SET A

B.Sc. PHYSICS
FIFTH SEMESTER
SOLID STATE PHYSICS
BSP – 502 [SPECIAL REPEAT]

[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. For lattice parameters, $a_1=a_2=a_3$, $\alpha=\beta=\gamma < 120°$ but $\neq 90°$, crystal structure is
   a. Triclinic
   b. Orthorhombic
   c. Tetragonal
   d. Trigonal

2. 5 and 7 fold rotation are not compatible with
   a. Translational symmetry
   b. Vibrational symmetry
   c. Reflection symmetry
   d. Inversion symmetry

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. A diamond structure is a combination of
   a. Cubic and Hexagonal
   b. Hexagonal and Orthogonal
   c. Orthogonal and Triclinic
   d. Triclinic and Cubic

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

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

7. 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

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. In a diatomic lattice, all atoms move in unity for
    a. Never move in unity
    b. Short wavelength
    c. Long wavelength
    d. All wavelength

11. Maximum angular frequency in a diatomic array is dependent on mass of
    a. Heavier atom
    b. Lighter atom
    c. Both heavy and light
    d. Independent of mass

12. For dispersion relation of a diatomic lattice, if masses of the two atom types are same, then the width of the forbidden band
    a. Increases to infinity
    b. Decreases to zero
    c. Remains unchanged
    d. Shifts

13. Smallest possible wavelength in the first Brillouin zone for a diatomic array is
    a. lattice constant
    b. 2x lattice constant
    c. 3x lattice constant
    d. 4x lattice constant

14. In the optical branch, two atoms move such that their directions
    a. are same
    b. are opposite
    c. are independent of wavelength
    d. are random

15. For a diatomic lattice of two atomic masses: m and M (M>m), every atom lattice oscillates isolated from neighbors for
    a. M=0
    b. M=m
    c. M≠m
    d. $M \rightarrow \infty$

16. Lowest energy band for an electron corresponds to
    a. $k = \pm \pi/a$
    b. $k = \pm 2\pi/a$
    c. $k = \pm \pi/2a$
    d. $k = \pm a/\pi$

17. Displacement of charged ion gives rise to
    a. Ionic polarization
    b. Electronic polarization
    c. Dipolar polarization
    d. All of the above

18. The real and imaginary parts of dielectric in case of dipolar dispersion are equal in
    a. Infrared regime
    b. Visible regime
    c. Ultraviolet regime
    d. Microwave regime

19. Periodic charge density and periodic potential well corresponds to
    a. Drude model and Bloch theory
    b. Bloch theory and Kronig-Penny model
    c. Kronig-Penny model and Drude model
    d. None

20. Potential barrier for an electron moving under the influence of Electric field becomes delta functions for
    a. $Vo \rightarrow 0, b \rightarrow 0$
    b. $Vo \rightarrow 0, b \rightarrow \infty$
    c. $Vo \rightarrow \infty, b \rightarrow 0$
    d. $Vo \rightarrow \infty, b \rightarrow \infty$

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Descriptive

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

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

1. a. Calculate the surface density of atoms in [111] plane of BCC lattice. Assume a=5Å. Also assume that he atoms are hard spheres with closest atoms touching each other. **2+2+2+ 2+2=10**
   b. Circular discs of 1m radius are placed on plane so as to form closely packed triangular lattice. Calculate the number of discs per unit area.
   c. A SCC with lattice constant a_c, undergoes transition into tetragonal structure $a_t=b_t= a_c\sqrt{2}$ and $c_t= 2ac$. Show that the ratio of interplanar spacing (101) planes for cubic and tetragonal structure will be $\sqrt{(3/8)}$.
   d. Draw the miller indices in a simple cubic unit cell
   (i)123 (ii) 110 (iii) 221 (iv) 111

2. a. Define reciprocal lattice and express the fundamental reciprocal lattice vectors in terms of the real space lattice vectors. **2+2+2+ 4=10**
   b. Explain Bragg's condition for diffraction in real space as well as in K-space
   c. Elaborate what is a Brillouin zone and describe the concept of Ewald construction
   d. Construct first and second Brillouin zones in a reciprocal space with $k_x=\pi/a=k_y$.

3. Write the expression and briefly elaborate dispersion relation with suitable plots:
   a. for a monoatomic chain for low frequency regime, high frequency regime and for wavelength, $\lambda=2a$ (a is the interatomic distance). **6**
   b. for a linear diatomic lattice **4**

4. Write and discuss Dulong-Petit law for specific heats of solids. Describe the assumptions made for classical explanation of specific heat of solids. 3+2+2+3=10

Describe how did Einstein model try to resolve the disagreement between experimental observations and classical theory of specific heat of solids. Distinguish between Einstein's model and Debye's model (quantitatively with expressions).

5. Describe briefly diamagnetism and paramagnetism. Write the expression for diamagnetic susceptibility according to Langevin theory and define the parameters involved. Elaborate how is paramagnetism dependent on temperature. 1+1+1+1+2+2+2=10

6. a. Elaborate the failures of classical theory of Drude-Lorentz electron model, 2+2+2+4=10
   b. Explain how introduction of Bloch function leads to band theory of solids.
   c. Discuss the origin of Band gap in accordance with the band theory of solids. Describe how the Kronig Penney model defines the formation of Band gap.

7. Write the expression for the effective mass of an electron in a solid under the influence of an electric field. Using proper plots describe how it depends on the shape of the E(k) curve. Elaborate the k-state factor and how it leads to the idea of negative effective mass. 2+4+4=10

8. a. Using Kronig-Penney Model, show that for $P<<1$, determine the energy of lowest energy band. 5+5=10
   b. For an electron with wave vector, $k = 10^{10}\ K_x m^{-1}$ is removed from an orbital in completely filled valence band. Determine the effective mass, velocity momentum and energy of a hole if energy near valence band of a crystal is, $E = -Ak^2$, where $A = 10^{-39}\ Jm^2$.

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