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 $\vec{E}$ 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

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)

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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 $dN_c=4\pi N\left(\frac{m}{2\pi kT}\right)^{3/2}c^2e^{-mc^2/2kT}dc$

(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.

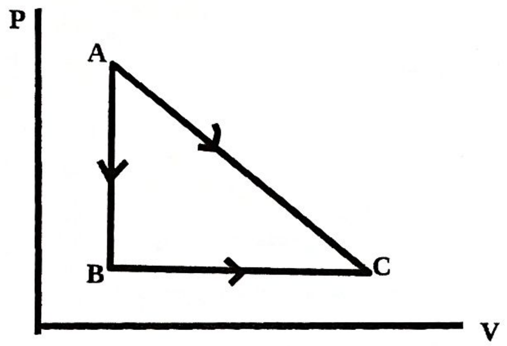
(c) Justify Avogadro's hypothesis from Kinetic theory of gases.

(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

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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2023

PHYSICS — HONOURS

Paper : CC-6

(Thermal Physics)

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.

Answer ***question no.*** **1** and ***any four*** questions from the rest.

1. Answer ***any five*** questions : 2×5

(a) An ideal gas expands (i) isothermally, and (ii) adiabatically to twice its initial volume from the same initial state. In which case does the gas do more work? Explain with the help of indicator diagram.

(b) Determine the efficiency of a Carnot engine with the help of T-S diagram.

(c) Under what condition equilibrium of a system is determined by the minimum of Gibbs free energy?

(d) One cylinder contains Helium gas and another contains Krypton gas at the same temperature. Draw their relative velocity distributions on the same diagram.

(e) Considering $\frac{dV}{V}$ an exact differential show that $-\left(\frac{\partial \kappa_T}{\partial T}\right)_p = \left(\frac{\partial \beta}{\partial p}\right)_T$, where κ_T and β are isothermal compressibility and coefficient of volume expansion respectively.

(f) Calculate the ratio of rms velocities of Hydrogen and Oxygen molecules at 0°C.

(g) What fraction of gas molecules will have free paths lying within λ and 2λ, where λ is the mean free path?

2. (a) Write the conditions for a thermodynamic process to be reversible.

(b) The equation of state of an ideal elastic substance is given by

$$F = KT\left(\frac{L}{L_0} - \frac{L_0^2}{L}\right),$$

where F is the tension, K is a constant, T is temperature, L_0 is the value of L (length) at zero tension. Find an expression for the work required to change L from L_0 to $\frac{L_0}{3}$ quasistatically and isothermally.

(c) Assuming air to be an ideal gas find an expression for variation of temperature of atmosphere with altitude. 2+4+4

3. (a) Prove that no heat engine operating between two temperatures ($T_1 > T_2$) can be more efficient than a Carnot engine operating between the same two temperatures.

(b) Using Clausius inequality show that in any thermodynamic process entropy of the universe can never decrease.

(c) Two identical bodies of constant heat capacity at temperatures T_1 and T_2, respectively, are used as heat reservoirs for a heat engine. If the bodies remain at constant pressure and undergo no change of phase, show that the maximum amount of work obtainable is $W = C_P\left(T_1 + T_2 - 2\sqrt{T_1T_2}\right)$.

4+3+3

4. (a) Prove that $\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$. Calculate $\left(\frac{\partial U}{\partial V}\right)_T$ for a van der Waals' gas.

(b) Prove that $C_P - C_V = T\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial V}{\partial T}\right)_P$. Show that for water at 4°C, $C_P = C_V$.

(c) Derive the expression for the change in temperature of a paramagnetic substance undergoing cooling process by adiabatic demagnetization. (2+2)+(2+1)+3

5. (a) Prove the relations, (i) $TdS = C_V dT + T\left(\frac{\partial P}{\partial T}\right)_V dV$, (ii) $U = \left[\frac{\partial\left(F/T\right)}{\partial\left(1/T\right)}\right]_V$.

(b) What are the characteristics of a first-order phase transition? Derive Clausius-Clapeyron's equation for first-order phase transition.

