**6 SEM TDC PHY M 2**

**2016**

( May )

PHYSICS

( Major )

Course : 602

**( Condensed Matter Physics )**

*Full Marks* : 60
*Pass Marks* : 24

*Time* : 3 hours

*The figures in the margin indicate full marks for the questions*

**1.** Answer the following as directed : 1×6=6

*(a)* If 0·28 nm is the spacing between the nearest neighbouring ions in NaCl lattice, the unit cell parameter is

*(i)* 1·4 Å

*(ii)* 5·6 Å

*(iii)* 0·7 Å

*(iv)* 1 nm

( Choose the correct answer)

(b) Sodium crystallizes in b.c.c. lattice with the cell edge 4·29 Å. What is the length of the body diagonal of the unit cell?

(c) Let $E$ be the energy of the lowest state of a one-dimensional potential box of length $L$. If the length of the box is halved, then the lowest state energy $E'$ will be

(i) $E' = E$
(ii) $E' = 2E$
(iii) $E' = E/2$
(iv) $E' = 4E$

( Choose the correct answer)

(d) What is the velocity of free electron when the slope $\frac{dE}{dk}$ of the $E$-$k$ curve is zero?

(e) The electron pairs in a superconductor are called

(i) BCS pairs
(ii) Bardeen pairs
(iii) Cooper pairs
(iv) Electron-hole pairs

( Choose the correct answer)

(f) With an increase in temperature, the Fermi level of an intrinsic semiconductor moves towards the conduction band.

( State True or False )



( Continued )



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2. (a) Draw the zinc blende structure. How does it differ from the diamond structure? 2

(b) What is meant by density of states? Write its expression for three-dimensional electron gas. 2

(c) Find the intrinsic carrier concentration of germanium if its conductivity is $2{\cdot}13\ (\Omega\text{-m})^{-1}$. Given the electron and hole mobilities as

$$\mu_e = 0{\cdot}39\ m^2\ V^{-1}\ s^{-1}$$
$$\mu_p = 0{\cdot}19\ m^2\ V^{-1}\ s^{-1}$$ 2

3. (a) What are Brillouin zones? Illustrate the first two Brillouin zones for a two-dimensional square lattice. 1+4=5

(b) Derive Bragg's diffraction condition in terms of the reciprocal lattice vector. 3

4. (a) Explain the terms 'ionization energy' and 'electron affinity'. Obtain an expression for the total cohesive energy of an ionic crystal in terms of Madelung constant and other parameters. 2+3=5



( Turn Over )

Or

What is reciprocal lattice? Show that f.c.c. lattice is reciprocal to b.c.c. lattice and vice versa. 1+4

(b) What is meant by Miller indices of a crystal plane? Show that in a cubic crystal the spacing between the consecutive parallel planes of Miller indices $(hkl)$ is given by

$$\frac{a}{\sqrt{h^2+k^2+l^2}}$$ 1+2

5. (a) What is effective mass of electron? Mention its significance. Show that the effective mass of an electron in a crystal is inversely proportional to the second derivative of the $E$-$k$ curve. At what condition the effective mass of an electron becomes negative? 1+1+3+1

(b) Describe the free electron gas model of metals. How does it help to explain the lattice heat capacity of metal?

6. (a) What is the basis of band theory? Using Kronig-Penney model, discuss the energy band structure of solid. 2+4



( Continued



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Or

Show that for a one-dimensional lattice of length $L$ the total effective number of free electrons in an energy band filled with electrons up to a certain value $k_1 (k_1 < \pi / a)$ is

$$N_{\text{eff}} = \frac{2Lm}{\pi\hbar^2}\left(\frac{dE}{dk}\right)_{k=k_1}$$

From this result, distinguish among metal, semiconductor and insulator. 6

(b) Obtain the expressions for Fermi energy and total energy of free electron gas in one dimension. 4

7. (a) Explain the term 'critical magnetic field' in a superconductor. How does it vary with temperature in type II superconductors? Show that superconductor exhibits perfect diamagnetism. 2+2+3=7

(b) What is Fermi level? Discuss the effects of temperature and doping on the position of Fermi level. 1+4=5

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