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( July )

PHYSICS

( Honours )

( Condensed Matter Physics )

[ PHY07(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. (a)** If the root-mean-square velocity of  $H_2$  molecules at 300 K is 1840 m/s. At what temperature will  $O_2$  molecules travel with the same root-mean-square velocity? 4
- (b)** The density of electron gas in a metal is approximately equal to  $2.6 \times 10^{28}$  per  $m^3$ . Assuming the metal has one free electron per atom, calculate the Fermi energy and the molar heat capacity at 300 K. 4

- (c)** The resistivity of a doped silicon sample is  $8.9 \times 10^{-3} \Omega m$ . The Hall coefficient was measured to be  $3.6 \times 10^{-4} m^3/C$ . Assuming single-carrier conduction, find the mobility and the density of charge carriers. 4

- 2. (a)** What are thermodynamic potentials? Write down the differential form of the four main thermodynamic potentials. 1+2=3

- (b)** Prove the relation

$$\frac{U}{V} = T \frac{P}{T} - P$$

by using Maxwell's relations. Hence, show that the internal energy of an ideal gas is independent of the volume. 2+2=4

- (c)** What is Joule-Thomson cooling? Deduce the thermodynamic expression for the Joule-Thomson coefficient. 2+2=4

- 3. (a)** Deduce the Stirling's formula  $\ln(n!) \approx n \ln n - n$ . 3

- (b)** Distinguish between microcanonical, canonical and grandcanonical ensembles. 3

- (c)** Obtain an expression for the probability distribution function in a canonical ensemble. 5

( 3 )

4. (a) What is a partition function? Mention its importance and write down its relation with entropy of a thermodynamic system. 1+1+1=3
- (b) Briefly explain the type of statistics obeyed by bosons. 2
- (c) Derive the distribution function
- $$f(E_i) = \frac{1}{e^{E_i} + 1}$$
- In what limit does this function become a Boltzmann distribution function? 5+1=6
5. (a) What is a reciprocal lattice? Obtain the reciprocal lattice vectors for a b.c.c. lattice. 1+3=4
- (b) Draw the first three Brillouin zones for a two-dimensional square lattice. 3
- (c) What are ionic crystals? Briefly explain why ionic crystals are generally poor conductors. 1+2=3
- (d) What is the significance of the Madelung constant? 1
6. (a) What are the assumptions of the Einstein's theory of specific heat of solids? 2

( 4 )

- (b) Obtain an expression for thermal conductivity of a metal on the basis of the free-electron model. 3
- (c) Discuss the motion of electron in a one-dimensional lattice according to the band theory of solids and explain the origin of the energy gap. 6
7. (a) Describe the Langevin theory of diamagnetism. 6
- (b) What are ferromagnetic domains? 2
- (c) What are ferrites? What are their advantages over ferromagnetic materials? 1+2=3
8. (a) Mention the important property change that occurs in materials when they transform to superconductors. 1
- (b) Describe how critical magnetic field varies with temperature in type I and type II superconductors. What is a vortex state? 2+2+1=5
- (c) Explain how Cooper pairs are formed in superconductors. 2
- (d) Define coherence length. 1
- (e) Give two differences between high temperature and low temperature superconductors. 2

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