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3 (Sem-5/CBCS) PHY HC 2

2022

PHYSICS

(Honours)

Paper : PHY-HC- 5026

(Solid State Physics)

Full Marks : 60

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Choose the correct answer from the following : **(any seven)** $1 \times 7 = 7$

(a) The number of atoms per unit cell of a body centred cubic lattice (bcc) is

(i) 8

(ii) 1

(iii) 3

(iv) 2

Contd.

(b) Classify the following unit cell into proper crystal system, $a = 1.08 \text{ nm}$, $b = 1.947 \text{ nm}$, $c = 0.52 \text{ nm}$ and $\alpha = 41^\circ$, $\beta = 82^\circ$, $\gamma = 95^\circ$

- (i) Triclinic
- (ii) Monoclinic
- (iii) Orthorhombic
- (iv) Hexagonal

(c) Because of which property of the crystals, X-rays can be diffracted from the crystals ?

- (i) Random arrangement of atoms
- (ii) Colour of the crystals
- (iii) Periodic array of atoms
- (iv) None of the above

(d) The harmonic oscillator can have values of energy as

- (i) $n\hbar\omega^2$
- (ii) $n^2\hbar\omega$
- (iii) $n\hbar\omega$
- (iv) $2n\hbar\omega$

(e) The unit of magnetic susceptibility is

- (i) Wb/m^2
- (ii) Wb/m
- (iii) amp/m
- (iv) unitless ratio

(f) Diamagnetic materials possess

- (i) permanent magnetic dipoles
- (ii) no permanent magnetic dipoles
- (iii) induced dipole moment
- (iv) None of the above

(g) Most widely used conducting materials are

- (i) germanium and silicon
- (ii) copper and aluminium
- (iii) gold and silver
- (iv) tungsten and platinum

(h) Transition temperature T_c and critical field H_c for a superconductor are related to (H_0 : critical field at 0K, T_0 : Transition temperature at 0°K .)

(i) $H_c = H_0(T_c - 1)$

(ii) $H_c = H_0(T_c + 1)$

(iii) $T_c = T_0 \left[1 - \left(\frac{H_0}{H_c} \right)^2 \right]$

(iv) $H_c = H_0 \left[1 - \left(\frac{T}{T_c} \right)^2 \right]$

(i) The forbidden energy gap of carbon in diamond structure is

(i) 0.7 eV

(ii) 1 eV

(iii) 0.01 eV

(iv) None of the above

(j) Intrinsic germanium can be made P-type semiconductor by doping with

(i) phosphorous

(ii) aluminium

(iii) sulphur

(iv) carbon

(k) The polarization P in a solid, dielectric field E and the electric flux density D can be related by the relation

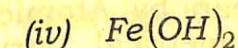
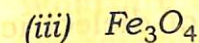
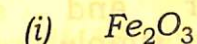
(i) $E = \epsilon_0 D + P$

(ii) $D = E + \epsilon_0 P$

(iii) $D = E \epsilon_0 + P$

(iv) $D = \epsilon_0 (E + P)$

(l) The chemical formula for magnetite is



2. Give short answers of the following questions : (**any four**) $2 \times 4 = 8$

(a) Write the basic differences between crystal and amorphous solid.

(b) Show that for a simple cubic lattice $d_{100} : d_{110} : d_{111} = \sqrt{6} : \sqrt{3} : \sqrt{2}$

(c) (i) Define Fermi energy level.

(ii) Draw the Fermi function with respect to energy for the temperature at $T = 0K$ and $T = 300K$.

(d) What do you mean by magnetic permeability and magnetic susceptibility ?

(e) (i) Write the Dulong and Petit law related to specific heat of solid.

(ii) What do you understand by phonon ?

(f) How are the variation of resistance (R) with temperature (T) changes for normal conductor and super-conductor ? Draw a simple graph of R vs T .

(g) Define dipole moment and polarization vector of dielectric.

(h) What do you mean by Atomic form factor and Geometrical structure factor ?

3. Answer **any three** from the following questions : $5 \times 3 = 15$

(a) (i) What do you mean by atomic packing factor of a crystal ? 1

(ii) Find out the packing factor of face centred cubic structure of a crystal. 4

(b) (i) Discuss the success and limitations of classical free electron theory of metal. 2

(ii) Why free electron theory is important in solid state physics ? 1

(iii) Write down basic differences of classical and quantum free electron theory of metals. 2

(c) (i) What is Hall effect ? 1

(ii) Find out the expression for Hall coefficient. 3

(iii) Write down the applications of phenomenon of Hall effect. 1

(d) What are differences between ferromagnetic, paramagnetic and diamagnetic materials ?

(e) Draw the band structure for intrinsic semiconductor, *p*-type and *n*-type semiconductor.

(f) (i) What do you mean by drift velocity, mobility of a conductor? 2

(ii) Write the expression for conductivity of intrinsic and extrinsic semiconductor. 2

(iii) Why conductivity of a metal decreases with the increase of temperature? 1

(g) (i) What is superconductivity? 1

(ii) Explain type-I and type-II superconductor. 4

(h) Discuss Meissner effect of superconductor.

4. Answer the following questions :

(any three) 10×3=30

(a) (i) Why X-rays are used for material characterization? Can X-ray be diffracted from a single slit of width 0.1 mm? Justify your answer. 1+1=2

(ii) State the Bragg's law in X-ray diffraction of a crystalline solid. Derive its expression. 1+2=3

(iii) The spacing between successive plane in NaCl is 2.82 Å. X-rays incident on the surface of the crystal is found to give rise to 1st order Bragg's reflections at glancing angle 8.8°. Calculate the wavelength of X-rays.

(Given $\sin 8.8^\circ = 0.152$) 5

(b) (i) What is Miller indices in a crystal? 1

(ii) How Miller indices are determined? 2

(iii) Draw (100), (001), (010) and (111) plane of a simple cubic structure. 2

(iv) Miller indices of a plane is (326). Find out the point of intercept made by the plane along the three crystallographic axes (*x*, *y*, *z*). 2

- (v) The density of iron (having bcc structure) is 7900 kg/m^3 and its atomic weight is 56. Calculate lattice parameters. 3
- (c) (i) State the Wiedemann-Franz law in solid. Discuss its physical significant. 2
- (ii) Discuss the classical and quantum mechanical expression of Lorentz number. 5
- (iii) For copper at 20°C , the electrical and thermal conductivity are $1.7 \times 10^8 \Omega\text{m}$ and $380 \text{ Wm}^{-1}\text{K}^{-1}$ respectively. Calculate Lorentz number. 3
- (d) (i) Discuss the original concept of band theory of solid. 1
- (ii) Discuss Kronig-Penney model related to band theory of solid. 8
- (iii) What do you mean by Brillouin zones? 1
- (e) (i) What is specific heat of solid? 2

- (ii) Discuss Einstein theory of specific heat of solid. 8
- (f) (i) Deduce the expression for Curie law using classical theory of paramagnetism. 8
- (ii) What is ferromagnetic domain? 1
- (iii) How hysteresis curve is related to energy loss? 1
- (g) (i) Define Piezoelectric effect, Pyroelectric effect and Ferroelectric effect in solid. 3
- (ii) Derive the Clausius-Mossotti equation for dielectric material. 7
- (h) Write short notes on **any two** of the following : $5 \times 2 = 10$
- (i) Bravais lattice
- (ii) Reciprocal lattice
- (iii) Symmetry in crystal
- (iv) Plasma oscillations