

Physics

Unit-I : Mathematical Physics and Classical Mechanics

1. Vector calculus and complex variable :

Vector Calculus, Gauss theorem and Stokes theorem.

Cauchy's theorem, Cauchy's integral formula, classification of singularities, branch point and branch cut, Residue theorem, evaluation of integral using residue theorem.

2. Special functions :

Basic properties and solutions (series expansion, recurrence and orthogonality relations) of Bessel, Legendre, Hermite, Beta and Gamma function, Fourier Series, Dirac delta function, Laplace and Fourier transform.

3. Hamilton's principle:

Hamilton's principle, Lagrange's equation from Hamilton's principle, Solution of Lagrange equation of motion for Simple harmonic oscillator. Hamilton's equations of motion, canonical equations from variational principle, principle of least action

4. Canonical transformation:

Generating function and Legendre transformation, Lagrange and Poisson's brackets, conservation theorems in Poisson bracket formalism, Jacobi Identity.

5. Coupled oscillations:

Theory of coupled oscillation, Normal modes, Energy relation and transfer.

Unit-II: Classical Electrodynamics

1. Electrostatics and Magnetostatics:

Scalar and vector potential, Gauge transformation, multipole expansion of (i) scalar potential and electrostatic energy due to static charge distribution, (ii) vector potential due to stationary current distribution, Electrostatic and magnetostatic energy, Poynting's theorem.

2. Maxwell's electromagnetic equations-wave equation in conducting medium. Reflection of electromagnetic waves (normal and oblique incidence) from (i) dielectric and (ii) metallic interface.

3. Relativistic electrodynamics:

Equation of motion in an electromagnetic field, electromagnetic field tensor, covariance of Maxwell's equation, Maxwell's equations as equations of motion, Lorentz transformation laws for electromagnetic field, and the fields due to point charge in uniform motion.

4. Radiation, scattering and diffraction:

Field due to localized oscillating source, electric dipole, magnetic dipole, electric quadrupole field radiation, centre-fed linear antenna with sinusoidal current, scattering by a small dielectric sphere in long wave length limit, Rayleigh scattering,

5. Growth and decay of current in dc circuit containing LR, CR and LCR. Alternating current circuits containing LR, CR and LCR – Resonance.

Unit-III: Quantum Mechanics

1. Wave packet: and Schrödinger's equation.

Gaussian wave packet, spreading of wave packet, Schrödinger's equation, probability interpretation of wave function, expectation values, coordinate and momentum representation, \mathbf{x} and \mathbf{p} in these representations, stationary states, Eigen states, Ehrenfest theorem, Quantum virial theorem. Linear independence and Linear dependence, Expansion Theorem, Ortho-normality and Completeness conditions.

2. Operator method in Quantum Mechanics: operator algebra, Eigen function and eigen values of Hermitian operator, Formulation of Quantum Mechanics in vector space language, uncertainty product of two non commuting Hermitian operators, one dimensional harmonic oscillator Matrix representation of operators, Schrodinger, Heisenberg and interaction pictures. Potential well (Finite, infinite) in one dimension, potential step.

3. Angular momentum:

Angular momentum algebra, addition of two angular momenta $j_1=1/2, j_2=1/2$. Clebsch-Gordon Coefficients, examples, matrix representation of $j_1=1/2$ and $j_2=1$. Spin angular momentum, Pauli spin matrices and their properties, eigen value and eigen function,

4. Radial solution of Hydrogen atom and its wave function in ground state.

5. Approximation methods:

Time independent perturbation theory, First and second order correction to energy and eigen functions, application to one electron system, Zeeman effect, linear Stark effect.

Unit-IV: Condensed matter Physics, Statistical Mechanics and Electronics

1. Classical Statistical Mechanics:

Microstates, macro states, phase space, Liouville's theorem, concept of ensembles, Ergodic hypothesis, postulates of equal a priori probability, Boltzmann's postulates of entropy, micro canonical ensemble, entropy of ideal gas, Gibb's paradox.

