PHYSICS - II
(PHYS 2111)

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) If two operators A and B have simultaneous eigen states which of the following is correct?

(a) $\left[\hat{A},\hat{B}\right] = -1$ (b) $\left[\hat{A},\hat{B}\right] = 0$

(c) $\left[\hat{A},\hat{B}\right] = -i\hbar$ (d) $\left[\hat{A},\hat{B}\right] = \infty$

(ii) The state $\begin{pmatrix}1\\0\end{pmatrix}$ is an eigen state of

(a) $\hbar\omega\begin{pmatrix}2 & 1\\1 & 2\end{pmatrix}$ (b) $\hbar\omega\begin{pmatrix}0 & 1\\1 & 0\end{pmatrix}$

(c) $\hbar\omega\begin{pmatrix}0 & -i\\i & 0\end{pmatrix}$ (d) $\hbar\omega\begin{pmatrix}1 & 0\\0 & -1\end{pmatrix}$

(iii) If A is a self-adjoint operator

(a) $\langle\boldsymbol{\psi}|\mathrm{A}\emptyset\rangle = \langle\boldsymbol{\psi A}|\emptyset\rangle$ (b) $\langle\boldsymbol{\psi}|\mathrm{A}|\emptyset\rangle = \langle\emptyset\,|\mathrm{A}|\psi\rangle$

(c) $\langle\boldsymbol{\psi}|\mathrm{A}\emptyset\rangle \neq \langle\boldsymbol{\psi A}|\emptyset\rangle$ (d) $\langle\boldsymbol{\psi}|\mathrm{A}\emptyset\rangle = 1$

(iv) Ferrimagnetic materials can be described as imperfect

(a) ferromagnets (b) anti-ferromagnets

(c) paramagnets (d) diamagnets.

(v) The area of his hysteresis loss is a measure of

(a) Permittivity (b) Susceptibility

(c) Energy loss per cycle (d) Magnetic flux

(vi) A lattice described by the following primitive basis vector is

$$\vec{a}_1 = 2(\hat{\imath}+\hat{\jmath}), \vec{a}_2 = 2\left(\hat{\jmath}+\hat{k}\right), \vec{a}_3 = 2(\hat{k}+\hat{\imath})$$

(a) fcc with cube edge π (b) fcc with cube edge 2π

(c) bcc with cube edge π (d) bcc with cube edge 2π.

(vii) The span of first Brillouin zone of a crystal vibration with monatomic lattice is

(a) $-\pi \leq \mathrm{k} \leq \pi$ (b) $-\frac{\pi}{2} \leq \mathrm{k} \leq \frac{\pi}{2}$

(c) $-\frac{\pi}{a} \leq \mathrm{k} \leq \frac{\pi}{a}$ (d) $-\frac{\pi}{2a} \leq \mathrm{k} \leq \frac{\pi}{2a}$

(viii) A point in reciprocal space correspond to in real space
(a) a unit cell (b) a point (c) a vector (d) a plane.

(ix) For a NaCl crystal, mass of Na and Cl atoms are m and M respectively, the ratio of vibrational amplitude is
(a) mM (b) $-mM$ (c) m/M (d) $-m/M$

(x) An electronic band is
(a) any range of energy levels
(b) energy levels where free electrons exist
(c) a range of energy level characterized by the existence of electrons
(d) all the above.

Group- B

2. (a) The hamiltonian operator for a two-state system is given by
$H = a(|1\rangle\langle 1| - |2\rangle\langle 2| + |1\rangle\langle 2| + |2\rangle\langle 1|)$
where a is a number with the dimension of energy and $|1\rangle$ and $|2\rangle$ are orthonormal vectors. Find the energy eigen values.
[(CO1)(Apply/HOCQ)]

(b) Use the normalization technique to normalize the wave function
$\psi(x) = A\, e^{-\frac{\sigma x^2}{2}} e^{i\,kx}; -\infty \leq x \leq \infty$ [(CO1)(Analyze IOCQ)]

(c) The state of a quantum system at t = 0 is given by $|U\rangle = \frac{1}{\sqrt{3}}|u_1\rangle + \sqrt{\frac{2}{3}}|u_2\rangle$; where $|u_1\rangle$ and $|u_2\rangle$ are the ortho-normal eigen vectors with eigen values $\mp \hbar\omega$ respectively.
(i) Calculate the probability of finding the system in the states $|u_1\rangle$ and $|u_2\rangle$.
(ii) Examine the expectation value of the Hamiltonian.
[(CO1)(Analyze/IOCQ)]
5 + 3 + (2 + 2) = 12

3. (a) Apply the normalization technique to normalize the wave function $\psi(x) = e^{-|x|}\sin ax$, a is a real constant . Calculate the probability of finding its position to the right of the point $x = 1$. [(CO1)(Apply/IOCQ)]

(b) Obtain the commutation relations for the following cases:
$[\hat{p}_x, \hat{x}^n]$; $\left[\hat{L}^2, \hat{L}_z\right]$ [(CO1)(Understand/LOCQ)]

(c) Calculate the uncertainty Δx in position of a quantum particle confined within an infinite potential well of width L having potential $V = 0$ for $0 < x < L$ and V=$\propto$ for $x = 0$ and $x = L$. [(CO1)(Analyse/IOCQ)]
(3 + 2) + (2 + 2) + 3 = 12

