2025

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) $\mathbf{E} = k(x\boldsymbol{j} - y\boldsymbol{i})$: can it be the expression for an electrostatic field? Give reasons.

(b) Show that, the electric field $\bar{E}$ at a point P on the surface of an equipotential is always perpendicular to the surface.

(c) What is the physical implication of the equation : $\nabla \cdot \mathbf{B} = \mathbf{0}$ and why?

(d) Obtain Charles's law, starting from the expression for pressure of an ideal gas : $P = 1/3\ mn\langle c^2 \rangle$.

(e) Starting from the same initial state, the volume of an ideal gas is doubled through (i) an isothermal and (ii) an adiabatic process. Which process will involve a greater amount of work? Explain using a P-V diagram.

(f) The ratio C_P/C_V of an ideal gas is 4/3. Calculate C_P and C_V separately.

(g) Why does an ideal gas cool down in an adiabatic expansion? Explain physically. How is the temperature maintained in an isothermal process?

(h) Define a 'reversible' process. What is the change in entropy in a reversible process?

Group - A

2. (a) State Gauss' theorem of electrostatics. Using Gauss' theorem find the electric field inside a uniformly charged solid sphere.

(b) Calculate the torque on an electrical dipole in a uniform electric field. When is the magnitude of this torque maximum and when is it minimum?

(c) Find the total charge on a circular ring with charge density $\lambda = \lambda_0 \cos\theta$ where θ, is measured w.r.t. the x-axis. (2+3)+(3+2)+2

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3. (a) Define capacitance. Find the electric field due to a uniformly charged, infinitely long cylinder at a point outside it. Hence, calculate the capacitance per unit length of a pair of infinite, coaxial cylinders with the inner one being charged and the outer one earthed.

(b) A charged particle is moving under the influence of a constant magnetic field along z-axis. If the initial position of the particle is $(a, 0, 0)$ and initial velocity is $(0, -u, 0)$, find the trajectory of the particle. (1+3+3)+5

4. (a) A square of side 'a' has equal charges q on three of its vertices. Find the electric field at the centre of the square.

(b) Write Biot-Savart's law. Using Biot-Savart's law obtain the expression for the magnetic field at the centre of a current carrying ring.

(c) Derive the expression for the magnetic field within an infinite, current carrying solenoid, using Ampere's circuital theorem. [Assume that the field outside the solenoid is zero.] 3+(2+4)+3

Group - B

5. (a) According to Maxwell's theory, the probability that the x-component of the velocity of a gas molecule lies between u to $u + du$, is given by : $f(u)du = A\ \exp(-mu^2/2kT)du$.

(i) Plot $f(u)$ against u,

(ii) Calculate $\langle u^2 \rangle$, the mean square value of u.

(b) If the probability that the speed of a gas molecule moving in 3-dimension, lies between c to $c + dc$, is : $f(c)\ dc = Nc^2\ \exp(-mc^2/2kT)dc$, then calculate the mean square speed $\langle c^2 \rangle$ in 3-dimension.

(c) Starting from the expression for the pressure of an ideal gas : $P = 1/3\ mn\langle c^2 \rangle$, obtain the expression for $\langle c^2 \rangle$ as a function of temperature. $\left[\text{Given } \Gamma(n) = \int_0^\infty x^{n-1} e^{-x} dx, n > 0 \text{ and } \Gamma(n+1) = n\Gamma(n)\right]$

(2+4)+4+2

6. (a) What do you mean by an 'exact differential'? Which of the differential quantities appearing in the first law of Thermodynamics is/are exact and which one(s) is/are inexact? Show that for an ideal gas, dU/T is an exact differential.

(b) If $\gamma_P = 1/V(\partial V/\partial T)_P$ and $\gamma_V = 1/P(\partial P/\partial T)_V$, then show that : $\gamma_P \times K_T = P\gamma_V$, where K_T stands for the isothermal Bulk modulus. Hence, relate γ_P with γ_V for an ideal gas. (2+3+2)+(3+2)

7. (a) Obtain the relation between the pressure and the volume of an ideal gas in an adiabatic process. Calculate the work done in such a process by direct integration and show that it is proportional to the change in temperature.

(b) Four litres of an ideal gas was compressed at a pressure of 2.7×10^5 N/m^2. The gas expands adiabatically, so that the pressure reduces to 0.8×10^5 N/m^2. Find out the final volume and the work done in the process. [Given : $\gamma = 1.5$] (4+4)+(2+2)

8. (a) Write down the expressions for the changes in entropy of the working gas in the four steps of the Carnot's cycle. Hence, show that the total change of entropy of the gas in the full cycle is zero.

(b) Define 'efficiency' of a heat engine. Represent a Carnot's cycle on a T-S diagram and hence calculate its efficiency. (3+3)+(1+2+3)

9. (a) A gas is contained within a cylinder with a movable piston at one end. State for each of the following conditions, whether work done by the system is $dW = PdV$ or not and whether the process is reversible, quasistatic or irreversible.

(i) There is no external pressure on the piston and there is no friction between the cylinder and the piston.

(ii) There is no external pressure and the friction is small.

(iii) The friction is adjusted to allow the gas to expand slowly.

(iv) No friction, but external pressure is adjusted to allow the gas to expand slowly.

Justify your answers.

(b) Discuss briefly the principle of a Carnot refrigerator. Derive a relationship between the efficiency of a Carnot engine and the coefficient of performance of the same engine working as a refrigerator.

(c) State Clausius' theorem. Show that, the entropy always increases in an irreversible process. 4+(2+2)+(2+2)
