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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 semi-conductor moves towards the conduction band.

(State True or False)

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

Or

What is reciprocal lattice? Show that f.c.c. lattice is reciprocal to b.c.c. lattice and vice versa. 1+4=5

(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=3

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=6

(b) Describe the free electron gas model of metals. How does it help to explain the lattice heat capacity of metal? 4

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

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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