B. Sc. Part-III (Honours) Examination, 2021

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 components of the velocity four-vector of a particle in an inertial frame S. How does the four-vector transform to another inertial frame S′?

    (b) Define a black body. Derive Planck's law regarding the spectral density of electromagnetic radiation emitted by a black body in thermal equilibrium.

    (c) Derive an expression of the mean square displacement per unit time of a Brownian particle suspended in a liquid at a temperature T.

    (d) Consider a system of particles obeying M.B. statistics and the energy of each particle can be expressed as $E(x) = ax^2$, $-\infty \leq x \leq +\infty$, a being a constant. Show that the average energy of the particle is in conformity with the law of equipartition of energy.

    (e) Give the statistical definition of entropy. Use this definition to obtain the entropy of a perfect gas.

    (f) Find the packing fractions of the body centered cubic structure and the face centered cubic structure.

2.   Answer any Three questions from the following: 10×3 = 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.

(i)   Write down the Lorentz transformation equations relating the space-time co-ordinates of two inertial frames S and S′.

(ii)   A rod of length *l* is at rest on the *x*-axis of S. Find the length of the rod *l′* measured by an observer in S′.

(iii)   A rod of length *l* is at rest, making an angle θ with respect to the *x′*-axis of S′. Find the length of the rod *l′* measured by an observer in S.

(iv)   A clock, at rest in the S-frame records a time interval as Δt. Find the corresponding time interval Δt′ recorded by an observer in the frame S′.   At what speed does a clock move if it runs at a rate which is one-half the rate of a clock at rest?

(b)   Show that the time component of the four-momentum vector is proportional to the total energy of the particle. Define four-vector force from Newton's law. Show that the force and velocity four-vectors are orthogonal. Show that the kinetic energy of a freely moving particle is equal to c^2 times its gain in mass (Δm) due to motion.

(c)   Derive an expression for the energy density of states of an electron gas in a metal. Calculate the Fermi energy of the metal at T = 0 K, in terms of the electron density in the metal. Estimate the value of the Fermi energy of Sodium metal at T = 0 K.
[Mass density of Sodium = 0.971 g/cm³, Atomic weight of Sodium = 23 u]

(d)   (i)   Explain with example the meaning of an "n-fold rotation axis". Prove that the ideal crystals cannot have five-fold rotational symmetry.
(ii) Define the term "reciprocal lattice". Show that the reciprocals of the reciprocal lattice parameters are the direct lattice parameters.

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