Exam. Code : 209003
Subject Code : 3763

M.Sc. Physics 3rd Semester

QUANTUM MECHANICS—II

Paper—PHY-501

Time Allowed—3 Hours] [Maximum Marks—100

Note :— Attempt **five** questions in all. Section A is compulsory. Attempt at least **one** question each from Sections B, C, D & E.

SECTION—A

1. (i) Define Scattering length. How is it related to zero energy cross-section ?

   (ii) Show that Dirac's matrices are even dimensional and have zero trace.

   (iii) Write short note on harmonic and sudden perturbations ?

   (iv) Explain Fermi-Golden rule.

   (v) Define differential cross-section. How the differential cross-section is related in CM and Lab frames.

   (vi) Find out the equation of motion for the state vectors and operators in the interaction picture.

   (vii) State optical theorem for scattering problem.

   (viii) Why does Dirac theory more important than Klein-Gordan theory ?

   (ix) What do you mean by negative energy state of an electron ?

   (x) Explain the ramsauer townsend effect. 10×2=20

SECTION—B

2. (a) Discuss time independent perturbation theory and obtain expression for the first order correction to energy and Eigen wave function. 10

   (b) Apply the first order perturbation result to calculate the energy of the helium atom in its ground state. 10

3. A two-level system is represented by the Hamiltonian $\hat{H}_0 = \begin{bmatrix} E_1^{(0)} & 0 \\ 0 & E_2^{(0)} \end{bmatrix}$. Now a time dependent perturbation $\hat{H}'(t) = \begin{bmatrix} 0 & \lambda\cos\omega t \\ \lambda\cos\omega t & 0 \end{bmatrix}$ is switched on. At $t = 0$, the system is in the ground state $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$. Using first-order time-dependent perturbation theory, find the probability that the system has made a transition to excited state $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$ at time t. (Assuming $E_2^{(0)} - E_1^{(0)} = \hbar\omega_{21}$ is not close to $\pm\hbar\omega$). 20

SECTION—C

4. What is phase shift ? Deduce an expression for it. Explain the nature of phase shift in case of repulsive and attractive potentials. 20

5. Find out differential cross-section, under Born approximation, in case a particle is scattered by the potential $V(r)$ given as $V(r) = -V_0 e^{-r^2/a^2}$. 20

SECTION—D

6. Derive the Klein-Gordon relativistic wave equation of a free particle. Explain how this equation leads to positive and negative probability density values. 20

7. Prove that a Dirac electron has a magnetic moment $\vec{\mu} = \frac{e\hbar}{2mc}\vec{\sigma}'$. 20

SECTION—E

8. (a) What is particle exchange operator ? Show that its eigenvalues are ± 1 and it is a constant of motion. 10

   (b) Two identical Fermions with antisymmetric spin wave function are placed in a one-dimensional box of length L. Each particle has mass 'm'. The energy of the system is $5\hbar^2\pi^2/(2mL^2)$. Write the space part of the wave function. 10

9. What are symmetric and antisymmetric wave-functions ? Show that the antisymmetric wave function for two electrons would vanish if both occupy the same position with identical spin. 20

Exam. Code : 209003
Subject Code : 3765

M.Sc. Physics 3rd Semester

PHY-503 CONDENSED MATTER PHYSICS–I

Time Allowed—3 Hours] [Maximum Marks—100

Note :— Attempt **all** the questions from Section-A and attempt one question from each of the Sections B,C,D and E.

SECTION—A

1. (i) Define tensor and discuss its significance in finding elastic constants.

   (ii) Write an expression for specific heat of metals and discuss the parameters which can affect it.

   (iii) Express Hooke's law in tensor form.

   (iv) Write the factors on which the dislocation density depends.

   (v) What is role of defects in a crystal ?

   (vi) Differentiate low angle grain boundaries from large angle grain boundaries.

   (vii) Discuss the significance of Boltzmann transport equation.

   (viii) What are the assumptions made by Drude and Lorentz in explaining the behavior of free electrons in metals ?

(ix) What is dielectric loss and dielectric breakdown?

(x) Define dielectric relaxation. 2×10=20

SECTION—B

2. (i) How the shortcomings of Einstein model were overcome by Debye model of specific heat ? 5

(ii) What is elastic stress and strain ? Express them in terms of tensor notations. 15

3. (i) Derive Debye's equation for molar lattice specific heat both at lower and higher temperatures. Discuss its agreement with experimental results. 15

(ii) Show that elastic constants are symmetrical, i.e. $C_{ij}=C_{ji}$. 5

SECTION—C

4. (i) Explain the formation of V-centres in a crystal. What are the applications of presence of V-centres in a crystal ? 10

(ii) Explain the process of self diffusion in metals qualitatively. 10

5. (i) Define Burgers vector and how it can be helpful in explaining the concept of grain boundaries. 10

(ii) Determine the concentration of Frenkel defect in a crystal in equilibrium state at a given temperature. 10

