PHYSICS
PAPER - II

Time Allowed : 3 hours Full Marks : 100

Marks for each question is indicated against it.
Attempt any 5 (five) questions taking not more than 3 (three) questions from each Part.

PART - A

1. (a) The one-dimensional wave equation for a free particular of mass \( m \) is given by

\[
\frac{-\hbar^2}{2m} \frac{\partial^2 \psi(x,t)}{\partial x^2} = i\hbar \frac{\partial \psi(x,t)}{\partial t}
\]

where \( \psi(x,t) \) represents the wave function of the particle. Solve the equation by the method of separation of variables. (7)

(b) The wave function for a particle confined in a one-dimensional box of length \( L \) is given by \( \psi(x) = A \sin \frac{n\pi x}{L} \). Normalize the wave function and evaluate the expectation values of its momentum. (5)

(c) (i) Find the probability that a particle trapped in a box \( L \) wide can be found between 0.45 \( L \) and 0.55 \( L \) for the first excited state.

(ii) Find the expectation value \( <x> \) of the position of a particle trapped in a box \( L \) wide. (4+4=8)

2. (a) Write down the Schrödinger equation of a one-dimensional harmonic oscillator, solve the equation to obtain the energy eigen values. Also draw a diagram to represent the energy levels and wave functions of the lowest four states of the linear harmonic oscillator. (8+4=12)

(b) If \( L_x, L_y, L_z \) are the Cartesian components of an angular momentum operator and \( L \) is their resultant, evaluate the following commutators \([L_x, L_y], [L_y, L_z], [L_z, L_x]\) and \([L^2, L_z]\). (8)

3. (a) Describe the Stern-Gerlach experiment. Give the explanation to the results of this experiment based on quantum mechanical theory. (10)

(b) Discuss the general quantum mechanical theory of the Anomalous Zeeman effect, with special reference to the sodium D lines. (10)
4. (a) What is Raman Effect? Explain how it is used in the study of molecular structure and tri-atomic molecules. (10)

(b) Obtain an expression for the resonance condition in NMR. (10)

**PART - B**

5. (a) What do you understand by the term Binding energy of a nucleus? Show the variation of Binding energy per nucleon with mass number of a nucleus and discuss its characteristics. Calculate the binding energy of a Helium nucleus.

Given mass of a helium atom = 4.002603 amu, mass of a hydrogen atom = 1.007825 amu, and the mass of a neutron = 1.08665 amu. (2+4+1=7)

(b) Discuss how the Shell model of a nucleus could explain the origin of Magic numbers in a nucleus. (7)

(c) Discuss the basic theory, construction and working of a nuclear reactor. (6)

6. (a) What is a neutrino? How does it differ from its anti-particle? Explain how the neutrino hypothesis solves the apparent breakdown of conservation of momentum and energy in $\beta^-$-decay. (1+1+3=5)

(b) What is the difference between fermions and bosons? Which of the following particles are fermions and which are bosons? (1+4=5)

$\mu^+, \Lambda^+, K^+, \Sigma^+$

(c) Check if the following reactions are allowed or forbidden:

(i) $\pi^- + p = \Lambda^+ + \pi^0$

(ii) $p + \bar{p} = 2\pi^+ + 2\pi^- + 2\pi^0$

(d) What are coloured quarks and gluons? State the properties of three generations of quarks and leptons. (2+2+2=6)

7. (a) Distinguish between metals, insulators and semi-conductors on the basis of band theory of solids. Why does a semi-conductor act as an insulator at 0K? (10)

(b) What are Type I and Type II superconductors? Describe the effect of an external magnetic field on the superconducting state of a material. (10)

8. (a) Draw the static characteristics of a field effect transistor (FET) and explain the different regions. (7)

(b) What is an OP-AMP? Describe the workings of the inverting and non-inverting operational amplifiers. (7)

(c) Give the truth tables of two-input OR and AND logic gates. Draw electrical circuits representing each one of them. (6)

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