2024

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

(a) A positive charge Q is to be divided into two positive charges q_1 and q_2. Show that, for a given separation, the force exerted by one charge on the other is greatest if $q_1 = q_2 = \frac{Q}{2}$.

(b) The electric field in a region is given by $\vec{E} = Kr^3\hat{r}$. Calculate the amount of charge contained within a spherical surface of radius 'a' centred at the origin.

(c) A square loop of side a lying in the yz plane and centred at the origin is subjected to an external magnetic field $\vec{B} = kz\hat{x}$. If the loop carries a constant current I, find the magnetic force on the loop.

(d) State Ampere's circuital law. Derive the differential form of it.

(e) What is Maxwell's velocity distribution law? Represent graphically the velocity distribution for two temperatures T_1 and T_2 $(T_1 > T_2)$.

(f) What is meant by extensive and intensive thermodynamic variables? Give one example of each.

(g) An electric current of 10 amp is maintained for 1s in a resistor of 25 ohm, while its temperature is kept constant at 27°C. Calculate the change in entropy of the resistor and the universe.

(h) Draw the T-S diagrams for (i) isobaric and (ii) isochoric processes with justification.

Group - A

2. (a) State Gauss's Law of electrostatics. Derive its differential form.

(b) Write down the expression for the electric field at a point due to a point charge placed at the origin. Show that the field is conservative.

(c) Suppose a charge Q is distributed within a sphere of radius R in such a way that the charge density $\rho(r)$ at a distance r from the centre of the sphere is

$$\rho(r) = \begin{cases} K(R-r), & \text{for } 0 < r < R, \\ 0, & \text{for } r \geq R. \end{cases}$$

(i) Determine K in terms of Q and R.

(ii) Calculate the electric field at any point inside the sphere.

(iii) Find the value of r for which the field is maximum.

(iv) What is the value of the maximum field? (2+1)+(1+2)+(2+2+1+1)

3. (a) Show that the electric potential at any arbitrary point $\vec{r}$ due to a dipole placed at $\vec{r}'$ with dipole moment $\vec{p}$ can be written as $\phi(r) = -\vec{p}\cdot\vec{\nabla}\phi_0$, where ϕ_0 is the potential at $\vec{r}$ due to a unit positive charge placed at $\vec{r}'$. Assume that the length of the dipole is very small compared to $|\vec{r}-\vec{r}'|$.

(b) If the plate separation for a parallel plate capacitor is 2.0×10^{-3} m, determine the area of the plate if the capacitance is exactly 1F.

(c) The electrostatic potential at any point is $V(x, y) = x^2 - y^2$. Calculate the electric field at $(1, 2)$.

(d) State Biot-Savart law and proceed to show that $\vec{\nabla}\times\vec{B} = \mu_0\vec{J}$ (symbols have their usual meaning). 3+2+2+(2+3)

4. (a) Using Biot-Savarts' law find the magnetic field at any point on the Z-axis due to a semi-infinite wire carrying a steady current I, placed along X-axis with the finite end at the origin.

(b) Show that the magnetic forces do no work on charge particles moving with constant velocities.

(c) A particle with charge q is projected along x-axis with speed v. This force on the particle in this situation is $qvB\left(-\frac{\hat{j}}{2}+\frac{\sqrt{3}}{2}\hat{k}\right)$. Find $\vec{B}$.

(d) Consider the magnetic field $\vec{B} = \exp\left(-y^2\right)\hat{i}$. Determine the current density responsible for this field. 4+2+3+3

Group - B

5. (a) Write down the postulates of Kinetic theory of an ideal gas.

(b) Maxwell's speed distribution law is given by $dN_c = 4\pi N\left(\frac{m}{2\pi kT}\right)^{3/2} c^2 e^{-mc^2/2kT}\, dc$

(i) Plot dN_c vs. c.

(ii) What is the value of area under the curve?

(iii) What do you mean by most probable speed? Calculate it.

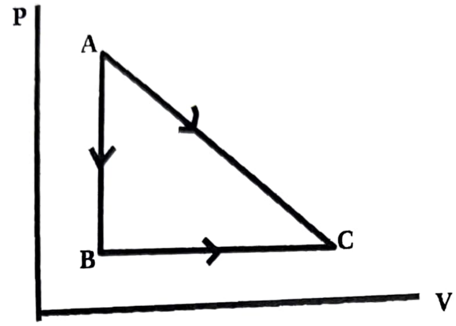
(c) Justify Avogadro's hypothesis from Kinetic theory of gases.

(d) Calculate the r.m.s. speed of hydrogen at NTP given that 1 litre of hydrogen weighs 0.08987 gm at NTP. 3+[1+1+(1+2)]+2+2

6. (a) What do you mean by thermodynamic equilibrium?

(b) State zeroth law of thermodynamics.

(c) A given quantity of gas is taken from the state A $\rightarrow$ C by two paths, A $\rightarrow$ C and A $\rightarrow$ B $\rightarrow$ C. During the process A $\rightarrow$ C the work done by the gas is 100J and the heat absorbed is 150J. If during the process A $\rightarrow$ B $\rightarrow$ C, the work done by the gas is 30J, what will be the heat absorbed?



(d) Find out the ratio of adiabatic elasticity and isothermal elasticity.

(e) Show that infinitesimal change in pressure is a quasistatic process is

$$dp = -\frac{E_T}{V}dV + \beta E_T dT,$$

where $\beta \rightarrow$ expansion coefficient

$E_T \rightarrow$ isothermal elasticity or reciprocal of isothermal compressibility. 2+1+3+3+3

7. (a) Define quasistatic process.

(b) Consider internal energy U is function of T and V. Show that

$$C_P = C_V + \left[\left(\frac{\partial U}{\partial V}\right)_T + P\right]V\beta,$$

where β is volume expansivity. Calculate this for ideal gas.

(c) Consider an ideal gas changes from initial state (P_1, V_1, T_1) to final state (P_2, V_2, T_2), characterized by the equation PV^n = const. Find work done for $n = 0$ and $n = 1$. Find changes in internal energy for both the cases.

(d) Show that adiabatic curve for an ideal gas is steeper than isothermal curve on a P-V diagram. 2+(3+1)+(3+1)+2

Please Turn Over

8. (a) State Kelvin-Plank and Clausius' statements of the 2nd law of thermodynamics.

(b) Explain the operation of a Carnot heat engine using *P-V* diagram and derive the expression of its efficiency.

(c) A Carnot's refrigerator takes heat from water at 0°C and discard it to a room at 27°C. Calculate the work done by the refrigerator to make 1 kg ice from 1 kg water at 0°C. What is the coefficient of performance of the machine? 3+(2+4)+(2+1)

9. (a) State Clausius inequality. Show that this theorem leads to a state function called entropy. Show that the entropy of an isolated system tends towards a maximum while it approaches equilibrium.

(b) Calculate the change in entropy for an isothermal expansion of ideal gas.

(c) A mass m of water at T_1 is isobarically and adiabatically mixed with an equal amount mass of water at T_2. Show that the change in entropy of the universe is always positive. (2+2+2)+3+3

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