourier transform), Bohr's principle of complementarity, wave function, boundary and continuity conditions of wave function, physical significance of wave function.

Schrodinger's equation, time dependent and time independent forms, probability current density, postulates of quantum mechanics, operators in quantum mechanics, linear and Hermitian operator, properties of Hermitian operators, expectation values of dynamical variables –position, momentum and energy, eigen functions & eigen values, degeneracy, orthogonality of eigen functions, Ehrenfest theorems, commutation relations, parity-symmetric and antisymmetric wave functions.

Particle in a one-dimensional box, eigen functions and eigen values, discrete energy levels, generalization to two and three dimensions and degeneracy of levels, potential step and rectangular potential barrier, calculation of reflection and transmission coefficients, alpha decay.

Square well potential problem, calculation of transmission and reflection coefficients, particle in one dimensional infinite potential well, particle in a one-dimensional finite depth potential well, energy eigen values and eigen functions, simple harmonic oscillator (one dimensional case), zero point energy.

## *Atomic, Nuclear & Particle Physics & Introductory Molecular Spectroscopy*

Wave-particle duality, Pauli exclusion principle, atomic models- Rutherford, Bohr, Sommerfeld, space quantization, quantum numbers, spectral lines, X-rays, generation of X-rays, continuous and characteristic spectrum, applications of X-rays, introductory Zeeman effect.

Nuclear Properties: mass, radius, variation of nuclear radius with mass number A, angular momentum, magnetic moment, electric quadrupole moment, parity, estimation of mass, basic concepts of mass spectrographs, Bainbridge Jordan's double focusing spectrograph, Coulomb's scattering of a charged particle by a nucleus.

Nuclear Binding : constituents of nucleus, properties of nuclear forces, binding energy, mass defect, variation of binding energy with mass number, liquid drop model, semiempirical mass formula, origin of various terms, stable nucleus and conditions for stability, Shell model of nucleus, radioactivity and its applications, laws of radioactive decay.

Nuclear fission: energy release in nuclear fission (using BE curve), spontaneous fission and potential barrier, liquid drop model, self sustaining chain reaction, neutron balance in a nuclear reactor, classification of reactors, uncontrolled reaction and atomic bomb, Nuclear fusion: energy released in nuclear fusion in stars, carbon-nitrogen and proton-proton cycle, problems of controlled fusion.

Particle accelerator: linear accelerator, cyclotron, synchrocyclotron, betatron, synchrotron, electron synchrotron, proton synchrotron, nuclear detectors: ionization chamber, proportional counter, GM counter, scintillation counters, solid state detectors, neutron detector.

Subatomic particles: properties of particles, classification into leptons, mesons and baryons, matter and antimatter, conservation laws, fundamental interactions, quark model for the structure of matter.

Introductory molecular spectroscopy: pure rotational, pure vibrational and rotational-vibrational spectra.