SECTION—D

6. State and derive the Boltzmann transport equation. Also describe its physical significance. 20

7. (i) What is activation energy and find its expression for the formation of defects in ionic crystals. 10

(ii) Discuss the process of ionic conductivity in pure alkali halides qualitatively. 10

SECTION—E

8. (i) At what frequency the real and imaginary parts of the polarizability become dominant and why ? 10

(ii) Explain electronic and orientational polarization in dielectrics. 10

9. (i) Consider a system of two neutral atoms separated by a fixed distance **a**, each atom having a polarizability α. Find the relation between **a** and α, for such a system to be ferroelectric. 10

(ii) State why the simple dipole theory fails to explain the ferroelectricity. Suggest a theory which can explain the ferroelectric nature of Barium Titanate. 10

Exam. Code : 209003
Subject Code : 3766

M.Sc. (Physics) 3rd Semester

PHY–504 : NUCLEAR PHYSICS

Time Allowed—3 Hours] [Maximum Marks—100

Note :— Section A is compulsory. Attempt **ONE** question each from Sections B, C, D and E. All questions carry equal marks.

SECTION—A

1. (a) A neutron-proton system can form a bound state while a neutron-neutron or a proton-proton system does not. Even though the nuclear forces are charge independent. Why does this happen ?

(b) In the β-decay, if a $\frac{3^+}{2}$ nuclear state decays by a first-forbidden transition. What will be the possible spin-parity state for the final nuclei ?

(c) The ground state spin-parity of $^{26}_{13}Al$ is 5^+. Justify its spin and parity based on single-particle shell model.

(d) When a particle is moving with velocity $\vec{v}$, which of the following quantities are conserved ? Energy (E), parity $(\hat{p})$, components of angular momentum (L_x, L_y, L_z) and L^2 :

(i) In the static central field

(ii) In the static uniform field along the z-direction.

(e) Calculate the differential and total cross-section of a particle by a central potential with phase shift 30°. Estimate the relative contribution of p-wave to the total cross-section when phase shift is 2°.

(f) Calculate the magnetic dipole moment of following nuclei :

(i) $^{39}_{20}Ca$

(ii) $^{41}_{21}Sc$

(g) The ground state spin-parity of $^{14}_{7}N$ is 1^+. What will be the isospin (T) value of this state ? What will be the ground state spin-parity of the isobaric analog state partner of $^{14}_{7}N$? Identify them.

(h) What is the difference between coherent and incoherent scattering ? For neutron scattering by the hydrogen-molecule (separation between protons 10^{-8} cm), if the energy of incident neutron 100 keV, will this scattering be coherent or incoherent ?

(i) What was the discrepancy in the observed vs. theoretical scattering cross-section in the low-energy elastic scattering of neutron by a free proton ? How can this discrepancy be resolved ?

(j) What is the physical significance of scattering length ? How can the total cross-section be written in terms of the scattering length ?

SECTION—B

2. (a) Define the ground state of deuteron. If a neutron interact with the nucleus, then define its various states including ground state.

(b) Evaluate the deuteron magnetic dipole moment and hence show that the probability of existence of deuteron in D-State is just 4%.

3. (a) Obtain the scattering cross-sections for the singlet and triplet spin states by using the neutron beam on ortho- and para-hydrogen molecules.

(b) Consider a nucleon-nucleon potential of the form

$$V = -V_0 \left[a + b\vec{\sigma}_1 \cdot \vec{\sigma}_2\right] f(r)$$

where r is the relative distance of two nucleons. Find the strengths of this potential in singlet and triplet states.

SECTION—C

4. (a) What are the limitations of liquid-drop model ? How would these be resolved in single-particle shell model ? Also draw its complete level diagram.

(b) The neutron and proton separation energies of $^{40}_{20}$ Ca are 15.6351 and 8.3282 MeV, respectively. Estimate the radius of the nucleus assuming that the particle is removed from its surface.

5. (a) How do vibrational spectra arise in nuclei ? Give a complete model which will be best suited for these spectra.

(b) The observed nuclear moments of $^{209}_{83}Bi$ are $I = \frac{9}{2}\hbar$; $\mu = 4.1\ \mu_N$ and $Q = -0.4 \times 10^{-28} m^2$. Determine the expected values for these moments using the shell model and comment on any significant differences.

SECTION—D

6. Examine critically the different physical processes resulting from the interaction of γ-rays with matter and the relative importance of these processes at different energies of radiation.

7. (a) Which of the following is Fermi, Gamow-Teller or mixed transitions (in case of forbidden, mention the degree of forbidden-ness) :

(i) $^{14}_{8}O(0^+) \rightarrow {}^{14}_{7}N^*(0^+)$

(ii) $^{40}_{19}K(4^-) \rightarrow {}^{40}_{20}Ca(0^+)$

(b) Which hypothesis was given to explain the continuous β-decay spectrum ? Describe the Fermi theory of β-decay.

SECTION—E

8. Describe the conditions for direct nuclear reaction to occur and its reaction cross-section.

9. Explain in detail nuclear resonance scattering and hence obtain its cross-section.