Ref. No.: Ex/IT/PHY/T/125/2019 (Old)

B.E. INFORMATION TECHNOLOGY FIRST YEAR SECOND SEMESTER-2019 (Old)

PHYSICS-IIA

Time: Three hours **Full Marks: 100**

Answer any **five** questions.

1. (a) (i) Define magnetization (M). (ii) Write down the equation relating magnetization, magnetic induction (B) and external magnetic field (H). (iii) Find the expression of magnetic moment, μ_{m}, due to the circular (orbital) motion of an electron about its nucleus.

   (c) Develop the Langevin (classical) theory of diamagnetism and derive the expression of diamagnetic susceptibility.

   (d) Consider a collection of n number of non-interacting atoms having magnetic moment, μ_{m}, confined within a unit volume at temperature T. Develop the Langevin (classical) theory of paramagnetism and derive the expression of paramagnetic susceptibility, χ_{P}. Plot the variation of χ_{P} with respect to T. [(1+2+2)+7+(7+1)=20]

2. (a) (i) What is canonical ensemble? (ii) Suppose that a system is in thermal equilibrium with a large heat reservoir at temperature, T. Derive the expression of probability for the system to have the energy ϵ.

   (b) Find the ratios of the number of atoms having energies $\epsilon_1 = -13.6$ eV and $\epsilon_2 = -3.4$ eV at the temperatures (i) 0°C and (ii) 10000°C. ($k_{\mathrm{B}} = 8.617 \times 10^{-5}$ eV/K).

   (c) Define (i) microstate and (ii) macrostate.

   (d) (i) State the equipartition theorem. (ii) Let the energy of a particular system be given by $E = \alpha\, x^2$, where α is a positive constant and x is some variable. Find the mean energy of the system. [(2+4)+(2+2)+(2+2)+(2+4)=20]

3. (a) By considering the conservation of electric charges obtain the continuity equation.

   (b) How did Maxwell fix the Ampere's law with the help of continuity equation?

   (c) Find the energy of a point charge distribution or how much work does it take to assemble the whole configuration of point charge distribution?

   (d) Show that the energy of a continuous charge distribution is given by $W_e = \frac{\epsilon_0}{2} \int E^2\, d\tau$.

   (e) Find the energy of a uniformly charged thin spherical shell of total charge q and radius r.

   [3+3+3+7+4=20]

4. (a) Suppose there is some charge and current distribution which at time t produces fields E and B. Now show that the rate at which work is done on all the charges in a volume V is

$$\frac{dW}{dt} = \int_V (\mathbf{E} \cdot \mathbf{J})\, d\tau,$$

where J is the current density.

(b) Define the Poynting vector, **S** and write down its mathematical expression.

(c) By using the Maxwell's equation derive the Poynting's theorem,

$$\frac{dW}{dt} = -\frac{d}{dt}\int_V u\, d\tau - \oint_A \mathbf{S}\cdot d\mathbf{a},$$

where u is the total electromagnetic energy density.

(d) Write down the statement of Poynting's theorem.

(e) If no work is done on the charges in the volume V, obtain the continuity equation for energy, $\frac{\partial u}{\partial t} = -\nabla\cdot\mathbf{S}$. Explain the significance of this equation. [4+(2+1)+7+2+(2+2)=20]

5. (a) Write down the Maxwell's equations in vacuum.

(b) Derive the differential wave equation for **E** and **B** in vacuum. Find the expression of velocity for both the waves in vacuum.

(c) By assuming the monochromatic plane wave solution of the form

$$\mathbf{E} = E_0\, e^{i(\mathbf{k}\cdot\mathbf{r}-\omega t)}\, \hat{\mathbf{n}},$$

where **k** and $\hat{\mathbf{n}}$ are the propagation and polarization vectors, respectively, show that (i) $\hat{\mathbf{n}}\cdot\mathbf{k} = 0$, (ii) $\mathbf{B} = \frac{1}{\omega}\,\mathbf{k}\cdot\mathbf{E}$ and (iii) $u = \epsilon_0 E^2$.

