RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College under University of Calcutta)

B.A./B.Sc. SIXTH SEMESTER EXAMINATION, MAY 2014

THIRD YEAR

Date : 20/05/2014 **PHYSICS (Honours)**

Time : 11 am – 2 pm **Paper :** VII(A) Full Marks : 60

[Use a separate Answer book for each group]

Group – A

(*Answer* ***any three*** *questions*)

1. a) Consider a system of N non-interacting particles, each of which can be in any of two energy levels— the level with lower energy being non degenerate has energy zero and the upper doubly degenerate level has energy $\in$. [6]

   b) Find the entropy of the system in terms of total energy $U, N, \in$. Derive the temperature of the system and show that $U = \frac{2N\in}{e^{\beta\in}+2}$. [4]

2. a) Obtain the basic distributions of B.E and F.D statistics using grand canonical formation. [6]

   b) Show with figure, the functional behaviour of the mean occupation number in the two cases. [2]

   c) Discuss the condition for these distributions to assume Boltzmann form. [2]

3. Consider a photon gas enclosed in a volume V and in equilibrium at temperature T.

   a) What is the chemical potential of the gas? Explain. [2]

   b) Determine how the number of photons in the volume depends upon the temperature. [3]

   c) Determine the spectral density $\rho(\omega)$ of energy. [4]

   d) What is the temperature dependence of energy? [1]

4. a) Determine the phase trajectory of a one dimensional harmonic oscillator of constant energy E moving along the x-axis. [3]

   b) The constant volume heat capacity of a system with average energy <E> is given by $C_V = \left(\frac{\partial < E >}{\partial T}\right)_V$. Use canonical ensemble to prove that C_V is related to the mean square fluctuation in energy by the relation $C_V = \frac{1}{KT^2}\left\langle\left(E - \langle E\rangle\right)^2\right\rangle$. [4]

   c) A system has two non-degenerate energy levels $E_0 = 0$ and $E_1 = 0{\cdot}5$ ev. Estimate the temperature at which 1% of the total population occupy the higher level.
   Boltzmann constant $k_0 = 8{\cdot}625\times10^{-5}\,\text{ev.K}^{-1}$. [3]

5. a) Write down the distribution law obeyed by electron gas. Show that at T = 0K, the average energy of an electron in a metal is $\frac{3}{5}\in_F$, where $\in_F$ is the Fermi energy. [1+4]

   b) Derive Richardson equation for thermionic emission. [5]

Group – B

(*Answer* ***any three*** *questions*)

6. a) Define Miller indices of a set of planes in a crystal. Derive an expression for the interplaner separation of the (h, k, ℓ) planes of a simple cubic lattice. [1+4]

   b) What is reciprocal lattice? Show that the reciprocal lattice to the body centered cubic lattice is face centered cubic lattice. [1+2]

c) The band theory of one-dimensional crystal of lattice constant a leads to discontinuities in the E(k) surface whenever k satisfies the condition $k = \pm\frac{\pi}{a}$. Show that this condition is equivalent to the Bragg's reflection of electrons from a crystal plane. [2]

7. a) Find out the dispersion relation of a monatomic linear lattice. Find the phase velocity and group velocity of disturbance in such a lattice. [4+2]

b) Derive a relationship between dielectric constant $(\in)$ and atomic polarizability (α) for dielectric material. [4]

8. a) Using free electron theory show that the electrical conductivity σ and the Fermi surface area S_F are related as $\sigma = \frac{e^2 \ell S_F}{12\pi^3 \hbar}$, where ℓ is the mean free path of the electron. [4]

b) If an electric field equal to $1 v \cdot m^{-1}$ is applied to a specimen of sodium metal find the drift velocity of the conduction electrons and the displacement of Δk of the Fermisurface [Given : $\tau_F = 3{\cdot}1 \times 10^{-14} s$]. [3]

c) Find the expression for effective number of free electrons in an energy band. [3]

9. a) Derive an expression for the built in electric field in a pn junction by solving one-dimensional Poisson's equation. Hence find the width of the space charge region. [4+2]

b) Consider a silicon npn transistor with emitter, base and collector doping concentration of $10^{18} cm^{-3}$, $10^{16} cm^{-3}$ and $10^{15} cm^{-3}$ respectively, Calculate—

i) the potential barrier of emitter and collector junction

ii) emitter-base space charge width and base-collector space charge width at 300k. [4]

[Given : $\in_r = 11$, $\in_o = 8{\cdot}85 \times 10^{-14}$ F.cm^{-1}]

10. a) Show that paramagnetic moment of atom/ion depends on angular momentum. The ground state of paramagnetic ion has angular momentum $5\hbar$. Find the magnitude of magnetic moment in terms of Bohr magneton. [4]

b) Derive the Curie-Weiss law of ferromagnetism. [6]