PG/IIS/PHS/203/25

M.Sc. 2nd Semester Examination, 2025

PHYSICS

(*Condensed Matter Physics*)

PAPER—PHS-203

Full Marks : 25

Time : 1 hour

Answer **all** questions

The figures in the right hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable

1. Answer any *two* of the following questions : 2×2

   (*a*) Plot the relationship between resistivity and temperature for both a perfect conductor and a superconductor.

(*b*) The penetration depths for lead are 396 Å and 1730 Å at 3K and 7.1 K respectively. Calculate the critical temperature for Lead.

(*c*) An ac current of frequency 1 GHz is observed through a Josephson junction. Calculate the applied dc voltage.

(*d*) Explain the physical significance of the Clausius-Mossotti equation.

2. Answer any *two* of the following questions : 4×2

(*a*) What is ionic polarizability ? Determine the percentage of ionic polarizability in the sodium chloride crystal which has the optical index of refraction and the static dielectric constant as 1.5 and 5.6 respectively.

(*b*) Deduce the expression of conductivity when an ac field is applied on a superconductor. Define inductive impedance from the expression.

(*c*) Empirically it is found that the temperature dependence of the critical field B_c of a type-I superconductor is given by $B_c = B_0\left[1-(T/T_c)^2\right]$. Use this to show that the entropy S_S per unit volume of the superconducting state is lower than that of the normal state S_N. Furthermore, show that $S_N - S_S = aT - bT^3$, where '*a*' and '*b*' are constants, and that $S_N = S_S$ when $T = T_c$.

(*d*) Prove that dielectric loss by ac field driven dielectric material is proportional to the frequency of the field.

3. Answer any *one* of the following questions : 8×1

(*a*) Considering the difference between the

free energy between normal and superconducting state

$$G_N(T, B_a) - G_S(T, B_a) = \frac{1}{2\mu_0}\left(B_c^2 - B_a^2\right),$$

deduce Rutger's formula for the specific heat of a superconductor. For a conventional superconductor, the critical magnetic field at zero temperature is measured to be $B_0 = 0.1T$ and the critical temperature is $T_C = 9\text{K}$. Using Rutger's formula, calculate the discontinuity in specific heat capacity per unit volume at the critical temperature. 5 + 3

(*b*) Discuss the complex dielectric constant in an alternating electric field. Define the loss tangent and explain its significance in dielectric materials. How is the imaginary part of the dielectric constant determined from the loss tangent ? The

space between a parallel plate capacitor is filled with a dielectric having dielectric constant $\epsilon_r' = 2.5$ when subjected to a 2 V alternating voltage at 1 MHz. The loss tangent at this frequency is 4×10^{-4}. Calculate the imaginary part of the dielectric constant ϵ_r'' at this frequency.

2+3+1+2

[Internal Assessment — 5 Marks]