(d) By assuming the monochromatic plane wave solution of the form

$$\mathbf{E} = E_0\, \cos(kz - \omega t)\, \hat{\mathbf{n}},$$

obtain the time average values, (i) $\langle u\rangle$, and (ii) $\langle S\rangle$ over a complete cycle.

[2+(2+2+1)+(3+4+2)+(2+2)=20]

6. (a) Write down the expression for expectation value of any operator $Q(\vec{r})$, when the state of the system is defined by the wave function $\Psi(\vec{r})$.

(b) The wave function of certain particle is $\psi = A\cos^2(x)$ for $-\pi/2 < x < \pi/2$. (i) Find the value of A. (ii) Find the probability that the particle be found between $x = 0$ and $x = \pi/4$.

(c) A particle restricted to move over the x-axis has the wave function $\Psi = bx^2$, (b is a constant) when $0 < x < 1$ and $\Psi = 0$, elsewhere. Find the probability that the particle can be found between $x = 0.20$ and $x = 0.40$.

(d) Consider the situation that is described in the Figure 1 of a particle of energy $E < U$ and mass m approaches a potential barrier of height U and width L. (i) Write down the Schrödinger equation for the particle in the regions I, II and III. (ii) Find the solutions of the Schrödinger equation for the particle in the regions I, II and III. (iii) Obtain the expression for transmission probability. [1+(2+3)+3+(3+6+2)=20]

7. Consider a particle trapped inside a one-dimensional infinite potential well, such that the potential energy, U satisfies the relations, $U = 0$ when $0 < x < L$ and infinity elsewhere. Now, derive the expressions for (i) energy eigenstates and (ii) energy eigenvalues by solving the Schrödinger equation for the particle when $0 < x < L$. (iii) Find the normalization constants of the energy eigenstates. (iv) Find the probability that the particle can be found between $0.35L$ and $0.65L$ for the (a) ground and (b) first excited states. (vi) Find the expectation values, (i) $\langle x\rangle$ and (ii) $\langle x^2\rangle$ of the particle in the first excited state. [5+2+3+5+3+2=20]

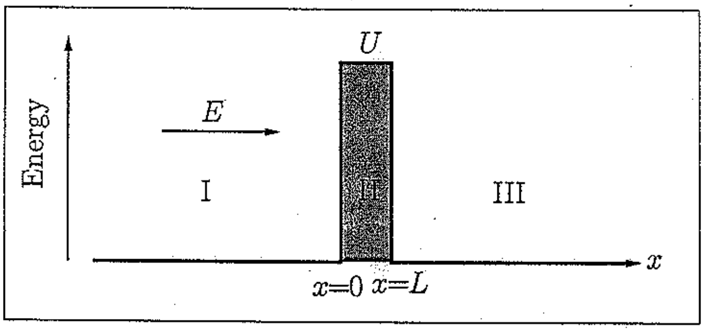

Figure 1: A particle of energy $E < U$ approaches a potential barrier of height U and width L.

8. (a) Consider a particle trapped inside a one-dimensional infinite potential well, such that the potential energy, V satisfies the relations, $V = 0$ when $0 < x < L$ and $V = \infty$, elsewhere (see Figure 2). Now, derive the expressions for (i) normalized energy eigenstates and (ii) energy eigenvalues by solving the Schrödinger equation for the particle when $0 < x < L$.

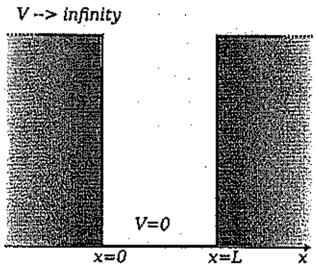

Figure 2: A particle of energy E has been trapped within an infinite potential well of width L.

(b) (i) Obtain the expression of Braggs law for diffraction in crystals. (ii) If the first order Bragg's peak for x-rays of wavelength 2.29 Å is observed at 28°, determine the interplanar spacing of the reflecting planes. (iii) Find the coordination number of a BCC lattice. (iv) Define atomic packing fraction of a crystal. (v) Calculate the atomic packing fraction for a FCC crystal by considering that the diameter of spherical atoms is equal to the side of the cube. [(4+2)+(3+3+2+2+4)=20]