M.Sc. PHYSICS
SECOND SEMESTER
CONDENSED MATTER PHYSICS
MSP – 203

(Use Separate Answer Scripts for Objective & Descriptive)

Duration: 3 hrs. Full Marks: 70

(PART-A: Objective)

Time: 20 min. Marks: 20

Choose the correct answer from the following: *1X20=20*

1. Which of the following materials exhibits long-range order?
   a. Polycrystals b. Single crystals
   c. Amorphous materials d. Ceramics

2. If a crystal is invariant under a rotation of 90^0, what fold of rotation axis will it possess?
   a. 1 b. 2
   c. 3 d. 4

3. Which one of the following are the Miller indices of a plane of a plane that makes intercepts of 2a, 3b, 7c in a simple cubic lattice?
   a. (21 14 6) b. (14 6 21)
   c. (21 6 14) d. (14 21 6)

4. Which one of the following is the packing fraction of a bcc structure?
   a. 0.52 b. 0.73
   c. 0.68 d. 0.83

5. Which one of the following indicates the first Brillouin zone in a one-dimensional monatomic lattice? (Symbols have usual meaning)
   a. $-\frac{2\pi}{a} < k < \frac{\pi}{a}$ b. $-\frac{\pi}{a} < k < \frac{2\pi}{a}$
   c. $-\frac{\pi}{a} < k < \frac{\pi}{a}$ d. $-\frac{2\pi}{a} < k < \frac{2\pi}{a}$

6. Which one of the following does not equal the volume of a parallelopiped? (Symbols have usual meaning)
   a. $\vec{a}.(\vec{b} X \vec{c})$ b. $\vec{c}.(\vec{a} X \vec{b})$
   c. $\vec{b}.(\vec{c} X \vec{a})$ d. $\vec{a} X (\vec{b} X \vec{c})$

7. Ionic bond is found in
   a. Oxygen b. Sodium chloride
   c. Xenon d. Diamond

8. Which one of the following is the maximum value of frequency for vibration of linear monatomic lattice? (Symbols have usual meaning)

a. $\frac{4C}{M}$ b. $(\frac{4C}{M})^{\frac{1}{2}}$

c. $4CM$ d. $(4CM)^{\frac{1}{2}}$

9. Polarization is defined as dipole moment per unit
   a. Length b. Area
   c. Volume d. Time
10. A normal metal passes into superconducting state at
   a. High temperature b. Low temperature
   c. Critical temperature d. No temperature
11. The velocity 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. Given: $E = -\alpha k^2$. The effective mass is
   a. $-\alpha$ b. -2α c. α d. 2α
14. At absolute zero temperature, below the Fermi level
   a. All energy levels are occupied b. All energy levels are empty
   c. Half of the levels are empty and the other half are occupied d. Only one level is occupied
15. The conduction electrons are spread
   a. throughout the crystal b. tightly bound to the atoms
   c. localized in a particular region d. delocalized in a particular region.
16. The susceptibility of diamagnetic materials are always
   a. Zero b. positive c. negative d. ∞
17. Curie law for paramagnetic materials (symbols have their usual meaning)
   a. $\chi = CT$ b. $\chi = C/T$
   c. $\chi = C/T^2$ d. $\chi = T^C$
18. Choose the correct statement for metals:
   a. $\frac{K_e}{100} \approx K_{ph}$ b. $K_e > K_{ph}$
   c. $K_e < K_{ph}$ d. $K_e = K_{ph}$
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

PART-B :Descriptive

Time : 2 hrs. 40 min. 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. Derive Bragg's law of X-ray diffraction.

2. a. Outline some differences between crystalline and amorphous solids. 4+6=10
   b. Describe different types of crystal symmetry operations.

3. a. Explain the formation of an ionic bond with an appropriate example. 5+5=10
   b. Mention five properties of ionic solids.

4. a. What are superconductors? 2+8=10
   b. Explain type- I and type-II superconductors with examples and magnetization curves.

5. a. Determine the electron concentration for Na with the expression $N = Z_v \frac{\rho_M N_A}{M'}$. 2+6+2 =10

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

   b. Derive the expression for the electrical conductivity $\sigma = \frac{Ne^2\tau}{m^*}$ (symbols have their usual meanings) based on free-electron model.

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

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 energy band formation is solids. You can take Li^3 for an example. Can you estimate the gap between two adjacent levels assuming the band width of metal is 5 eV? 6+4=10

b. What are the failures of the free-electron gas model?

8. Derive the susceptibility for the paramagnetic materials for a two level system, *i.e.* $j = \frac{1}{2}$ using the quantum theory. 10

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