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6 SEM TDC PHY M 2

2017

(May)

PHYSICS

(Major)

Course : 602

(Condensed Matter Physics)

Full Marks : 60

Pass Marks : 24/18

Time : 3 hours

The figures in the margin indicate full marks for the questions

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

(a) A metal crystallizes with a face-centred cubic lattice. The edge of the unit cell is 408 pm. The diameter of the metal atom is

(i) 204 pm

(ii) 288 pm

(iii) 408 pm

(iv) 144 pm

(Choose the correct answer)

(b) What is the coordination number of the HCP structure?

(c) The effective number of free electrons in a completely filled band is zero.

(State True or False)

(d) Write the relation between average kinetic energy of electrons in the ground state ($\overline{E}_0$) with Fermi energy in one-dimensional crystal.

(e) The slope of the ln σ (σ is conductivity) versus $1/T$ plot is a measure of

(i) mobility

(ii) resistivity

(iii) band gap

(iv) None of the above

(Choose the correct answer)

(f) The Meissner effect in superconductor is a/an

(i) reversible process

(ii) irreversible process

(iii) isothermal process

(iv) adiabatic process

(Choose the correct answer)

2. (a) Calculate the efficiency of packing in the case of a metal crystal in simple cubic lattice. 2

(b) How energy levels of an atom become energy band in a solid? 2

(c) The intrinsic carrier concentration in an Si sample is $1 \cdot 5 \times 10^{16}$ atoms/m^3. It is doped with 10^{23} phosphorus atoms/m^3. Determine its hole concentration and conductivity. Given electron mobility = $0 \cdot 135\ m^2 V^{-1} s^{-1}$. 2

3. (a) Calculate the binding energy of an ionic crystal and obtain an expression for the Madelung constant. Evaluate Madelung constant for a linear ionic crystal. 3+1+2=6

(b) Find the angle between [111] and [110] directions of a cubic lattice. 2

4. (a) Describe the nature and origin of various forces existing between the atoms of a crystal. Explain the formation of stable bond using the potential energy versus interatomic distance curve. 3+3=6

Or

How does Bragg's reflection differ from ordinary reflection? What is Ewald construction? How does it help to interpret X-ray diffraction photographs? 1+2+3=6

(b) Prove that f.c.c. lattice is reciprocal to b.c.c. lattice. 2

5. *(a)* Write down the postulates of free electron gas model. A particle of mass m is confined in a field-free region between impermeable walls at $x = 0$ and $x = L$. Show that the stationary energy levels of the particles are given by

$$E_n = \frac{n^2 h^2}{8mL^2}$$ 2+5=7

Or

What is density of states? Show that the density of states at the Fermi surface is

$$D(E_F) = \frac{V}{2\pi^2}\left(\frac{2m}{\hbar^2}\right)^{3/2} E_F^{1/2}$$ 1+6=7

(b) Find the relation between Fermi energy and average kinetic energy of an electron at absolute zero temperature. 3

6. *(a)* State and explain the Bloch theorem. Discuss its importance in the band theory. 2+3=5

(b) What is the nature of potential experienced by an electron in a crystal? Using the Kronig-Penney model, show that for $p \ll 1$, the energy of the lowest energy band is

$$E = \frac{\hbar^2 p}{ma^2}$$

1+4=5

7. *(a)* What is meant by Fermi level? Sketch the Fermi level in *p*-type and *n*-type semiconductors. Show that the Fermi level of an intrinsic semiconductor lies at the middle of the band gap. 1+2+4=7

(b) State two basic characteristics of super-conductors. Explain the difference between type–I and type–II super-conductors using Meissner effect. 1+4=5

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