PHYSICS - II
(PHYS 2001)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The degrees of freedom relation for a system of N particles with K constraints is given by
(a) N-K (b) 3N-K (c) N-3K (d) 3K-N.

(ii) The value of $[L^2, L_Z]$ is
(a) 1 (b) $i\hbar$ (c) $-i\hbar$ (d) 0.

(iii) The total wave function of a quantum particle
(a) is always complex
(b) is always real
(c) can be real or complex
(d) is a solution of the time independent Schrodinger equation.

(iv) The number of possible arrangements of three fermions in three cells is
(a) 27 (b) 9 (c) 3 (d) 1.

(v) The average velocity of an electron at T = 0K in a metal in terms of velocity v_f at the Fermi level is
(a) $\frac{2}{3}v_f$ (b) $\frac{1}{3}v_f$ (c) $\frac{3}{2}v_f$ (d) $\frac{3}{4}v_f$.

(vi) At Fermi level, the probability of electron occupation at T > 0K is
(a) 0 (b) 1 (c) ½ (d) ¼.

(vii) In a linear, isotropic dielectric, the relationship between the polarization vector $\vec{P}$, the electric susceptibility χ, and the electric field $\vec{E}$ is given by
(a) $\vec{P} = \chi\vec{E}/\varepsilon_0$ (b) $\vec{P} = \varepsilon_0\vec{E}/\chi$ (c) $\vec{P} = \chi\varepsilon_0\vec{E}$ (d) $\vec{P} = \chi\vec{E}$.

(viii) The magnetic induction, $\vec{B}$, the magnetic field intensity $\vec{H}$, the magnetization $\vec{M}$, and the permeability of free space μ_0 are related as follows

(a) $\vec{B} = \mu_0(\vec{H} + \vec{M})$ (b) $\vec{B} = \mu_0\vec{H} + \vec{M}$

(c) $\vec{B} = \mu_0(\vec{H} - \vec{M})$ (d) $\vec{B} = \mu_0\vec{H} - \vec{M}$

(ix) In a p-type semiconductor, the donor level

(a) lies near the valence band edge
(b) lies near the conduction band edge
(c) lies halfway between the valence and conduction band edges
(d) does not exist.

(x) Which one of the following functions is an eigen function of the operator $\frac{d^2}{dx^2}$?

(a) x (b) x^2 (c) e^{-x^2} (d) $cosx$.

Group- B

2. (a) What are generalized coordinates? Write down the Lagrangian and Lagrange's equation defining all the terms. [(CO6) (Remember/LOCQ)]

(b) Consider a particle sliding down a frictionless inclined plane. Write down Hamilton's equations for this system. [(CO6) (Apply/IOCQ)]

(c) The kinetic and potential energies of a system are given respectively by $T = \frac{1}{2}m\dot{x}^2$ and $V = \frac{1}{2}kx^2$ where m and k are constants. Construct the Lagrangian. Find the expressions for the generalized momentum and generalized force for this system. Derive the equation of motion of this system. [(CO6) (Apply/IOCQ)]

(d) Consider a simple pendulum with a mass m and string length l. Obtain Lagrange's equation of motion for this system. [(CO6) (Evaluate/HOCQ)]

(1 + 2) + 2 + (1 + 2 + 1) + 3 = 12

3. (a) What do you mean by normalization condition of a wave function? If a wave function of a quantum mechanical particle is given by

$\psi(x,t) = A\,Sin\left(\frac{n\pi x}{L}\right)e^{-\frac{iEt}{\hbar}}$ for $0 \le x \le L$

= 0 otherwise

where, n = 0, 1, 2, 3, ... etc. Find the value of A from normalization condition. Also find the value of x corresponding to maximum probability of finding the particle for the above system. [(CO1)(Evaluate/HOCQ)]

(b) Find $[\hat{x}, \hat{L}_z]$, for a quantum mechanical system, where the terms have their usual meaning. [(CO1)(Apply/IOCQ)]

(c) Why do you think that the operators in quantum mechanics must be Hermitian in nature? [(CO1)(Understand/LOCQ)]

(d) Show that in case of a quantum system the eigen functions corresponding to two different eigen values are orthogonal to each other. [(CO1) (Apply/IOCQ)]

(1 + 2 + 2) + 2 + 2 + 3 = 12

Group - C

4. (a) Derive Planck's radiation law from Bose –Einstein statistics. State clearly the assumptions made in the theory. [(CO3)(Evaluate/HOCQ)]

   (b) Using Fermi-Dirac statistics, calculate the concentration of holes in the valence band of an intrinsic semiconductor. [(CO3) (Evaluate/HOCQ)]

   (c) The electron concentration of silver is $1.38 \times 10^{-23} m^{-3}$. Find its Fermi energy. [(CO3) (Apply/IOCQ)]

   (d) Express the Fermi energy value in a metal in terms of free electron density at T = 0K. [(CO3) (Create/HOCQ)]

(2 + 2) + 3 + 2 + 3 = 12

5. (a) 3 particles each of which can be in any one of the non-degenerate energy levels having energy values ε, 2 ε, 3 ε, 4 ε. Find all possible macrostates of the particles in the energy levels for which the total energy of the system is 6 ε. And also find the number of microstates of any one of the macrostates if
   (i) Particles are obeying B-E statistics.
   (ii) Particles are obeying F-D statistics. [(CO3) (Apply/IOCQ)]

