

2026

## PHYSICS — HONOURS

Paper : DSCC-2

(Basic Physics - 2)

Full Marks : 75

*The figures in the margin indicate full marks.**Candidates are required to give their answers in their own words as far as practicable.*Answer **question no. 1** and **any five** questions, taking at least **one** question from each **Group**.1. Answer **any five** questions :

3×5

- Two positive charges 1C and 2C are placed at a distance 'a' apart. Find the point on the line joining them, where the intensity of the electric field vanishes.
- A point charge 'Q' is situated at the centre of a cube with side 'a'. Calculate the flux of the electric field through any one of its faces.
- Obtain the differential form of Ampere's circuital law.
- Derive the expressions for the potential and the intensity of the electric field due to an ideal electric dipole.
- Which of the following parameters is(are) 'intensive' and which one(s) is(are) 'extensive' : (i) density, (ii) internal energy, (iii) entropy?
- Write down the Maxwell velocity distribution function in 2D. Hence find the mean KE for this case.
- What do you mean by the 'efficiency' of a heat engine? If the efficiency of an engine is 30%, how much heat does it deposit to the sink in order to produce 30J of work?
- Find the change in entropy for an ideal gas to go from a state of  $(P_1, T_1)$  to a state of  $(P_2, T_2)$  where the symbols have their usual meaning.

## Group - A

- Write down the expression for the electric field due to a general volume distribution of charge. (Explain your notation clearly, using a figure). Show that the field can be expressed as the gradient of a scalar. Is this field 'irrotational'?
  - Calculate the electric potential due to a uniformly charged disc of radius 'a', at a point on its axis but not at its centre. Calculate the intensity of the electric field at that point. Find the value of the intensity in the limit  $a \rightarrow \infty$ .  
(2+2+1)+(3+2+2)

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3. (a) Derive using Gauss' theorem, the electric field due to a uniformly charged, infinite plane sheet. Hence derive an expression for the capacitance of a parallel plate capacitor.
- (b) The charged solid sphere of radius  $R$  has charge density  $\rho = kr \sin \theta \cos \phi$ . Find the total charge and dipole moment for the configuration. (3+3)+(3+3)
4. (a) The magnetic field due to a circular coil of radius 'a', carrying a current 'I', at a point on its axis at a distance 'x' from the centre, is given by :  

$$B = \mu_0 I a^2 / [2 (a^2 + x^2)^{3/2}]$$
Hence find the expression for the magnetic field on the axis of a semi-infinite solenoid at its edge.
- (b) Show that the magnetic field does no work on a moving charge.
- (c) Consider two such wires, running parallel to each other with currents  $I_1$  and  $I_2$  flowing in opposite direction in them. Calculate the force per unit length on any of them. Find the direction of this force. (Assume the expression for the magnetic field for infinitely long straight wire)
- (d) Find the electrostatic energy of a uniformly charged sphere of radius  $R$  having charge density  $\rho$ . 4+2+3+3

### Group - B

5. (a) According to Maxwell, number of molecules in an ideal gas with speed lying between  $c$  and  $c+dc$  is given by :  $dn_c = 4\pi n (m/2\pi kT)^{3/2} c^2 \exp(-mc^2/2kT)dc$ , where 'm' is the molecular mass and 'n' is the number density of the molecules. Derive an expression for the mean speed for the molecules.
- (b) Define a dimensionless parameter :  $x = (mc^2/2kT)$ . Find the number of molecules for which the value of this parameter lies within a range  $x$  to  $x + dx$ .
- (c) Starting from the expression :  $P = 1/3 mnc^2$  for pressure of an ideal gas, where 'm' stands for molecular mass, 'n' for the number density and 'c' for the r.m.s. speed, find a relation between 'c' and the absolute temperature of the gas. Hence calculate 'c' for the oxygen molecules at  $27^\circ\text{C}$ . (Given  $R \approx 8.3 \times \text{J K}^{-1} \text{mole}^{-1}$ ) 3+3+(3+3)
6. (a) State the zeroth law of thermodynamics. Explain how it leads to the concept of temperature.
- (b) One mole of an ideal gas expands adiabatically from  $(P_1, V_1)$  to  $(P_2, V_2)$ . What is the change in the internal energy?
- (c) An ideal gas at absolute temperature 'T', doubles its volume in an isothermal process. Find out (i) the work done by the gas, (ii) the change in its internal energy and (iii) the heat absorbed by the gas. (2+2)+3+(2+2+1)
7. (a) Prove that :  $C_p - C_v = [(\partial U/\partial V)_T + P] (\partial V/\partial T)_p$  for any gas. Hence calculate  $(C_p - C_v)$  for an ideal gas.

- (b) Obtain the relation between the absolute temperature and the volume of an ideal gas, in an adiabatic process.
- (c) The volume of an ideal gas is doubled in an adiabatic expansion. Find the final temperature if the initial temperature is 300 K. What would be the final temperature, if the process were isobaric? (Given  $\gamma = 1.5$  for the gas.) (3+2)+4+(2+1)
8. (a) State the Kelvin-Planck version of the Second Law of Thermodynamics.
- (b) Calculate the total work done in a Carnot Cycle. Hence calculate the efficiency.
- (c) State Carnot's Theorem. Explain what you mean by the 'Thermodynamic scale of temperature'. 2+(4+2)+(2+2)
9. (a) Show that the entropy of one mole of an ideal gas is given by  $S(T, V) = C_V \ln T + R \ln V + S_0$ .
- (b) Initially a gas mixture is at temperature  $T_1$  and occupies a volume  $V_1$ . The gas is then compressed quasistatically and adiabatically to volume  $V_2$  and temperature  $T_2$ . Show that  $\left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^g$ , where 'g' is a constant. Find 'g'.
- (c) Establish the following  $TdS$  equation :
- $$TdS = C_p dT - \beta VT dP$$
- where  $\beta$ , the volume expansivity is defined as  $\beta = \left(\frac{\partial V}{\partial T}\right)_P$ . 4+4+4
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