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)*** 1×7=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

(b) Classify the following unit cell into proper crystal system, $a = 1.08$ *nm*, $b = 1.947$ *nm*, $c = 0.52$ *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 defracted 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) $n\hbar w^2$

(ii) $n^2\hbar w$

(iii) $n\hbar w$

(iv) $2n\hbar w$

(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 alumium

(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 $0^\circ K$.)

(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) $E = \varepsilon_0 D + P$

(ii) $D = E + \varepsilon_0 P$

(iii) $D = E\varepsilon_0 + P$

(iv) $D = \varepsilon_0 (E + P)$

(l) The chemical formula for magnetite is

(i) Fe_2O_3

(ii) FeO

(iii) Fe_3O_4

(iv) $Fe(OH)_2$

2. Give short answers of the following questions : ***(any four)*** 2×4=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 $T = 300\,K$.

(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 : 5×3=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 defracted 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 $\mathring{A}$. 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 areas (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 $1.7\times10^8\ \Omega m$ and 380 $Wm^{-1}K^{-1}$ 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 : 5×2=10

(i) Bravais lattice

(ii) Reciprocal lattice

(iii) Symmetry in crystal

(iv) Plasma oscillations
