SET A

M.Sc. PHYSICS
SECOND SEMESTER
SOLID STATE PHYSICS
MSP – 202

[USE OMR FOR OBJECTIVE PART]

Duration: 3 hrs. **Full Marks: 70**

(Objective)

Time: 30 min. **Marks: 20**

Choose the correct answer from the following: ***1×20=20***

1. Area of non-primitive cell is
   a. zero
   b. Equal to area of primitive cell
   c. Integral multiple of area of primitive cell
   d. Never equal to area of a primitive cell

2. Number of atoms per unit cell in FCC lattice type structure is
   a. 2
   b. 4
   c. 1
   d. 8

3. The co-ordination number of SC, BCC and FCC are
   a. 6, 8, 12 respectively
   b. 6, 12, 8 respectively
   c. 8, 6, 12 respectively
   d. None of the above

4. Packing fraction of HCP lattice is
   a. 52.4%
   b. 68%
   c. 74%
   d. 100%

5. Number of atoms per unit cell in NaCllattice type structure is
   a. 1
   b. 2
   c. 4
   d. none of the above

6. For a 60° rotation, the number of fold symmetry would be
   a. 3
   b. 6
   c. 5
   d. 9

7. Permissible fold symmetry in an infinite lattice array are
   a. 2 fold, 3 fold, 4 fold
   b. 3 fold, 4 fold, 5 fold
   c. iii. 4 fold, 5 fold, 6 fold
   d. 5 fold, 6 fold, 7 fold

8. The Bragg's law doesn't hold true for _____ order diffraction
   a. Zeroth
   b. First
   c. Second
   d. Third

9. For a monoatomic lattice, in accordance with the dispersion relation, angular frequency can be
   a. Only positive
   b. Only negative
   c. Positive (travelling right) Negative (travelling left)
   d. Positive (travelling left) Negative (travelling right)

10. Lattice parameters of two interpenetrating hexagonal lattices gives rise to the HCP packing. The lattice paramenters of the two lattices that penetrate into each other have a ratio
    a. 1:2 b. 1:3
    c. 1:4 d. 1:1

11. The effective mass of a Bloch electron is
    a. proportional to the slope of the energy curve (E vs k plot) b. proportional to the curvature of the energy curve
    c. independent of energy curve d. any point on the energy curve

12. Usually holes lie
    a. near top of the valence band b. near bottom of the valence band
    c. near top of the conduction band d. near bottom of the conduction band

13. The finiteness of the electrical conductivity is due to the
    a. scattering on the surface of the metal b. scattering among the electrons themselves
    c. imperfection of the crystal d. scattering with the ions

14. K_e and K_{ph} are the thermal conductivities due to electrons and phonons, respectively. In metals, we usually have
    a. $K_e = K_{ph}$ b. $K_e \sim 10K_{ph}$
    c. $K_e = 10^2 K_{ph}$ d. $K_e = 10^{-2} K_{ph}$

15. If the frequency ω of the signal is exactly equal to the cyclotron frequency, the rate of absorption is
    a. greatest b. lowest
    c. constant, independent of frequency d. none of these

16. Diamagnetism occurs due to
    a. Orbital motion of electrons only b. Spin of electrons only
    c. Both (a) and (b) d. None of these

17. Curie law for paramagnetic materials (symbols have their usual meanings)
    a. = b. = /
    c. = /^{2} d. =

18. Density of states for a 3D material varies with energy as
    a. $\sqrt{}$ b.
    c. ^{0} d. ^{2}

19. Ferromagnetism occurs
    a. Below the Curie temperature b. Above the Curie temperature
    c. At any temperature d. None of these

20. The Fermi energy lies in semiconductors
    a. at the bottom of the conduction band b. At the top of the valence band
    c. Within the conduction band d. Close to the middle of the band gap

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Descriptive

Time : 2 hrs. 30 mins. **Marks : 50**

[Answer question no.1 & any four (4) from the rest]

1. **a.** Why are X-rays used for crystal structure analysis? **2+8=10**
   b. Outline difference between von Loue and Braggs' treatment of X-ray crystallography.

2. **a.** Draw the Miller planes inside a cell for the following intercepts: **4+6=10**
   (i) 1, 2, 5 (ii) 2, 4, 6 (iii) 1, 2, 1 (iv) 0, 3, 2

   b. Determine the packing fraction of HCP lattice and compare it with that of BCC and FCC packing.

3. Elaborate 'Atomic Scattering Factor' in crystallography. Provide an evaluation to Hartee approximation of charge distribution from the general expression of Atomic scattering factor with a suitable diagram. **2+8=10**

4. **a.** Mathematically determine the possible rotation angles for permissible rotation symmetry in 2D lattice systems. **4+6=10**

   b. Atoms of radius R are arranged in an FCC packing with lattice parameters 'a', such that each atom with radius 'R' touches its nearest neighbours. Taking centre of one of the FCC atom as the origin, another atom of radius 'r' is accommodated at (0, a/2, 0) without distorting the lattice. Determine the maximum value of r/R

5. **a.** Determine the electron concentration for Na with the expression $N = Z_v \frac{\rho_M N_A}{M^*}$. **3+3+2+2=10**

   [Given: $\rho_M = 0.971$ g/cc, $N_A = 6 \times 10^{23}$ /mol, $M^* \approx 23$ g/mol]

   b. Compute the electrical conductivity for Na. [Given: $\frac{m^*}{m_0} = 1.2$, $m_0 = 9.1 \times 10^{-31}$ kg, $\tau = 3.1 \times 10^{-14}$ s]

c. What are the basic assumptions of free-electron theory model?

d. What are the failures of free-electron theory model?

6. a. Discuss the Bloch theorem. **5+5=10**

b. From the Kronig-penny model, one can arrive at the following equation

$$P\frac{sin(\alpha a)}{\alpha a} + cos(\alpha a) = cos(ka),$$

where $P = \frac{mV_0 ba}{\hbar^2}$, which is a measure of the area $V_0 b$ of the potential barrier and $\alpha^2 = \frac{2mE}{\hbar^2}$.

Plot $\left[P\frac{sin(\alpha a)}{\alpha a} + cos(\alpha a)\right]$ versus αa for $P = 3\pi/2$. Indicate the allowed regions in your plot in view of the equation given above.

7. a. Discuss the thermionic emission process. **6+4=10**

b. Obtain the expression for the current density in thermionic emission process.

8. a. Derive the expression for susceptibility for the diamagnetic materials. **6+4=10**

b. The diamagnetic susceptibility due to ion cores in metallic copper is -0.20×10^{-6}. The density of Cu is 8.93 g/cm^3 and its atomic weight is 63.5. Calculate the average radius of the Cu ion.

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