Canonical ensemble:

Expression for entropy, canonical partition function, Helmholtz free energy, energy fluctuation, Max well Boltzmann distribution law.

2. Digital Circuits

Logic fundamentals, Boolean theorem, Logic gates-RTL, DTL, TTL, RS flipflop, JK flip-flops Boolean algebra, De Morgan theorem, AND, NAND, NOT, NOR gates Logic Circuits.

3. Lattice Dynamics:

Classical theory of lattice vibration under harmonic approximation, vibration of linear mono atomic and diatomic lattices, acoustical and optical modes, optical properties of ionic crystal in the infrared region, normal modes and phonon, inelastic scattering of neutron by phonon, lattice heat capacity, models of Debye and Einstein.

Free Electron Theory:

Free electron theory of metal, one dimensional infinite potential well. Electron gas in three dimension, density of states, electronic specific heat, electrical conductivity and Wiedeman-Franz law, Hall effect, cyclotron resonance.

4. Band Theory of Solid:

Nearly free electron model, effective mass of electron in the band, concept of holes, classification of metal, semiconductor and insulator, intrinsic and extrinsic semiconductors, intrinsic carrier concentration,

5. Magnetic Properties of Solids:

Quantum theory of diamagnetism, paramagnetism, Pauli Paramagnetism, Ferromagnetism, Curie-Weiss law.

Unit-V: Nuclear and Particle Physics.

1. Nuclear Properties:

Basic nuclear properties: nuclear size, nuclear radius and charge distribution, nuclear form factor, mass and binding energy, Angular momentum, parity, Magnetic dipole moment and electric quadrupole moment,

2. Two body bound state;

Properties of deuteron, Schrodinger equation and its solution for ground state of deuteron, rms radius, spin dependence of nuclear forces, electromagnetic moment and magnetic dipole moment of deuteron and the necessity of tensor forces.

3. Beta-decay :

β - emission and electron capture, Fermi's theory of allowed β -decay, Selection rules for Fermi and Gamow-Teller transitions, Parity non-conservation and Wu's experiment.

Liquid drop model, Bethe-Weizsacker binding energy/mass formula, Shell model and Collective model.

4. Nuclear Reactions and Fission.

Different types of reactions, Quantum mechanical theory, Resonance scattering and reactions, Breit-Wigner dispersion relation; Compound nucleus formation and break-up Nuclear fission: Experimental features, spontaneous fission, liquid drop model, barrier penetration and Alpha decay.

5. Particle Physics:

Basic forces, classification of elementary particle, Gellmann-Nishijima scheme, meson and Baryon octet, isospin, strangeness, spin, parity, Lepton and baryon number conservation, parity conservation and non conservation, time reversal and consequence of time reversal invariance, charge conjugation, G-parity, Statement of CPT theorem and its consequences,

Hadron classification by isospin and hypercharge, SU(2) Symmetry Groups, algebras and generators; Elementary idea of SU(3) symmetry and Quark model, need for Color;

SAMPLE QUESTIONS (PHYSICS)

