Total No. of Printed Pages—6

6 SEM TDC PHY M 2

2014

(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 questions as directed : 1×6=6

(a) What is the angle between [111] direction and [110] direction of a cubic lattice?

(b) The closest distance of approach of monoatomic b.c.c. structure in terms of lattice parameters is

(i) $\frac{a}{2}$

(ii) $\frac{a}{\sqrt{2}}$

(iii) $\frac{\sqrt{3}}{2}a$

(iv) $\sqrt{\frac{3}{2}}a$ (Choose the correct answer)

(c) How does Fermi energy E_F vary with electron concentration n?

(d) An electron behaves as free electron if the ratio f_k of electronic mass to its effective mass is

(i) 0

(ii) 1

(iii) ∞

(iv) < 1 (Choose the correct answer)

(e) In a p-type semiconductor the concentration of acceptor atoms is 2×10^{21} m^{-3}. What is its conductivity if the hole mobility is $0 \cdot 17$ $m^2V^{-1}s^{-1}$?

(f) Below the transition temperature, a superconducting material exhibits

(i) only zero resistance

(ii) only diamagnetic property

(iii) zero resistance and paramagnetism

(iv) zero resistance and diamagnetism

(Choose the correct answer)

2. (a) Show that a 5-fold rotation axis cannot exist in a lattice. 2

(b) Obtain an expression for the average kinetic energy of a three-dimensional free electron gas at 0 K. 2

(c) When does an intrinsic semiconductor behave as an insulator and why? 2

3. (a) What is meant by Miller indices of a crystal plane? What is the purpose of taking reciprocals in determining Miller indices? Show that in a cubic crystal the spacing between the consecutive parallel planes of Miller indices (*hkl*) is given by

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$ 1+1+2=4

(b) Describe the nature and origin of various forces existing between the atoms of a crystal. Explain the formation of stable bond from the potential energy versus interatomic distance curve. 4

4. (a) Derive Bragg's law for X-ray diffraction. Discuss the formation of diffraction pattern on the photographic film in powder method of X-ray diffraction. 2+3=5

(b) What is Brillouin zone? Find Brillouin zone for b.c.c. lattice. 1+2=3

5. (a) What is density of states? Find an expression for the density of states at energy E in a three-dimensional box of volume V. 2+4=6

(b) Applying free electron gas model, derive Ohm's law and find an expression for conductivity. 4

Or

Using Kronig-Penny model, show that the width of the allowed energy bands increases with increase in total energy and decrease in binding energy of electron. 4

6. *(a)* What is meant by the effective mass of an electron? What is its significance? Show that the effective mass of an electron in a crystal is inversely proportional to the *E-K* curve. Under what conditions the effective mass of an electron may be positive, negative or infinity? 1+1+3+1=6

Or

The energy near the valence band edge of a crystal is $E = -AK^2$, where $A = 10^{-39}\ \text{J m}^2$. An electron with wave vector $K = 10^{10}\ \text{m}^{-1}$ is removed from an orbital in the completely filled valence band. Determine the effective mass, velocity, momentum and energy of the hole. (Given $\hbar = 1{\cdot}05 \times 10^{-34}\ \text{J s}$) 1½×4=6

(b) Distinguish between metals, semiconductors and insulators on the basis of their energy band structure. 4

7. *(a)* What is Fermi level? Show that the Fermi level of an intrinsic semiconductor lies near the middle of the forbidden gap. 1+5=6

(b) Distinguish between type—I and type—II superconductors using Meissner effect. Prove that the Meissner effect and disappearance of resistivity in a superconductor are mutually consistent. 3+3=6

★★★