(c) The rate of increase of vapour pressure of steam at 100°C is 3.68×10^4 dyne.cm^{-2}.°C^{-1}. If one gram of steam occupies a volume of 1674 cc, what is the specific latent heat of vaporization?

(2+2)+(1+3)+2

6. (a) The probability of a gas molecule having velocity lying between u and $u + du$ in a given direction is,

$$f(u)du = Ae^{-bu^2}du, \text{ where } A = \sqrt{\frac{m}{2\pi kT}} \text{ and } b = \frac{m}{2kT}.$$

Using the above derive Maxwell's speed distribution formula.

(b) Calculate average value of u^2.

(c) Which physical quantity is transported in case of viscosity of a gas? Explain how the coefficient of viscosity of an ideal gas depends on temperature. 4+3+(1+2)

7. (a) Write the van der Waals' equation of state for n mole gas occupying volume V. Plot $P - V$ diagram of van der Waals' gas at temperatures $T_1 < T_C$ and $T_2 > T_C$.

(b) Determine critical constants of a real gas obeying van der Waals' equation of state.

(c) Write the Fourier equation for rectilinear flow of heat along a metallic bar. Hence write the steady state equation and solve it when there is no radiation loss. (1+1)+4+(1+1+2)

2022

PHYSICS — HONOURS

Paper : CC-6

(Thermal Physics)

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.

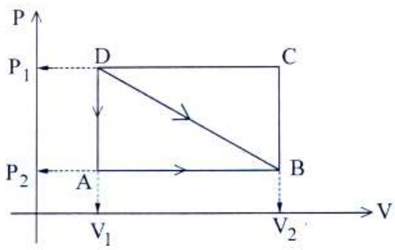
Answer ***question no.*** **1** and ***any four*** questions from the rest.

1. Answer ***any five*** questions : 2×5

(a) Distinguish between extensive and intensive variables.

(b) The mean free path of a gas is 5.0 cm. Among 100 free paths of those molecules, how many are between 4.9 cm. and 5.1 cm?

(c) Using the indicator diagram shown below, show that the work done is not a state function.



(d) Explain the concept of temperature on the basis of Zeroth law of thermodynamics.

(e) What is the reason for considering Quasi-static process in the context of thermodynamics?

(f) Show that Clausius's theorem leads to the concept of entropy as a state function.

(g) State Gibbs phase rule. Explain the rule with an example.

2. (a) Write down the assumptions used in the derivation of Maxwell's speed distribution law.

(b) According to Maxwell's speed distribution law, the number of molecules per unit volume with speed between v and v + dv is given by $n(v)dv = na^3 e^{-b\left(v_x^2+v_y^2+v_z^2\right)} dv_x dv_y dv_z$ where symbols have their usual meaning. Calculate the constant 'a' in terms of the constant 'b'.

(c) Show that Maxwell's speed distribution law is normalized.

(d) Calculate the average of x-component of velocity of a Maxwellian gas. 2+3+3+2

3. (a) Equation of state of a non-ideal gas is given by $P(V-b) = RT\exp\left(-\frac{a}{RVT}\right)$ [a, b are constants].

Show that the above equation reduces to the ideal gas equation (i) as $V \to \alpha$ and (ii) if 'a' and 'b' are small.

(b) What is Brownian motion?

(c) Obtain the expression for the mean free path of a molecule of an ideal gas as a function of its molecular diameter. (2+2)+2+4

4. (a) What do you mean by internal energy of a thermodynamic system? What are the limitations of the first law of thermodynamics?

(b) What is adiabatic lapse rate? Find an expression for it.

(c) A certain gas has equation of state $P = \frac{\alpha N^2 T}{V^2}$, where P is the pressure, N is the number of moles, V is the volume, T is the temperature and α is a constant. One mole of the gas undergoes expansion from volume V to $2V$ at a constant temperature T. If the change in energy in the isothermal expansion is $\beta\frac{\alpha T}{V}$, find the value of β. (1+2)+(1+3)+3

5. (a) "The perpetual motion machine of 2nd kind is impossible to construct." — Justify this statement.

