B.Sc. Part-III (Honours) Examination, 2020

Subject: Physics

Paper: IX

(New Syllabus)

Time: 2 Hours Full Marks: 50

The figures in the margin indicate full marks. Candidates are required to give their answers in their own words as far as practicable.

1. Answer any FOUR questions from the following: $5 \times 4 = 20$

(a) Write down the time component of four-momentum vector in an inertial frame S. How does the four-momentum vector transform to another inertial frame S′?

(b) Derive an expression for the chemical potential (μ_0) of a free electron gas at T = 0 K, in terms of number of electrons (n) per unit volume.

(c) A one-dimensional quantum harmonic oscillator (Energy levels $E_n = (n+1/2)\hbar\omega$) is in thermal equilibrium at a temperature T. Find the mean energy of the oscillator. Find the same for $kT >> \hbar\omega$.

(d) Consider a photon gas enclosed in a volume at temperature T. Determine the temperature dependence of the number of photons and the energy density.

(e) Consider an ideal gas of N molecules enclosed in a volume V at a temperature T. Each molecule is of mass m. Write down an expression for the number of molecules with velocities lying between c and c + dc. Derive an expression for the most probable velocity of the molecules.

(f) Define Madelung constant with the help of a mathematical expression. Show that the Madelung constant for a equally spaced one dimensional array of alternate positive and negative ions is $2\log_e 2$.

2. Answer any THREE questions from the following: $10 \times 3 = 30$

(a) S and S′ are two inertial frames of reference. Their origins coincide at t = t′= 0, and S′ moves with speed v along positive direction of *x*-axis relative to S. Determine the relationship between the electric and magnetic fields in S with those in S′.

(b) In the Minkowski's four dimensional representation, show that Lorentz transformations are equivalent to a transformation from a rectangular co-ordinate system to an oblique one. Explain the length contraction in Minkowski's geometrical representation.

(c) State and explain Bragg's law of X-ray diffraction from a crystal. What are Miller indices for a set of parallel planes in a crystal? If (3 2 6) are the Miller indices of a set of planes, find the intercepts of the plane on the three crystallographic axes in terms of the lattice parameters *a*, *b*, *c*. Find the inter-planar spacing between two adjacent planes of Miller indices (h k l) in a cubic lattice.

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(d) State the characteristics of paramagnetic and ferromagnetic materials with examples. According to Weiss model, treating a ferromagnet as a simple paramagnet with an effective field $H_{eff} = H + \lambda M$, find an expression for the Curie temperature. Show that for small H and $T > T_C$, the magnetic susceptibility (χ) can be expressed as $\chi = \frac{C}{T-T_C}$. (Symbols have their usual meaning).

(e) Explain the orientational polarization in dielectrics. Derive an expression of the same using Langevin's theory. Derive the Clausius-Mosotti relation.