Ref. No.: EX/IT/PHY/T/125/2017

B. IT 1ST YR 2ND. SEM. EXAM.-2017

PHYSICS-IIA

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

Answer any **five** questions.

1. (a) Derive the expression for Poynting vector for an e. m. field. State what does the terms signify. Show that for an e. m. wave the electric and the magnetic field are perpendicular to the direction of propagation of the wave and also to each other. [5+5=10]

   (b) Derive the expression for Maxwells field equation from the Gauss's law of magnetostatics. What does this expression signify? Derive the Maxwells field equation from Amperes circuital law. How was the law inconsistent? Derive the modified law. [2+1+3+1+3=10]

2. (a) Define packing fraction of a crystal. Calculate the packing fraction for a simple cubic and FCC crystal (consider the radius of atoms to be half of the dimension of the cube). Calculate the Miller indices for (i) the planes parallel to y and z planes. (ii) plane having intercepts (1/2, 3/4, 1). If the dimension of the cube is 0.36 nm find the lattice spacing for the above two cases. The first order (100) reflection angle is 18° for a cubic crystal using x-ray of wavelength 1.54 Å. Determine the distance between (100) and (111) plane. [1+2+2+2+3=10]

   (b) Explain the phenomena and derive the expression for Braggs diffraction law for crystals. A simple cubic crystal illuminated by x-ray of wavelength 0.09 nm is rotated, the first order Braggs reflection occurs at a minimum glancing angle of 8.8°. Which set of crystal plane is responsible for this reflection? Find the spacing between the plane. Find the angle of reflection for (111) crystal plane. [5+5=10]

3. (a) Write the Maxwells field equation for free space. Derive the expression of magnetic field vector in terms of electric field vector for an e. m. wave. Derive the Maxwells field equation from Faraday's law of electromagnetic induction. The electric field associated with an e. m. wave is 240 V/m, calculate the magnetic field vector associated with the same wave in free space.

   [2+3+3+2=10]

   (b) Define (i) space lattice and (ii) basis vector. A crystal plane has a Miller indices of (632), find the intercept of the plane along the respective axis. If the d-spacing of the crystal is 0.54 nm, find the dimension of the cube. If an x-ray is incident on the crystal at an angle of 10°, find the wavelength of the incident x-ray. [2+2+6=10]

4. (a) State the properties of quantum mechanical wave functions, Ψ. [2]

   (b) Suppose a particle is restricted to move along the x-direction. Write down the probability of finding it between x_1 and x_2. [2]

   (c) A particle restricted to move over the x-axis has the wave function $\Psi = ax$, (a is a constant) when $0 < x < 1$ and $\Psi = 0$, elsewhere. (i) Find the probability that the particle can be found between $x = 0.45$ and $x = 0.55$. (ii) Find the expectation value, $\langle x \rangle$, of the particle's position.

[2+3=5]

(d) Consider the situation that is described in the Figure 1 of a particle of energy $E < U$ 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

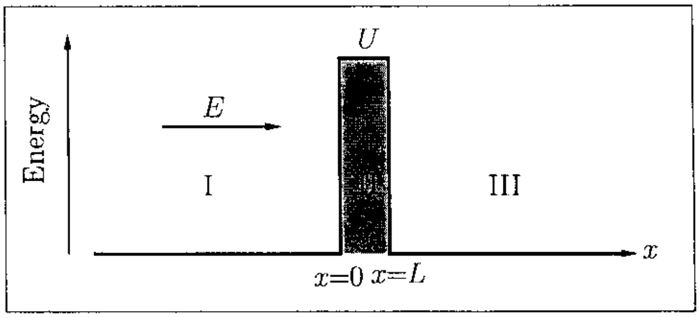

Figure 1: A particle of energy $E < U$ approaches a potential barrier of height U and width L.

equation for the particle in the regions I, II and III. (iii) Obtain the expression for transmission probability. [3+6+2=11]

5. 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) Draw the four lowest energy eigen functions. (v) Find the probability that the particle can be found between $0.45L$ and $0.55L$ for the (a) ground and (b) first excited states. (vi) Find the expectation value $\langle x \rangle$ of the position of the particle. [5+2+3+2+5+3=20]

6. (a) Compare the characteristics of diamagnetic, paramagnetic and ferromagnetic materials. [3]

   (b) (i) Define magnetization ($\vec{M}$). (ii) Write down the equation relating magnetization, magnetic induction ($\vec{B}$) and external magnetic field ($\vec{H}$). (iii) Find the expression of magnetic moment, μ_m, due to the circular (orbital) motion of an electron about its nucleus. [1+2+2=5]

   (c) Develop the Langevin (classical) theory of diamagnetism and derive the expression of diamagnetic susceptibility. [7]

   (d) Starting from the wave function, $\Psi = A e^{-i\omega(t-x/v)}$, obtain the expression of one-dimensional time-dependent Schrödinger equation. [5]

7. (a) Consider a collection of n number of non-interacting atoms having magnetic moment, μ_m, confined within a unit volume at temperature T. (i) Develop the Langevin (classical) theory of paramagnetism and derive the expression of paramagnetic susceptibility, χ_P. (ii) Plot the variation of χ_P with T. [8+2=10]

   (b) (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 $\mathcal{E}$. [2+4=6]

(c) Show that the number of molecules in an isothermal atmosphere at a height z, $n(z)$, obeys the following equation,

$$n(z) = n(z=0)\, e^{-mgz/k_B T}.$$

Symbols have their usual meaning. [4]

8. (a) Define (i) microstate and (ii) macrostate. [2+2=4]

(b) Consider two systems 1 and 2 having energies E_1, E_2 and number of microstates $\Omega_1(E_1)$, $\Omega_2(E_2)$, respectively as shown in the Figure 2. By considering the thermal equilibrium between the systems 1 and 2 derive the expression of temperature, T. [6]

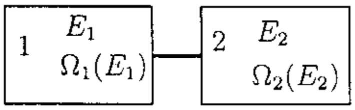

Figure 2: Two systems 1 and 2 able only to exchange energy between them.

(c) By using the first law of thermodynamics and the expression of temperature to be derived in the question no. 8. (b), obtain the expression of entropy, S, in terms of number of microstate, Ω.

[4]

(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=6]