(b) Starting from 2nd law of thermodynamics show that for a mechanically isolated system at constant temperature, the Helmholtz free energy never increases.

(c) Derive Clausius-Clapeyron equation from TdS equation.

(d) Write down the characteristics of second-order phase transition with a suitable example. 2+3+3+2

6. (a) What is entropy? State its properties.

(b) Entropy of an ideal gas with N number of molecules in a volume V is given by

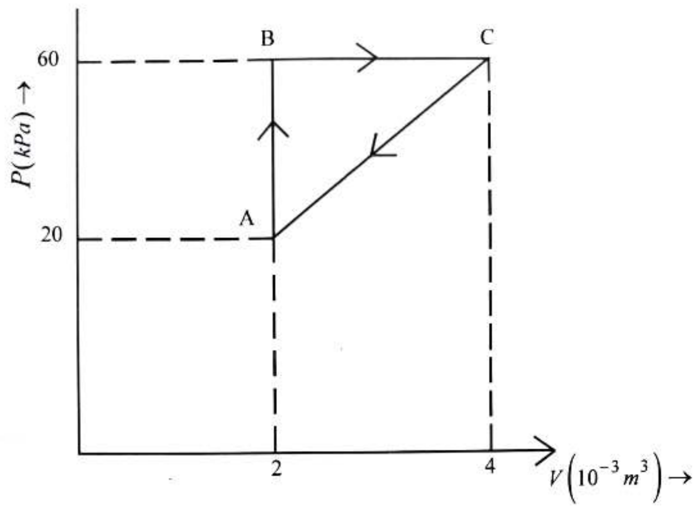
$$S = Nk_B \ln\left[V\left(\frac{E}{N}\right)^{3/2}\left(\frac{4\pi m}{3h^2}\right)^{3/2}\right] + \frac{3Nk_B}{2},$$

where m is the mass of one molecule, E is the energy, h is Planck's constant and k_B is the Boltzmann constant.

Show that this expression for entropy does not satisfy extensive property of entropy and leads to Gibbs paradox.

(c) How is this paradox removed?

(d)



In the cycle ABC, heat is added to a thermodynamic system in the process AB and BC are 400 J and 100 J respectively. Heat rejected during the process CA is 460 J. Find its efficiency.

(1+2)+3+2+2

7. (a) Distinguish between free expansion and Joule-Thomson expansion.

(b) What is Joule-Thomson effect? Show that Joule-Thomson coefficient of a real gas is given by

$$\mu = \left(\frac{\partial T}{\partial p}\right)_H = \frac{1}{C_P}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right],$$

where symbols have their usual meaning.

(c) Calculate the rate of heat flow through a composite slab of widths 2 cm and 0.8 cm with thermal conductivities of 0.043 $Wm^{-1}K^{-1}$ and 0.11 $Wm^{-1}K^{-1}$ respectively. The cross-sectional area of the composite slab is 26 cm^2 and the temperature difference between the two faces of the slab is 20°C.

2+(2+3)+3

2021

PHYSICS — HONOURS

Paper : CC-6

(Thermal Physics)

Full Marks : 50

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Candidates are required to give their answers in their own words as far as practicable.

Answer ***question no.*** **1** and ***any four*** questions from the rest.

1. Answer ***any five*** questions : 2×5

(a) Why is it necessary to introduce the concept of quasi-static process in thermodynamics?

(b) Explain why the specific heat of gas at constant pressure is greater than that at constant volume.

(c) Explain that the perpetual motion machine is not possible according to thermodynamics.

(d) Prove that the adiabatic elasticity of a gas is γ times the isothermal elasticity.

(e) Prove the relation $\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$.