   (b) For particles obeying M-B Statistics, write down the expression of thermodynamic probability of a macrostate (N_1, N_2, N_3,.....,N_i) having g_1, g_2, g_3,....., g_i number of energy states corresponding to 1st, 2nd, 3rd, ..., i^{th} energy level respectively. From that expression, establish $N(E)dE = \frac{g(E)dE}{e^{\alpha+\beta E}}$, where the symbols have their usual meaning. [(CO3)(Evaluate/HOCQ)]

   (c) Find out the expression of average speed [v_{avg}] of ideal gas molecules. Given that $N(E)dE = \left[\frac{2\pi N}{(\pi KT)^{\frac{3}{2}}}\right] e^{-\frac{E}{KT}} E^{\frac{1}{2}} dE$, where symbols have their usual meaning. [(CO3)(Evaluate/HOCQ)]

(2 + 1 + 1) + (1 + 4) + 3 = 12

Group - D

6. (a) State Curie's law of paramagnetism. Write down Weiss' hypotheses for a ferromagnetic material and derive the Curie-Weiss law. [(CO5) (Remember/LOCQ)]

   (b) Define electric polarizability? What are the different kinds of polarizabilities that may appear in a dielectric material? [(CO5) (Remember/LOCQ)]

   (c) Write the differences among dia, para and ferro-magnetic materials on the basis of magnetic moment. [(CO5) (Remember/LOCQ)]

   (d) What do you mean by hysteresis loss of magnetic material? [(CO5) (Understand/LOCQ)]

(1 + 1 + 3) + 2 + 3 + 2 = 12

7. (a) What is dielectric susceptibility? How is it related to the dielectric constant of dielectric material? [(CO5) (Understand/LOCQ)]

   (b) Establish the relation concerning D, E and P. (Symbols have their usual meaning.) [(CO5) (Evaluate/HOCQ)]

(c) The magnetic field intensity in a ferrite oxide is 10^6 A/m. If the susceptibility of the material at room temperature is 1.5×10^{-3}, compute the magnetization of the material and the magnetic field induction. ($\mu_0 = 4\pi \times 10^{-7}$ N/A^2).
[(CO5)(Apply/IOCQ)]

(d) Draw the hysteresis loops of a soft and a hard magnetic material in the same plot. [(CO5) (Apply/IOCQ)]

(1 + 2) + 3 + (2 + 2) + 2 = 12

Group - E

8. (a) The energy – wave vector dispersion relation for a one-dimensional crystal of lattice constant a is given by $E(k) = E_0 - 2ak^2$ where E_0 is a constant. Find the expression of the effective mass of an electron in this crystal as a function of k.
[(CO2) (Create/HOCQ)]

(b) What is the Meissner effect? Show that a superconducting material behaves as a perfect diamagnetic material below its transition temperature.
[(CO5) (Remember/LOCQ)]

(c) State and explain Bloch's theorem in one dimension.
[(CO2) (Understand/LOCQ)]

(d) What is the critical magnetic field for a superconductor?
[(CO5)(Understand/LOCQ)]

2 + (2 + 2) + (2 + 2) + 2 = 12

9. (a) Distinguish between type I and type II superconductors. Name some materials belonging to these two types of superconductors. [(CO5) (Analyze/IOCQ)]

(b) Lead (Pb) gets transition to its superconducting state at 7.20 Kelvin. Lead has critical magnetic field at 0K is 65100 A/m, calculate its critical magnetic field at $-271^0\ C$. [(CO5) (Apply/IOCQ)]

(c) An electron is moving in one dimension periodic lattice with lattice constant 'a' with potential V(x) = V(x + a). If 'H' be the Hamiltonian of the electron and $\widehat{T_a}$ be the lattice translational operator, then
(i) Show that H is periodic function of x with periodicity 'a'.
(ii) Show that, if $\psi(x)$ is an eigen function of H with eigen vale E then "$\widehat{T_a}\,\psi$(x)" is also an eigen function of H with the same eigen value.
[(CO2) (Apply/IOCQ)]

(d) Qualitatively explain the formation of energy bands in crystals.
[(CO2)(Understand/HOCQ)]

(2 + 1) + 2 + (2 + 2) + 3 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	31%	33%	36%

Course Outcome (CO):
After the completion of the course students will be able to:

1. Understand and apply Vector Calculus as tool for solving different physical problems.
2. Analyze the nature of central forces and rotating frame phenomenon to understand basic space science and real world applications understand basic space science and real world applications.
3. Interpret the different types of oscillatory motion and resonance.
4. Apply fundamental theories and technical aspect in the field of electricity and magnetism in solving real world problems in that domain magnetism in solving real world problems in that domain.
5. Understand the Electrical and Magnetic properties of different types of materials for scientific and technological use materials for scientific and technological use.
6. Develop Analytical & Logical skill in handling problems in technology related domain.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question

Department & Section	Submission Link
BACKLOG	CLASS ROOM LINK:https://classroom.google.com/c/NDc1MDgwMzg3MjI0?cjc=vxq2ael SUBMISSION LINK: https://classroom.google.com/c/NDc1MDgwMzg3MjI0/a/NDc1MDgwNDA4NTU5/details