

2021

PHYSICS — HONOURS

Paper : VII-A

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 five** questions :

2×5

- (a) Show that the number of microstates available to a rigid rotor with angular momentum less than M is $\left(\frac{2\pi M}{h}\right)^2$.
- (b) Three identical bosons can be distributed among two states. Show all possible configuration of the microstates.
- (c) State the postulate of equal a priori probability.
- (d) Draw the phase trajectory of one dimensional linear harmonic oscillator of constant energy E .
- (e) The field components $E_y = E_0 \sin(kx + \omega t)$ and $B_z = -B_0 \sin(kx + \omega t)$ satisfies Maxwell's equations in free space. Find relation between k and ω .
- (f) What is Rayleigh Scattering?
- (g) Find from Poynting flow, the mean value of the intensity of the magnetic field in air at a distance of 100 cm from a radiating, source of power 10 KW.

Answer **any four** questions.2. (a) Show that the partition function of ideal gas consisting of N non-interacting particles of mass m is

$$Z = \left[\left(\frac{2\pi m k_B T}{h^2} \right) V \right]^N$$

where symbols have their usual meanings. Hence derive the equation of state of ideal gas from it.

(b) Derive the following relations :

(i) mean energy $\bar{E} = -\frac{\partial \ln Z}{\partial \beta}$

(ii) Pressure $\bar{P} = \frac{1}{\beta} \frac{\partial \ln Z}{\partial V}$. (4+2)+(2+2)

Please Turn Over

3. (a) A system of non-relativistic neutrons at temperature $T = 0$ has a density $10^{48}/\text{m}^3$. What is the value of the Fermi momentum for the system? (mass of Neutron is 1.67×10^{-27} kg.)
- (b) Sketch the Fermi distribution function for three temperatures $T_3 > T_2 > T_1 = 0$ on the same graph.
- (c) Show that the Fermi energy E_F of electrons in a metal at $T = 0$ is given by, $E_F = \frac{h^2}{2m} \left(\frac{3n}{8h} \right)^{\frac{2}{3}}$, where symbols have their usual meanings. 3+3+4

4. (a) From Einstein's theory of specific heat, show that $C_V = 3R \left(\frac{h\nu}{k_B T} \right)^2 \frac{e^{h\nu/k_B T}}{\left(e^{h\nu/k_B T} - 1 \right)^2}$, where symbols have their usual meanings. How does it explain the low temperature behaviour of specific heat.

(b) Evaluate the sum, $Z = \sum_{n=0}^{\infty} e^{-\beta \left(n + \frac{1}{2} \right) h\nu}$ and then calculate $U = -\frac{\partial \ln Z}{\partial \beta}$ where $\beta = \frac{1}{k_B T}$.

(6+1)+3

5. (a) Starting from Maxwell's equations, show that any initial change density in a conductor dissipates in a characteristic time.
- (b) Find the average energy density for a plane monochromatic wave.
- (c) Show that Poynting theorem predicts Joule heating in a wire. 3+3+4
6. (a) The refractive index for a gaseous system is given by

$$n = 1 + \frac{Nq^2}{2m\epsilon_0} \sum_j \frac{f_j (\omega_j^2 - \omega^2)}{(\omega_j - \omega)^2 + \gamma_j^2 \omega^2}$$

Show that, away from resonance, it reduces to the Cauchy equation

$$n = 1 + A \left(1 + \frac{B}{\lambda^2} \right),$$

the symbols have their usual meanings.

- (b) What is anomalous dispersion? Find out the width of the anomalous dispersion region for a single resonance frequency ω_0 . Given the damping constant $\gamma \ll \omega_0$. Using dimensional analysis, find out how does the intensity depend on the wavelength in Rayleigh Scattering. 2+(1+4+3)

7. (a) A metal has a conductivity 6×10^6 mhos/m. Obtain the skin depth in that metal for an electromagnetic wave of frequency 100 Hz. Deduce the formula that you use.
- (b) An electromagnetic wave is incident at the surface of two linear homogeneous dielectrics. Write down the boundary conditions at the surface. Find out the conditions under which there is a phase reversal for the reflected wave.
- (c) A rectangular wave guide has dimensions $2.3 \text{ cm} \times 1.0 \text{ cm}$. If the driving frequency is 1.70×10^{10} Hz, find out the TE modes that would propagate through this guide. 3+4+3
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