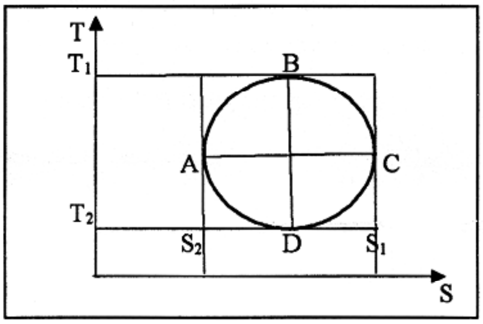
(f) At what temperature will root mean square speed of oxygen molecule be double its value at N.T.P., while pressure remaining constant?

(g) Draw the pressure-temperature diagram of H_2O indicating the phases, boundaries and the tripple point.

2. (a) A Carnot engine operates between temperatures T_1 and T_2 with a gas as working substance whose equation of state is given by $P(V\text{-}b) = RT$. Work out the expression for the heat absorbed and the work done in each part of the cycle and show that the efficiency of the cycle is $\left(1-\frac{T_2}{T_1}\right)$.

(b) Give the Kelvin-Planck statement and Clausius statement of the second law of thermodynamics. Establish the equivalence of the above two statements.

(c) Show that the efficiency of the cycle ABCDA is given by $\eta = \dfrac{2\pi(T_1 - T_2)}{\pi(T_1 - T_2) + 4(T_1 + T_2)}$.



Given $AC = BD$. 3+3+4

3. (a) Show that the probability of a gas molecule traversing a distance x, without collision, is $e^{-x/\lambda}$, where λ is the mean free path of the gas molecule.

(b) Find out the expression for the most probable speed c_m and the number of molecules $n(c_m)$ having speed c_m.

Plot $n(c)$ vs. c for two different temperatures T and $4T$ on the same graph. 4+(2+2+2)

4. (a) Why isotropic distribution of particles is needed to derive the Maxwell's velocity distribution?

(b) Why Brownian motion is observed below a definite size of particles only?

(c) Find the number of degrees of freedom for (i) H_2O and (ii) CO_2 molecule, assuming linear configuration of the molecules.

(d) State law of equipartition of energy. Hence establish the relation between degrees of freedom and the ratio of two specific heats of a gas. 2+2+3+(1+2)

5. (a) Show that for a real van der Waals' gas $C_P - C_V = R\left\{1 + \dfrac{2a}{RTV^3}(V-b)^2\right\}$.

(b) Show that for an isentropic transformation $\left(\dfrac{\partial V}{\partial T}\right)_S = -\dfrac{C_V}{C_P - C_V}\left(\dfrac{\partial V}{\partial T}\right)_P$.

(c) Assuming the relation $Tds = C_P\,dT - T\left(\dfrac{\partial V}{\partial T}\right)_P dP$, show that for isothermal compression $\Delta Q = -TV\alpha(p_2 - p_1)$, where ΔQ is the heat transfer when the fluid is compressed isothermally, from a pressure p_1 to p_2, α = coefficient of volume expansion. 4+3+3

6. (a) For all living systems, ageing process cannot be stopped. —Which thermodynamics law supports this statement? Explain your answer.

(b) Using the Clausius theorem, show that for any process $S_f - S_i \geq \int_i^f \frac{dQ}{T}$ where the symbols have their usual meanings.

(c) Apply the suitable transformation technique to define Enthalpy in mathematical form.

(d) Using the Clausius-Clapeyron equation, investigate the possibility of latent heat to be zero.

(1+2)+3+2+2

7. (a) Deduce the expression for amount of cooling of a paramagnetic substance by adiabatic demagnetization.

(b) The specific volume of water at 0°C increases by 9.1% on freezing and the latent heat of fusion of ice is 80 cal/gm at atomospheric pressure. Calculate the pressure needed to lower the melting point of ice by 1°C.

(c) Show that the enthalpy $H = \left[\frac{\partial\left(G/T\right)}{\partial\left(1/T\right)}\right]_V$, where G is the Gibbs energy.

3+4+3

2020

PHYSICS — HONOURS

Paper : CC-6

(Thermal Physics)

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.

Symbols have the usual meanings everywhere.

Answer ***question no.*** **1** and ***any four*** questions from the rest.

