CSM – 58 / 15
Physics
Paper – I

Time : 3 hours

Full Marks : 300

The figures in the right-hand margin indicate marks.

Candidates should attempt Q. No. 1 from Section – A and Q. No. 5 from Section – B which are compulsory and ***three*** *of the remaining questions, selecting at least* ***one*** *from each Section.*

Section – A

1. Answer any **three** of the following : 20×3 = 60

   (a) Describe the classical theory for angular momentum of an atom, considering current of an electron orbit.

   (b) Consider a elliptical disk with semi-major axis b and semi-minor axis a. Show a method to obtain moment of inertia, for rotation about

(i) the major axis and (ii) about the minor axis.

(c) Describe hysteresis of a magnetic object. Indicate graphically the difference between hysteresis loops for paramagnetic and ferromagnetic materials. Write a corresponding Entropy plot, considering the domains are ordered.

(d) Discuss the stationary wave formation in a string tied at both the ends.

2. (a) Starting from the Maxwell Thermodynamic relations, derive the equations relating entropy of ideal gas to entropy of real gas. 30

(b) Describe the Carnot heat engine, clearly identifying all points on the PV diagram. Show from this that efficiency of any engine is always less than 1. 30

3. (a) Consider a spherical object of radius 'a' freely falling from a height 'h'. If the air drag can not be neglected, then the object attains

terminal velocity in a given time. Write the appropriate differential equations to show the dynamics of this object. Show the solution at which the terminal velocity occurs. 20

(b) Consider a glass cylinder in which micron sized latex spheres are dispersed. The number of particles at a vertical position z is given by $n(z) = n(0)\exp(-m^* gz/K_B T)$. m^* is the effective mass given by real mass minus buoyancy. The latex spheres sink down due to gravity, but also diffuse upwards, with a diffusion constant D. Derive equations for rate of sinking and rate of upwards motion. Show the situation when the two rates are equal to create steady state and how the Boltzmann constant k_B can be obtained from this. 40

4. (a) Derive Fresnel equations for reflection at an interface. 20

(b) Discuss Brewster's angle from above equations. 20

(c) Show how Quarter wave plates and Half wave plates function, using the phase difference generated by them. 20

Section – B

5. Answer any **three** of the following : $20 \times 3 = 60$

(a) Derive Planck's radiation formula and show that the Stefan's constant (σ) is given by $\sigma = \frac{2}{15} \frac{\pi^2 K^4}{c^2 h^3}$ where the symbols used have their usual meaning.

(b) Show that $\frac{E_S}{E_T} = \frac{C_P}{C_V}$, where E_S and E_T correspond to adiabatic and isothermal elasticities and C_P and C_V are the specific heat of the substance at constant pressure and volume respectively.

(c) Define the peak, mean and root-mean square (r. m. s.) value of an alternating voltage. An alternative EMF is applied to a circuit containing pure inductance only. Obtain an expression for the current flowing in the circuit at any time.

(d) What is an electrical image ? Obtain the image system for a point charge at a distance 'c' from the centre of a conducting sphere of radius 'b' (< c) at zero potential.

6. Consider a system of three slits, with distances d_{12} between slits 1 and 2 and d_{23} between slits 2 and 3. Position of slit number 2 is considered for the optical axis. A screen is at distance L from the three slits.

(a) Derive the set of equations to show intensity at any point P on the screen, due to interference of light from all three slits. 30

(b) How will this modify if the distances between slits are equal, i. e., $d_{12} = d_{23}$. 10

(c) Clearly elucidate the difference in the interference pattern obtained here, as opposed to a standard Young's double slit situation. 20

7. (a) Describe ray matrix approach for paraxial optics. Derive the equations for a thin lens. 30

(b) Consider an optical system of four thin lenses, with focal lengths f_1, f_2, f_3 and f_4 respectively and distances between them d_{12}, d_{23} and d_{24}. Write the relevant component matrices and obtain the final solution in ray matrix approach. 30

8. (a) Consider two pendulums, with masses of bobs respectively m_1 and m_2, connected by a spring of constant k. Write the equations for the dynamics of the individual bobs, convert them into a matrix form and solve it using Eigenvalue method. Show the normal modes of oscillation. 30

(b) Write the Lagrangian for above system and solve the same. 30