2022

(May/June)

PHYSICS

(Honours)

(Condensed Matter Physics)

[PHY–07 (T)]

Marks : 56

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer Question No. **1** and *any* **four** from the rest

1. Answer any *three* of the following : 4×3=12

(a) Calculate the melting point of ice when it is subjected to pressure of 100 atmosphere. Given density of ice is 917 kg/m^3, density of water is 1000 kg/m^3 and latent heat of ice is $3{\cdot}36 \times 10^5 J/kg$.

(b) At what temperature will the average speed of molecules of hydrogen gas is seven times the average speed of nitrogen gas at 300 K?

(c) Find out the reciprocal lattice vectors for a space lattice defined by the following primitive translation vectors :

$$\vec{a} = 5\hat{i} + 5\hat{j} - 5\hat{k}\ ;\ \vec{b} = -5\hat{i} + 5\hat{j} + 5\hat{k}\ ;$$

$$\vec{c} = 5\hat{i} - 5\hat{j} + 5\hat{k}$$

Also find out the volume of the primitive cell.

(d) Calculate the probabilities for an electronic state to be occupied at 27 °C if the energy of the states lie 0·11 eV above and 0·11 eV below the Fermi level.

2. (a) Define different thermodynamical potential and derive related Maxwell's thermodynamic relations. 4+4=8

(b) Establish Clausius-Clapeyron relation from Maxwell's thermodynamic relations. 3

3. (a) State and prove Liouville's theorem. 1+4=5

(b) What is Gaussian or Normal distribution? Obtain an expression for it. 1+5=6

4. (a) Deduce Boltzmann's entropy probability relation $S = K_B \ln \Omega(\epsilon)$, where symbols carry their usual meanings. 4

(b) Probability function $P(v)$ of speed of a given number of molecules is expressed as

$$P(v) = 4\pi\left(\frac{m}{2\pi kT}\right)^{\frac{3}{2}} v^2 e^{-\frac{mv^2}{2kT}}$$

Find the expressions for mean and root mean square speed. 3½×2=7

5. (a) If $\vec{T}$ is the translation vector in direct lattice and $\vec{G}$ is the reciprocal vector in corresponding reciprocal lattice, then prove that $e^{i\cdot\vec{G}\cdot\vec{T}} = 1$. 3

(b) Define structure factor and atomic form factor. Calculate the structure factor for a bcc unit cell and determine from which planes will X-rays not be reflected. 1½+1½+4+1=8

6. (a) What is Madelung constant? Show that Madelung constant for an infinite linear chain of ions of alternating unit charge at an equilibrium separation is $2\ln 2$. 1+3=4

(b) What is a 'phonon'? Obtain the dispersion relation for elastic waves in a linear monoatomic chain with nearest neighbour interaction and show that the group velocity vanishes at zone boundary. 1+5+1=7

7. *(a)* What is Hall effect? Find the expression for Hall coefficient. 1+3=4

(b) What are Fermi level and Fermi energy? Find an expression for Fermi energy at $T = 0$ K of an electron system with electron density n. 2+5=7

8. *(a)* Describe in detail Langevin's theory of paramagnetism. 5

(b) Discuss the thermodynamics of superconducting transition and show that there exists a discontinuity in the value of specific heat at the transition temperature. 6

★★★