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Chairman, Subject Committee

- Find the directional derivative of $f(x, y, z) = (2x^2 + 3y^2 + z^2)$ at a point $\bar{p}(2, -1, 3)$ in the direction of $\bar{a} = (\sqrt{5}, 0, -2)$ and state the correct answer from the alternative choices below :
(a) $4(2\sqrt{5} - 3)$ (b) $(2\sqrt{5} - 3)$ (c) $\frac{4}{3}(2\sqrt{5} - 3)$ (d) $\frac{2}{3}(\sqrt{5} - 3)$
- Given the differential equation $\frac{d^2y}{dx^2} + \frac{2x}{(x^2 - 1)} \frac{dy}{dx} - \frac{6}{(x^2 - 1)}y = 0$, which one of the following is the correct solution for $y(x)$?
(a) $(2x + 3)$ (b) $\frac{1}{2}(5x^2 - 3x)$ (c) $\frac{1}{2}(3x^2 - 1)$ (d) $7x$
- If $J_n(ax)$ is the Bessel function of n^{th} order; the integral $\int_0^b x J_0(ax) dx$ would have the value
(a) $\frac{a}{b} J_1(ab)$ (b) $\frac{b}{a} J_0(ab)$ (c) $a J_1(ab)$ (d) $\frac{b}{a} J_1(ab)$
- Using Cauchy's integral formula evaluate the integral $\oint_C dz e^z / (z + 1)^4$ when the contour C is a circle, with $|z| = 3$ in the complex z -plane, state which of the following is the correct answer.
(a) $-i\pi/6e$ (b) $i\pi/3e$ (c) $i\pi/e$ (d) $\pi/3e$
- A rigid body moving freely in space has how many degrees of freedom ?
(a) 3 (b) 6 (c) 7 (d) 5
- Consider a rigid body rotating about the Z -axis that passes through its center of mass. The angular velocity of rotation is $\bar{\omega}$. If \bar{v} is the velocity vector for a point on the body; then which of the following is the value of $\bar{\omega} \times \bar{v}$?
(a) $\bar{\omega}$ (b) $2\bar{\omega}$ (c) $3\bar{\omega}$ (d) Zero
- The generalized momentum P_x of a charged particle of mass 'm' and charge q moving with velocity V_x along x -direction in an electro-magnetic field describable by the vector potential \bar{A} and scalar potential ϕ would be;
(a) $P_x = mV_x$ (b) $P_x = mV_x + qA_x$
(c) $P_x = mV_x - qA_x$ (d) $P_x = mV_x + q\phi$
- If the generating function has the form $F = F(q_k, P_k, t)$; then
(a) $p_k = \partial F / \partial q_k, \quad Q_k = \partial F / \partial P_k$
(b) $p_k = \partial F / \partial q_k, \quad Q_k = -\partial F / \partial P_k$
(c) $p_k = -\partial F / \partial q_k, \quad Q_k = -\partial F / \partial P_k$
(d) $p_k = -\partial F / \partial q_k, \quad Q_k = \partial F / \partial P_k$

9. An electro-magnetic field is described by the scalar potential $\phi(\vec{r}, t) = 0$ and the vector potential $\vec{A}(\vec{r}, t) = \frac{1}{4\pi\epsilon_0} \frac{qt}{r^2} \hat{r}$; where 'q' is the charge and t is time. Then which one of the following gives the correct set of values for \vec{B} and \vec{E} ?

(a) $\vec{B} = -\frac{qt}{2\pi\epsilon_0} (\hat{r}/r^3); \quad \vec{E} = 0$

(b) $\vec{B} = -\frac{q}{4\pi\epsilon_0} (\hat{r}/r^2); \quad \vec{E} = \frac{q}{4\pi\epsilon_0} (\hat{r}/r^2)$

(c) $\vec{B} = 0 \quad ; \quad \vec{E} = \frac{q}{4\pi\epsilon_0} (\hat{r}/r^2)$

(d) $\vec{B} = 0 \quad ; \quad \vec{E} = \frac{q}{2\pi\epsilon_0} (\hat{r}/r^2)$

10. Two dielectric slabs with dielectric constants k_1 and k_2 are separated by a plane interface. There is no free charge distribution on the interface. To the normal at a point on the interface; the electric displacement vector \vec{D} , makes an angle θ_1 in slab I and θ_2 in slab II. Which one of the followings is the relationship between θ_1 and θ_2 ?

(a) $\tan \theta_1 / \tan \theta_2 = K_1 / K_2$

(b) $\tan \theta_2 / \tan \theta_1 = K_1 / K_2$

(c) $\sin \theta_1 / \sin \theta_2 = K_1 / K_2$

(d) $\sin \theta_2 / \sin \theta_1 = K_1 / K_2$

11. A parallel plate capacitor with a dielectric slab fully inside is charged to a potential difference V_0 and then the battery is disconnected. The capacitor plates are of width 'a' and length 'b' which are separated by a distance d ($d \ll a, b$). The dielectric slab has the relative dielectric constant K. If the dielectric slab is pulled out such that only a length x remains inside the plates; then in the context of the slab experiencing a force, which one of the following cases would be correct if one neglects the edge effects ?

