Physics

Unit-I : Mathematical Physics and Classical Mechanics

1.Vector calculus andcomplex 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 usingresidue theorem.

2. Special functions :

Basic properties and solutions (series expansion, recurrence and orthogonalityrelations) of Bessel, Legendre, Hermite, Beta and Gamma function, Fourier Series , Dirac delta function, Laplace and Fourier trans form.

3. Hamilton's principle:

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

4. Canonical transformation:

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

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 andmagnetostatic 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 ofmotion, Lorentz transformation laws for electromagnetic field, and the fieldsdue 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 sinusoidalcurrent, scattering by a small dielectric sphere in long wave length limit,Raleigh 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 momentumrepresentation, **x** and **p** in these representations, stationary states, Eigen states, Ehrenfest theorem, Quontumvirial theorem. Linear independence and Linear dependence, Expansion Theorem, Ortho-normality and Completeness conditions.

2. Operator method in Quantum Mechanics: operator algebra, Eigen function and eisen values of Hermitian operator,Formulation of Quantum Mechanics in vector space language, uncertaintyproduct of twonon commutingHermitian operators, one dimensional harmonic oscillator Matrix representation of operators, Schrodinger, Heisenberg and interactionpictures. 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 theirproperties, eigen value and eigen function,

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

5. Approximation methods:

Time independent perturbation theory, First and second order correction toenergy and eigen functions, application toone electron system, Zeemaneffect, 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 ofensembles, Ergodic hypothesis, postulates of equal a priory probability,Boltzmann's postulates of entropy, micro canonical ensemble, entropy of idealgas, 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,NORgates Logic Circuits.

3. Lattice Dynamics:

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

Free Electron Theory:

Free electron theory of metal,one dimensional infinite potential well. Electrongas in three dimension, density of states, electronic specific heat, electricalconductivity 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, PauliParamagnetism, 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, parityMagnetidipole moment and electric quadrupole moment,

2. Two body bound state;

Properties of deuteron, Schrodinger equation and its solution for ground stateof deuteron, rms radius, spin dependence of nuclear forces, electromagneticmoment and magnetic dipole moment of deuteron and the necessity of tensorforces.

3. Beta-decay :

β- emission and electron capture, Fermi's theory of allowed β-decay, Selectionrules for Fermi and Gamow-Teller transitions, Parity non-conservation andWu'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, Resonancescattering and reactions, Breit-Wigner dispersion relation; Compound nucleusformation and break-up Nuclear fission: Experimental features, spontaneous fission, liquiddrop model, barrier penetration and Alpha decay.

5. Particle Physics:

Basic forces, classification of elementary particle, Gellmann-Nishijimascheme,meson and Baryon octet, isospin, strangeness, spin ,parity, Leptonand baryon number conservation, parity conservation and non conservation ,time reversal and consequence of time reversal invariance, chargeconjugation, 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 Quarksmodel, need for Color;

SAMPLE QUESTIONS (PHYSICS)

Prof. Niranjan Barik
Chairman, Subject Committee

1. Find the directional derivative of $f(x,y,z)=(2x^2+3y^2+z^2)$ at a point $\vec{p}(2,-1,3)$ in the direction of $\vec{a}=(\sqrt{5},0,-2)$ 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) $\frac{2}{3}(\sqrt{5}-3)$

2. 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) $7x$

3. If $J_n(ax)$ is the Bessed 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) $\frac{b}{a}\,J_1(ab)$

4. 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-plans, state which of the following is the correct answer.

(a) $-i\pi/6e$ (b) $i\pi/3e$ (c) $i\pi/e$ (d) $\pi/3e$

5. A rigid body moving freely in space has how many degrees of freedom ?

(a) 3 (b) 6 (c) 7 (d) 5

6. Consider a rigid body rotating about the Z-axis that passes through its center of mass. The angular velocity of rotation is $\vec{w}$. If $\vec{v}$ is the velocity vector for a point on the body; then which of the folowing is the value of $\vec{\nabla}\times\vec{v}$?

