RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College affiliated to University of Calcutta)

B.A./B.Sc. SIXTH SEMESTER EXAMINATION, MAY 2018

THIRD YEAR [BATCH 2015-18]

Date : 10/05/2018 **PHYSICS (Honours)**

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

Answer <u>any five</u> questions of the following : [5×10]

1. a) What do you understand by crystal lattice and the unit cell? [2]
   b) Determine the volume of the fcc unit cell in terms of the volume of its primitive unit cell. [3]
   c) Show that a crystalline solid can not possess a five-fold rotational symmetry. [3]
   d) Sodium has bcc structure and atomic weight is 23. Calculate the atomic radius of the sodium. The density of sodium is 963kg/m^3. [2]

2. a) What do you mean by reciprocal lattice. Explain. Show that reciprocal lattice corresponding to a bcc lattice is an fcc lattice in the reciprocal space. [2+2]
   b) Write down Bragg's law in reciprocal lattice space. [2]
   c) In the bcc crystal the Bragg's diffraction condition is satisfied but x-ray diffraction line is not observed. Explain. [2]
   d) Calculate the lattice energy and cohesive energy of NaCl crystal. Given : I.P.= 5·14 eV, E.A. = 3·61 eV, r_e = 0·28 nm, $\varepsilon_0 = 8\cdot85\times10^{-12}\,\text{F.m}^{-1}$, m = 9, $\alpha = 1\cdot748$, symbols have their usual meanings. [2]

3. a) Using the Debye approximation, show that the lattice heat capacity of a solid at $T << \Theta_D$ is proportional T^3. Given $g(\omega) = \dfrac{9N}{\omega_D^3}\omega^2$, symbols have their usual significance. [4]
   b) A circularly shaped chain of 16 atoms with interatomic spacing 3Å. Calculate the values of discrete wave vectors. [2]
   c) Show that the structure factor for reflection (khl) can be written as $F(hkl) = \sum_j^N f_j e^{i2\pi(hu_j+kv_j+lw_j)}$, where symbols have their usual meanings. [4]

4. a) What is Hall effect? Find the expression for Hall coefficient. [1+3]
   b) The internal energy of the free electron gas at temperature T is given by $U = \dfrac{3}{5}NE_{F0}\left[1+\dfrac{5\pi^2}{12}\left(\dfrac{T}{T_F}\right)^2\right]$, where N is number of electrons per unit volume, E_{F0} is Fermi energy at 0K and T_F is Fermi temperature. Using this relation calculate the molar specific heat of electron in a metal of $E_{F0} = 5\cdot5\text{eV}$ at 300K. [3]
   c) Find the temperature at which the lattice specific heat and electronic specific heat of copper are equal. Given, $E_{F0} = 5\cdot5\text{eV}$ and Debye temperature is 350 K. [3]

5. a) Write down the classical relationship between force and kinetic energy of a free particle. Hence obtain the expression of isotropic effective mass of the electron in an energy band. In which way is it different from Free electron mass? [1+3+1]

b) Consider the following dispersion relation for a cubic structure $E = E_0 - \alpha - 2\gamma(\cos K_x a + \cos K_y a + \cos K_z a)$ where; α, γ, E_0 are constants and a is lattice constant.

i) Find out the points for which the energy is maximum and minimum. Hence find energy band width. [2+1]

ii) Obtain the expression of effective mass for small values of K in terms of other parameters. [2]

6. a) Derive an expression for the built-in-electric field in a pn junction by solving one-dimensional Poisson's equation. [4]

b) A pn junction is formed by n-type and p-type semiconductor of doping concentration N_d and N_a respectively. Find the expression for barrier potential of the pn junction at temperature T. [4]

c) Consider a silicon pn junction of V_{bi} = 0·63 V at T = 300K with doping concentrations of $N_a = 10^{16} cm^{-3}$ and $N_d = 10^{15} cm^{-3}$. If the corss sectional area is 10^{-4} cm^2. Calculate the junction capacitance of the pn junction when a reverse bias of 5V is applied. [Assume : $\epsilon_r = 11$ and $\epsilon_0 = 8{\cdot}85 \times 10^{-14} F.cm^{-1}$] [2]

7. a) Using Langevin theory show that paramagnetic susceptibility of a material is inversely proportional to the temperature. [5]

b) The paramagnetism in copper sulphate arises mainly from copper ions with $S = \frac{1}{2}$, L = 0. Show that the magnetization (M) is given by the expression $M = N\mu_B \tanh\left(\frac{\mu_B B}{kT}\right)$, where N is the number of ions per unit volume, B is applied field, μ_B = Bohr magneton, k is the Boltzmann constant and T is temperature. [3]

c) Find the total polarisability of CO_2, if its susceptibility is $0{\cdot}985 \times 10^{-3}$. Density of CO_2 is 1·977 kg/m^3. [2]

8. a) Compute the Local Lorentz field due to the polarization charges on the surface of a spherical cavity. Using this relation, derive the Clausius-Mosetti relation. [2+3]

b) Briefly explain Meissner effect with a suitable diagram. Show that the magnetic field decays inside the superconductor exponentially with a characteristic length scale. [2+1]

c) The electronic configuration of Pm^{3+} ion is $4f^4 6s^0$. Calculate the magnetic susceptibility for a salt containing one 1kg mole of Pm^{3+} ion at 300K. [2]

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