RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College affiliated to University of Calcutta)

B.A./B.Sc. FOURTH SEMESTER EXAMINATION, MAY 2024

SECOND YEAR [BATCH 2022-25]

Date : 27/05/2024 **PHYSICS [HONOURS]**

Time : 11 am – 1 pm **Paper : CC 10** Full Marks : 50

Answer **any five** questions: [5×10]

1. a) Derive the Compton equation : $\lambda' = \lambda + \frac{h}{m_0 c}(1 - cos\,\theta)$

   b) Show that a free electron at rest cannot absorb a photon.

   c) When a light of wave length 3000Å falls on a surface, the kinetic energies of emitted photoelectrons remain in the range from 0 to 4.0×10^{19}J. Calculate the stopping potential for this emission. [5+3+2]

2. a) Is $\psi(x,t) = c_1\psi_1(x)e^{-E_1 t/\hbar} + c_2\psi_2(x)e^{-E_2 t/\hbar}$ a stationary state? explain.

   b) The wave function of a quantum state is given by $\psi(x) = Bxe^{-\alpha x^2}$. Calculate the expectation value of the momentum operator for the state.

   c) If $\rho(\vec{r},t) = \psi^*(\vec{r},t)\psi(\vec{r},t)$ is the probability density then show that the conservation of probability requires that there must be a probability current density $\vec{J}(\vec{r},t) = \frac{i\hbar}{2m}\left(\psi^*\vec{\nabla}\psi - \psi\vec{\nabla}\psi^*\right)$ which satisfies the equation, $\frac{\partial}{\partial t}\rho(\vec{r},t) + \vec{\nabla}\cdot\vec{J}(\vec{r},t) = 0$ [2+4+4]

3. a) The state of a free particle is described by the following wave function

   $\psi(x) = 0$ for $x < -3a$

   $= c$ for $-3a < x < a$

   $= 0$ for $x > a$

   i) Determine c using the normalization condition.

   ii) Find the probability of finding the particle in the interval $[0, a]$.

   iii) Compute $\langle x\rangle$ and σ^2 (variance).

   b) State the properties of a valid wave function. [(2+2+2)+4]

4. a) Show that the group velocity of a wave packet does not exceed the speed of light in vacuum.

   b) Find the wavefunction $\psi(x, 0)$ that results from taking the function $a(k) = (C\alpha/\sqrt{\pi})\exp(-\alpha^2k^2)$, where C and α are constants. Estimate the product $\Delta x.\Delta k$ for this case.

   c) Explain double slit experiment with electrons. [2+4+4]

5. a) In a LASER device how is the stimulated emission collimated?

   b) What is coherence length?

   c) In the Helium-Neon laser (three-level laser), the energy spacing between the upper and lower levels $E_2 - E_1 = 2.26$ in the neon atom. If the optical pumping operation stops, at what temperature would the ratio of the population of upper level E_2 and the lower level E_1, be 1/10?

   d) Find the mean-life of ^{55}Co radionuclide if its activity is known to decrease by 4.0% per hour. The decay product is non-radioactive. [3+2+3+2]

6. a) Explain Davisson-Germer experiment and its importance.
   b) Calculate the energy to be imparted to an α-particle to force it into the nucleus of $^{238}U_{92}$ ($r_0 = 1.2$ fm).
   c) Write the solar PP-III chain reaction. [(4+1)+3+2]

7. a) Show that electron–positron pair cannot be created by an isolated photon.
   b) How Pauli resolved the enigma of the missing energy of beta decay?
   c) For the nucleus ^{16}O the neutron and proton separation energies are 15.7 and 12.2 MeV, respectively. Estimate the radius of this nucleus assuming that the particles are removed from its surface and that the difference in separation energies is due to the Coulomb potential energy of the proton. [3+3+(2+2)]

8. a) Two copper conducting wires are separated by an insulating oxide layer (CuO). Modeling the oxide layer as a square barrier of height 10.0 eV, estimate the transmission coefficient for penetration by 7.00 eV electrons if the layer thickness is 5.00 nm.
   b) What is quantum entanglement? Discuss qualitatively.
   c) Discuss the nature of nuclear force. [3+3+4]

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