(a) $\vec{w}$ (b) $2\vec{w}$ (c) $3\vec{w}$ (d) Zero

7. 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 $\vec{A}$ 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) $P_x=mV_x+q\varphi$

8. If the generating function has the form $F=F(q_k, P_k, t)$; then

(a) $p_k=\partial F/\partial q_k$, $Q_k=\partial F/\partial P_k$

(b) $p_k=\partial F/\partial q_k$, $Q_k=-\partial F/\partial P_k$

(c) $p_k=-\partial F/\partial q_k$, $Q_k=-\partial F/\partial P_k$

(d) $p_k=-\partial F/\partial q_k$, $Q_k=\partial F/\partial P_k$

9. An electro-magnetic field is described by the scalar potential $\varphi(\vec{r}, t) = 0$ 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) $\text{Sin}\,\theta_1/\text{Sin}\,\theta_2 = K_1/K_2$

(d) $\text{Sin}\,\theta_2/\text{Sin}\,\theta_1 = K_1/K_2$

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 << a, b). The dielectric slab has the relative dielectric constant K. If the dielectric slab is pulled out sch 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 $\hat{e}_\varphi$ as the counter clockwise direction).

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

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

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

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

13. A thick wire of length 'L' and cross-sectonal 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 cyllindrical 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 'w' and total energy E. What would be the shape of the phase-trajectory and the area of the phase-space covered ?

(a) Circle will area $2\pi E/mw^2$ (b) Ellipse with area $2\pi E/w$

(c) Ellipse with area $\pi E/mw$ (d) Circle with area $4\pi E/mw^2$

16. Consider an electro magnetic field $(\vec{E}, \vec{B})$ propagating in free space along Z - directon with wave number k and frequency w, such that ; $\vec{E} = \hat{i}E_0 \,\text{Sin}(kz - wt)$ 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) $I = \epsilon_0 CE_0^2/2$ (d) $I = \epsilon_0 CE_0^2/4$

17. A particle is confined in a one-dimensional box of length L. Its wave function $\psi(x) = N\text{Sin}(\pi x/L)$ in the regon $0 \le x \le L$ and $\psi(x) = 0$ outside this region. The expectation value $<p_x^2>$ would be (when $\hbar = h/2\pi$)

(a) $<p_x^2> = \pi^2\hbar^2/2L^2$ (b) $<p_x^2> = h^2/4L^2$

(c) $<p_x^2> = \hbar^2/4L^2$ (d) $<p_x^2> = \pi^2\hbar^2/4L^2$

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) $E_n = n^2\hbar^2/2mR^2, n = 0, \pm 1, \pm 2 ...$ (b) $E_n = n^2\hbar^2/mR^2, n = 0, \pm 1, \pm 2 ...$

(c) $E_n = n^2\hbar^2/2mR^2, n = 0, 1, 2, ...$ (d) $E_n = n^2\hbar^2/mR^2, n = 1, 2, 3, ...$

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 $w = (k/m)^{1/2}$

(a) $E_n = \left(n + \frac{1}{2}\right)\hbar w, n = 0, 1, 2, ...$

(b) $E_n = \left(n + \frac{1}{2}\right)\hbar w - \frac{a^2}{2mw^2}; n = 0, 1, 2, ...$

(c) $E_n = \left(n + \frac{1}{2}\right)\hbar w + \frac{a^2}{2mw^2}; n = 0, 1, 2, ...$

(d) $E_n = \left(n + \frac{1}{2}\right)\hbar w, n = 1, 2, 3, ...$

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

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

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. It $\hat{A}$ and $\hat{B}$ are two Hermitian operators such that they comute 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) $w = \pm\sqrt{\frac{4\beta}{m}} \text{ Sin } (ka/2)$ (b) $w = \sqrt{\frac{2\beta}{m}}$

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

(a) ${}_1H^1 + {}_1H^1 \rightarrow {}_1H^2 + e^+$ (b) ${}_1H^2 + {}_1H^1 \rightarrow {}_2He^3 + \gamma$

(c) ${}_1H^1 + {}_1H^1 \rightarrow {}_1H^2 + e^+ + \bar{\nu}$ (d) ${}_1H^2 + {}_1H^1 \rightarrow {}_2He^3 + \nu$

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

(a) $\bar{p} + p \rightarrow K^+ + K^0 + \overline{\wedge^0} + \Sigma^-$ (b) $\pi^- + p \rightarrow \Sigma^+ + K^-$

(c) $\wedge^0 \rightarrow p + \pi^-$ (d) $\bar{p} + p \rightarrow K^+ + K^- + \wedge^0 + \overline{\wedge^0}$

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