The force experienced will,

(a) pull back the slab into the plates only if $x > b/2$

(b) push out the slab from within the plates only if $x < b/2$

(c) pull back the slab into the plates always irrespective of $x > b/2$ or $x < b/2$

(d) push out the slab from within the plates always irrespective of $x > b/2$ or $x < b/2$

12. A uniform magnetic field $\vec{B}(t)$ pointing straight up in the z - direction fills a circular region of radius R on the (x - y) plane. If $\vec{B}(t)$ is changing with time increasing it at the rate $dB(t)/dt$; what is the induced electric field \vec{E} at $r < R$ where 'r' is the distance of the point from the center of the circular region ? (Given \hat{e}_ϕ as the counter clockwise direction).

(a) $-\frac{1}{2} \frac{dB(t)}{dt} r \hat{e}_\phi$

(b) $\frac{2}{r} \frac{dB(t)}{dt} \hat{e}_\phi$

(c) $\frac{dB(t)}{dt} r \hat{e}_\phi$

(d) $-\frac{dB(t)}{dt} r \hat{e}_\phi$

13. A thick wire of length 'L' and cross-sectional radius 'a' carries a current I due to a battery source of potential V connected to it. Which one of the following statements is the correct expression for the Poynting Vector \vec{S} at any point on the cylindrical surface of the wire ? (Given \hat{e}_a as a unit vector radially outward).

(a) $\vec{S} = -\frac{VI}{2\pi aL} \hat{e}_a$

(b) $\vec{S} = \frac{VI}{2\pi aL} \hat{e}_a$

(c) $\vec{S} = -\frac{VI}{\pi aL} \hat{e}_a$

(d) $\vec{S} = \frac{VI}{\pi aL} \hat{e}_a$

14. Consider a system of three distinguishable particles in a box of volume V . What would be probability of finding $n = 2$ particles in a volume $V/3$?
- (a) $2/27$ (b) $2/9$ (c) $1/27$ (d) $4/9$
15. A single particle of mass 'm' executes simple harmonic motion in one dimension with angular frequency ' ω ' and total energy E . What would be the shape of the phase-trajectory and the area of the phase-space covered ?
- (a) Circle with area $2\pi E/m\omega^2$ (b) Ellipse with area $2\pi E/\omega$
- (c) Ellipse with area $\pi E/m\omega$ (d) Circle with area $4\pi E/m\omega^2$
16. Consider an electro magnetic field (\vec{E}, \vec{B}) propagating in free space along Z - direction with wave number k and frequency ω , such that ; $\vec{E} = \hat{i}E_0 \sin(kz - \omega t)$ what would be the average intensity 'I' of this wave ?
- (a) $I = \epsilon_0 E_0^2/2$ (b) $I = \epsilon_0 E_0^2/2C$ (c) $I = \epsilon_0 C E_0^2/2$ (d) $I = \epsilon_0 C E_0^2/4$
17. A particle is confined in a one-dimensional box of length L . Its wave function $\psi(x) = N \sin(\pi x/L)$ in the region $0 \leq x \leq L$ and $\psi(x) = 0$ outside this region. The expectation value $\langle p_x^2 \rangle$ would be (when $\hbar = h/2\pi$)
- (a) $\langle p_x^2 \rangle = \pi^2 \hbar^2 / 2L^2$ (b) $\langle p_x^2 \rangle = \hbar^2 / 4L^2$
- (c) $\langle p_x^2 \rangle = \hbar^2 / 4L^2$ (d) $\langle p_x^2 \rangle = \pi^2 \hbar^2 / 4L^2$
18. A quantum particle of mass 'm' is moving on the xy - plane in a circular path of radius R with center at the origin. The allowed energy values would be.
- (a) $E_n = n^2 \hbar^2 / 2mR^2, n = 0, \pm 1, \pm 2 \dots$ (b) $E_n = n^2 \hbar^2 / mR^2, n = 0, \pm 1, \pm 2 \dots$
- (c) $E_n = n^2 \hbar^2 / 2mR^2, n = 0, 1, 2, \dots$ (d) $E_n = n^2 \hbar^2 / mR^2, n = 1, 2, 3, \dots$
19. Find the energy eigen values E_n of a particle in a potential $V(x) = \frac{1}{2}kx^2 + ax$, where 'a' and 'k' are constants, and $\omega = (k/m)^{1/2}$
- (a) $E_n = \left(n + \frac{1}{2}\right) \hbar\omega, n = 0, 1, 2, \dots$
- (b) $E_n = \left(n + \frac{1}{2}\right) \hbar\omega - \frac{a^2}{2m\omega^2}; n = 0, 1, 2, \dots$
- (c) $E_n = \left(n + \frac{1}{2}\right) \hbar\omega + \frac{a^2}{2m\omega^2}; n = 0, 1, 2, \dots$
- (d) $E_n = \left(n + \frac{1}{2}\right) \hbar\omega, n = 1, 2, 3, \dots$

