Minor Exam- Course PYL102
Full Marks: 25, Time: 60 Min
Date: 26.09.2022, 13:00-14:00Uhr

Dept. of Physics, IIT Delhi

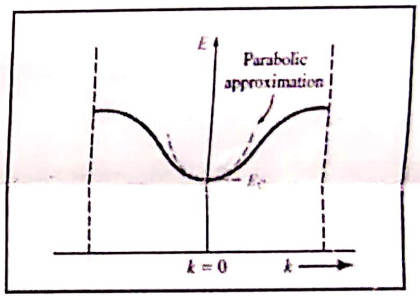
**Answer ALL the questions (Two Group)**

**Group-A (4X4= 16 Marks)**

1. What is the Fermi Sphere? How does quantum free electron theory explain the observed linear temperature dependent small values of electronic specific heat of metal? **[1+3]**

2. Aluminium is a trivalent with atomic weight 27 and density 2.7g/ $cm^3$, while the mean collision time between electrons is $4 \times 10^{-14}$s. Calculate the current flowing through an Al wire with 20m long and $2mm^2$ cross section area when a potential of 3V is applied to its ends. **[4]**

3. The dispersion relation (black solid line) for the electron in conduction band is shown in the fig.
   a) Draw how the velocity and mass of conduction electron change in the band. **[1+1]**
   b) Qualitatively explain the meaning of positive and negative effective mass. **[0.5+1.5]**



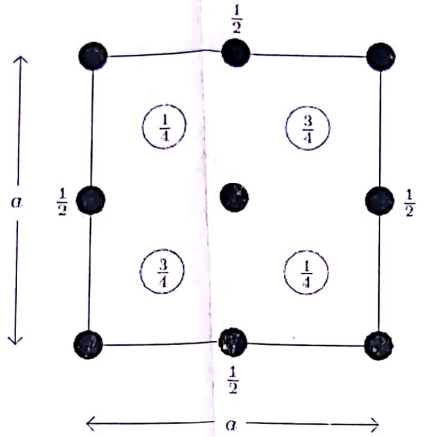

OR

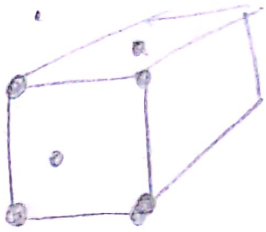
3. The energy dispersion (E-k) relation for electrons in a one-dimensional array of atoms having lattice constant a and total length L is $E = E_0 - \beta - 2\gamma \cos(ka)$, where $E_0$, $\beta$ and $\gamma$ are constants and k is the wave vector.
   a) Calculate the density of states of electrons (including spin degeneracy) in the band. **[3]**
   b) Calculate the effective mass of electrons in the band. **[1]**

4. Describe three Major assumptions of Drude free electron theory. Prove that the total number of possible states in an allowed energy band of a finite crystal is equal to the number of primitive cells in it. **[1.5+2.5]**

## Group-B (3x3= 9 Marks)

5. The diagram given below shows a plan view of a structure of cubic ZnS (zincblende) looking down the z axis. The numbers attached to some atoms represent the heights of the atoms above the z = 0 plane expressed as a fraction of the cube edge a. Unlabeled atoms are at z = 0 and z = a.
   (a) What is the Bravais lattice type? **[0.5]**
   (b) Describe the basis of unit cell. **[1]**
   (c) Given that a = 0.541 nm, calculate the nearest neighbor Zn–Zn, Zn–S, and S–S distances. **[1.5]**



Zn= ● S = ○

6. The electron concentration in silicon at T = 300 K is $n_0 = 2 \times 10^5$ cm$^{-3}$. (a) Determine the value of $p_0$. (b) Calculate the position of the Fermi level (in eV) with respect to the valence band energy level. (c) Is this n- or p-type material? Provided, tThe intrinsic carrier concentration $n_i = 2 \times 10^{10}$ cm$^{-3}$ and the effective density of state $N_v = 1.04 \times 10^{19}$ cm$^{-3}$. **[1+1.5+0.5]**

7. Calculate the intrinsic carrier concentration in Germanium at T=400 K and at T = 250 K. The values of effective density of state $N_c$ and $N_v$ for silicon at $T$ =300 K are 2.8 x10$^{19}$ cm$^{-3}$ and 1.04 x10$^{19}$ cm$^{-3}$ respectively. Assume that both $N_c$ and $N_v$ are vary as $T^{3/2}$ and Germanium band gap $E_g$ =0.6 eV is constant over this temperature range. **[1.5+1.5]**

OR

7. The primitive translational lattice vectors of the hexagonal space lattice are given as **a**= $\sqrt{2}a\,x - \frac{a}{2}y$, **b**= $\frac{a}{\sqrt{2}}x + \frac{a}{2}y$, **c**= c$^3$z, where $x$,y,z are unit vectors and a,c are lattice vector in conventional unit cell. (a) Determine the primitive vectors of reciprocal lattice. Calculate the square volume of the principle unit cell. **[2.5+ 0.5]**

$$p_0 = 2\left(\frac{2\pi m k T}{h^2}\right)^{3/2} e^{-\frac{E_F - E_V}{kT}}$$