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End Semester Examination of Semester–II, 2016

Subject : PHYSICS (PG)

Paper : PHSPG–202 (Theory)

Group : A & B

Full Marks : 40

Time : 2 Hrs

The figures in the margin indicate the marks corresponding to the question

Candidates are requested to give their answers in their own word as far as practicable.

Illustrate the answers whenever necessary

Use separate Answer scripts for Group A and Group B

Group A : Full Marks 20

PHSPG 202(A) : Quantum Mechanics

Answer **Q1** and any **one** out of **Q2** and **Q3**:

Q1. Answer any **five** questions: 2x5=10

i) Show that the time reversal operation is represented by an antiunitary operator.

ii) Show that for a system with orbital angular momentum $\vec{L}$, the operator for the rotation of the system about the Z axis, through an angle ϕ is given by

$$\hat{R}_z(\phi)=\exp\left(-\frac{i}{\hbar}\phi\vec{L}_z\right)$$

where L_z is the z component of $\vec{L}$.

iii) Suppose a spin $-\frac{1}{2}$ particle is in the state $\varphi=\frac{1}{\sqrt{6}}\begin{pmatrix}1+i\\2\end{pmatrix}$ what are the probabilities of getting $\pm\frac{\hbar}{2}$ if you measure S_z?

iv) Prove that parity operator is hermitian and unitary.

v) A charged harmonic oscillation is placed in an uniform electric field $\vec{E}$. The perturbing potential is qEx. Find the correction in the ground state energy level upto second order in E.

given $\langle n|x|m\rangle = \begin{cases} \frac{1}{\infty}\sqrt{\frac{n+1}{2}} & \text{if } m=n+1 \\ \frac{1}{\infty}\sqrt{\frac{n}{2}} & \text{if } m=n-1 \\ 0 & \text{otherwise} \end{cases}$

vi) Define $\sigma_x = f^+ + f$ and $\sigma_y = -i\left(f^+ - f\right)$. f and f^+ obey anticommutation relating {f, f} = 0 and {f, f^+} = 1. Then show that $\sigma_z = 2f^+f - 1$.

vii) An electron is in the p state with orbital angular momentum quantum number l = 1, and spin angular

momentum number $s=\frac{1}{2}$. Find the wave function for the state $\left|\frac{3}{2}, \frac{1}{2}\right\rangle$ and $\left|\frac{1}{2}, \frac{1}{2}\right\rangle$ using Clebsch Gordan Coefficients.

viii) Consider a system in the unperturbed state described by the Hamiltonian, $H_0=\begin{bmatrix} E & 0 \\ 0 & E \end{bmatrix}$. The system is subjected to a perturbation of the form $H'=\begin{bmatrix} A & B \\ B & A \end{bmatrix}$, where A and B<<E. Find the energy eigen values of the perturbed system using the first order perturbation approximation.

2. a) Consider the Hamiltonian $H=-\frac{\hbar^2}{2m}\frac{d^2}{dx^2}-\alpha\delta(x)$, ($\alpha$ = constant). Find out the bound on ground state energy using Variational Principle with trial wave function $\psi(x)=Ae^{-bx^2}$.

$\left[\text{Given}: \int_0^\infty e^{-t}t^a\,dt=\Gamma(a+1)\right]$ 4

b) A particle of mass m is moving in the potential

$$V(x)=\begin{cases}\infty & x\le 0\\ \frac{1}{2}kx^2 & x>0\end{cases}$$

Estimate the ground state energy of this particle using WKB method. 3

c) A particle is moving in the Potential $V(x)=\frac{1}{2}Kx^2-ax$.

Find out the exact energy eigen values of the particle. 3

3. a) For a charged particle in an electromagnetic filed

i) Write the Hamiltonian. 1

ii) Simplify the Hamiltonian netaining only terms upto first order in vector potential. 1

iii) Applying time dependent perturbation theory obtain an expression for transition probability per unit time for absorption. 6

iv) Explain the selection rules from electrical dipole transition mentioning the approximations involved in it. 2

Group B : Full Marks 20

PHSPG 202(B) : Solid State Physics-II

Answer **Q1** and **any one** out of **Q2** and **Q3**:

1. Answer **any five** questions : 2x5=10

i) χ = Magnetic susceptibility, T = Temperature. In a single $\frac{1}{\chi}$ versus T plot show the following :

$$\chi = -\chi_0,\ \chi=\frac{C}{T},\ \chi=\frac{C}{T-\theta} \text{ and } \chi=\frac{C}{T+\theta},$$

Where, χ_0, C and θ are constants, and designate each cure by the type of substances which behave in this way.

ii) State Hund's Rules. Apply them to find the effective number of Bohr magnetons for Gd^{3+} ion (Configuration ...$4f^7\ 5s^2p^6$).

iii) What is Lorentz-Lorenz equation for refractive index? Apply it to find the sum of electronic polarizabilites of Na^+ ion and Cl^- ion in NaCl Crystal, given its lattice constant = 5·63 Å and its refractive index = 1·5.

iv) Distinguish between Type I and Type II superconductors by drawing curves of magnetization versus magnetic field and curves of resistivity versus magnetic field. What is a vortex state?

v) If the number of magnetic dipoles (spins) in a ferromagnetic material is $3X10^{-28}/m^3$ and the spin moment is $3X10^{-23}$ Am^2, determine the saturation magnetism.

vi) The density and the atomic number of niobium are $8{\cdot}57X10^3$ Kg/m^3 and 93. It has one conduction electron per atom. Calculate Loudon penetration depth of niobium.

vii) Explain the hysteresis of a ferromagnetic element by domains. What is a domain wall?

viii) Show and explain the frequency dependence of total polarizability of a dipolar system.

2. a) Derive the expression of difference in entropics of normal superconducting states. 2

b) Empirically it is found that the temperature dependence of the critical field Bc of a type–I superconductor is given by $B_c = B_0\left[1-\left(\frac{T}{T_c}\right)^2\right]$. Use this to show that the entropy S_s per unit volume of the superconducting state is lower than that of the normal state S_n. 2

c) Furthermore, show that $s_n - s_s = aT - bT^3$ where 'a' and 'b' are constants. Also find the value of $(S_n - S_s)$ when $T = T_c$. 1

d) State the Lorentz relation for the local electric field at a cubic site inside a dielectric crystal. Apply it to

find the relation between the dielectric constant and polarizability of a crystal. 1+2

e) What is coherence length of a superconductor? Find its value for a cooper pair. 2

3. a) Considering quantum theory of paramagnetism derive the expression of the magnetization given by

$$M=NgJ\mu_B B_J(x) \left(x=\frac{gJ\mu_B H}{k_B T}\right)$$

Where the symbols have their usual meanings.

Draw curves of $B_J(x)$ versus x for $J = \frac{1}{2}, 1, \ldots\ldots, \infty$.

Show that for $J = \frac{1}{2}$ $M = N\mu_B \tanh x$.

Consider the case $x \ll 1$. Show that the Curie law is obtained for any J. Find the value of the Curie constant for any J. What is the effective number of Bohr magnetons? 7

b) While deriving the classical paramagnetic susceptibility it was assumed that $\frac{\mu_m B}{KT} \ll 1$. Show its validity at room temperature when the magnetic moment one atom is one Bohr magneton and B = 1 Tesla. 2

c) What is nuclear magnetion? 1