20. The ground state wavefunction of the hydrogen atom is given by

$$\Psi(r, \theta, \phi) = \frac{1}{(\pi a_0^3)^{1/2}} \exp(-r/a_0).$$

Then the radial probability density P(r) would be,

(a) $P(r) = \frac{1}{\pi a_0^3} \exp(-2r/a_0)$

(b) $P(r) = \frac{4}{a_0^3} \exp(-2r/a_0)$

(c) $P(r) = \frac{4r^2}{a_0^3} \exp(-2r/a_0)$

(d) $P(r) = \frac{r^2}{\pi a_0^3} \exp(-2r/a_0)$

21. If \hat{A} and \hat{B} are two Hermitian operators such that they commute with their commutator $[\hat{A}, \hat{B}]$; then $[\hat{A}^3, \hat{B}]$ would be,

(a) $3\hat{A}^2 [\hat{A}, \hat{B}]$

(b) $4\hat{A}^2 [\hat{A}, \hat{B}]$

(c) $2\hat{A}^2 [\hat{A}, \hat{B}]$

(d) $\hat{A}^2 [\hat{A}, \hat{B}]$

22. For a mono-atomic lattice vibration, the dispersion relation is given by :

(Given; m = mass of the atom, k = wave vector, a = lattice constant and β = force constant)

(a) $w = \pm \sqrt{\frac{4\beta}{m}} \sin(ka/2)$

(b) $w = \sqrt{\frac{2\beta}{m}}$

(c) $w = \sqrt{\frac{m}{2\beta}} \sin(ka/2)$

(d) $w = \sqrt{\frac{m}{2\beta}}$

23. In Band theory of solids, the effective mass of an electron is given by ;

(a) $\hbar^2 / \left(\frac{d^2E}{dk^2} \right)$

(b) $\hbar^2 \left(\frac{d^2E}{dk^2} \right)$

(c) $\frac{1}{\hbar^2} \left(\frac{d^2E}{dk^2} \right)$

(d) $1/\hbar^2 \left(\frac{d^2E}{dk^2} \right)$

24. The Boolean expression $Y = A \oplus B$ is true for,

(a) OR - gate

(b) NAND - gate

(c) NOT - gate

(d) EXCLUSIVE OR - gate

25. Spontaneous fission occurs in nuclei having

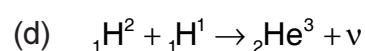
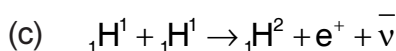
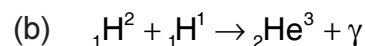
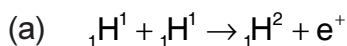
(a) $A > 90$ and $Z < 40$

(b) $A > 40$ and $Z < 20$

(c) $A > 90$ and $Z > 40$

(d) $A < 90$ and $Z < 40$

26. Identify the correct possible fusion reaction from amongst the followings.



27. Which one of the following reactions will go through strong interaction.