Group - C

4. (a) What kind of modifications do we need if we want to apply Curie-Weiss law to find an expression for magnetic susceptibility of antiferromagnets? Graphically show the variation of inverse susceptibility with temperature of any antiferromagnetic sample. [(CO2)(Understand/LOCQ)]

(b) Suppose $\overrightarrow{\mu_m^0}$ is the magnetic dipole moment of an individual atom in a paramagnetic sample kept in an absolute temperature T. If we keep that sample inside an external magnetic field $\vec{B}$ what will be the probability of this magnetic dipole to make an angle between θ and $\theta + d\theta$ with the external magnetic field? [(CO2) (Create/IOCQ)]

(c) Applying Hund's rule and Pauli's exclusion principle calculate the magnetic dipole moment of a Godolinium (Gd^{3+}) ion. (electronic configuration of Gd^{3+} is $4f^7$). [(CO2) (Analyse/IOCQ)]

(2 + 2) + 4 + 4 = 12

5. (a) Using a thought experiment highlight the differences between a perfect conductor and a superconductor and hence explain Meissner effect. [CO3 (Understand/LOCQ)]

(b) Applying Hund's rule and Pauli's exclusion principle explain that the Cr^{2+} ion does not have permanent magnetic dipole moment (atomic number of Cr is 24). [CO3 (Analyze/IOCQ)]

(c) Write down the empirical formula to show the variation of London penetration depth with temperature of a superconducting sample explaining all the physical quantities involved in the expression. Graphically present your answer. [CO3 (Understand/LOCQ)]

4 + 4 + (2 + 2) = 12

Group - D

6. (a) A 2-fold rotation plus a mirror plane is equivalent to an inversion, justify. Determine the linear density of atoms of bcc Ba along [110] direction. Atomic volume of Ba is 39.24 cm^3/cell. [(CO4) (Analyse/HOCQ)]

(b) Illustrate [121], [$1\bar{2}0$] directions on a cubic unit cell. Show that [121] is in the normal direction to (121) plane in a cubic crystal. [(CO4) (Understand/LOCQ)]

(c) Estimate the h, k, l values for (hkl) planes with an interplanar spacing of 1.246 Å in cubic Ni, having $a = 3.524$ Å. [(CO4) (Evaluate/IOCQ)]

(2 + 2) + (2 × 2 + 2) + 2 = 12

7. (a) Explain Ewald construction with diagram. (CO4) (Understand/LOCQ)

(b) Is Bragg's law a necessary and sufficient condition for diffraction to occur? Explain your answer with example. (CO4) (Understand/IOCQ)

(c) If energy required taking an atom from lattice site inside the crystal to lattice site on surface is 1 eV at temperature 1000 K, examine to calculate the ratio of number of vacancies to that of atoms. (CO4) (Analyze/IOCQ)

(d) Prove that the volume of the first Brillouin zone is $(2\pi)^3/V$, where V is the volume of crystal primitive cell. (CO4) (Evaluate/IOCQ)

4 + 3 + 2 + 3 = 12

Group - E

8. (a) Explain elastic and inelastic scattering of phonon. [(CO5) (Understand/IOCQ)]

(b) Explain the condition for two phonons interacting to create third phonon. Describe the phonon dispersion relations from the inelastic scattering of neutrons with emission or absorption of phonon. [(CO5) (Create/IOCQ)]

(c) For a CsCl crystal where mass of Cs and Cl atoms are m and M respectively, determine the ratio of vibrational amplitudes? Justify the name 'optical' of optical branch. [(CO5) (Analyse/HOCQ)]

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

9. (a) If V(x) is periodic, prove that the Hamiltonian is also periodic. For Tf(x)=f(x+a), prove that H{Tφ(x)}=E{Tφ(x)}. (CO5)(Evaluate/HOCQ)

(b) The energy-wave vector dispersion relation for a crystal of lattice constant a is given by $E(k) = \mathrm{b}k^2 + \mathrm{c}\cos ka$, where b, c are constants. Determine the expression for the velocity, effective mass of the electron, effective mass of hole as a function of k. For what value of k the velocity is the maximum? (CO6)(Evaluate/HOCQ)

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

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	25 %	54 %	20 %

Course Outcome (CO):

After the completion of the course students will be able to:

1. Understand the concept of mechanics of Quantum Particles and hence their strange behavior which ultimately imparting the knowledge of nano – science and its applications in nanotechnology.
2. Understand magnetic properties and magnetic behaviour of materials which will enrich the industrial use of different materials for various purposes.
3. Understand the physics behind the superconducting properties of materials and their industrial and medical usefulness.
4. Understand the physics behind X-ray diffraction in crystalline structure of a material, and the different imperfection in it.
5. Understand the basic difference between the atomic structure of an isolated atom and atoms in solids differ and accordingly assures the electrical and thermal properties of solids.
6. Study the energy band formation in solids and the behavior of electron and hole in the bands.

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

Department & Section	Submission Link
CHE	https://classroom.google.com/c/NDA1OTgxMDI5MjAy/a/NDc1MTQxMjQ0MTg2/details
BACKLOG	CLASS ROOM LINK:https://classroom.google.com/c/NDc1MDgwMzg3MjI0?cjc=vxq2ael SUBMISSION LINK: https://classroom.google.com/c/NDc1MDgwMzg3MjI0/a/NDc1MDgwNDA4NTU5/details