1. Answer ***any five*** questions : 2×5

(a) Under what conditions is the equilibrium of a system determined by the minimum of the Helmholtz free energy?

(b) Calculate the RMS velocity of Argon gas molecule at 200K (molecular weight of Argon = 40).

(c) Find the change in entropy in an adiabatic process when the temperature of an ideal gas is increased from T_1 to T_2.

(d) Define enthalpy and cite an example of an iso-enthalpic process.

(e) What is the order of the phase transition in ferromagnetic to paramagnetic transition of a metal and why?

(f) Find the ratio of the coefficient of viscosity of two gas molecules A and B if the diameter of A is twice that of B while the molecular weight is thrice.

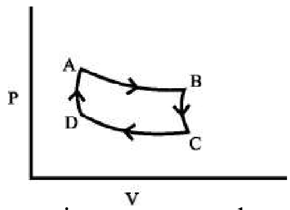
(g) A certain system has Gibbs free energy given by

$$G(p,T) = RT \ln\left[\frac{ap}{(RT)^{5/2}}\right]$$

where a and R are constants. Find out C_P, the specific heat at constant pressure.

2. (a) Prove that for an ideal gas, in an adiabatic process, PV^{γ} is constant. Is this relation valid in an irreversible process?

(b) A Carnot engine is shown below :



State the nature of the thermodynamic processes along AB, BC, CD and DA.

Where is work put in and where is it extracted?

If the above is a steam engine with $T_{in} = 500$ K operating at room temperature, calculate the efficiency of the engine. (3+1)+(2+2+2)

3. (a) Show that if average velocity is taken as the unit of speed of gas molecules, the probability of speed between v and $v + dv$ is independent of temperature.

(b) Find the fraction of gas molecules whose velocities are greater than the r.m.s. value by at least 2%.

(c) The speed of longitudinal waves of small amplitude in an ideal gas is $v = \sqrt{\dfrac{\partial p}{\partial \rho}}$

Show that for an adiabatic process $v = \sqrt{\dfrac{\gamma RT}{M}}$ where ρ is the density and M is the mass of the gas molecule.

(d) Justify that for a very dilute van der Waals gas, $C_P - C_V = R$. 3+3+2+2

4. (a) Calculate the probability that the speed of an O_2 molecule will lie between 200 and 201 ms^{-1} at 300 K (mass of oxygen molecule is 32 units).

(b) Using Maxwell's distribution for speed of molecules in a gas, establish that $v_{rms} > \bar{v} > v_p$, where $\bar{v}$ and v_p are the average and most probable speeds respectively. Why do the velocities increase with temperature? Is the distribution symmetric about v_p? 3+(4+2+1)

5. (a) For the equation of state

$$V = \frac{RT}{p} - \frac{C}{T^3}$$

show that

$$\left(\frac{\partial C_P}{\partial p}\right)_p = \frac{12C}{T^4}$$

(b) The Helmholtz free energy function A can be obtained from the internal energy U by a Legendre transformation. Show that it is a function of T and V.

(c) Liquid helium has a normal boiling point = 4.2 K. However, at a pressure of 1 mm of mercury, it boils at 1.2 K. Estimate the average latent heat of vaporization of helium in this temperature range (Take the volume in the liquid state $\ll$ volume in gaseous phase). 3+3+4

6. (a) Establish the relation for the rate of change of temperature with pressure in a Joule-Thomson process :

$$\mu_{JT} = \left(\frac{\partial T}{\partial P}\right)_H = \frac{V}{C_P}(\alpha T - 1)$$

What is the value of μ_{JT} for an ideal gas? What do you mean by the inversion temperature?

(b) Indicate the coexistence curves and the critical point in a solid-liquid-gas phase diagram.

(c) Show schematically the variation of the order parameter with temperature in a (i) first-order and (ii) a continuous phase transition. (4+1+1)+2+2

7. (a) Using the fact that dS is an exact differential, derive the following relation :

$$\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$$

Hence show that for a van der Waals gas, the internal energy is not a function of temperature alone.

(b) Establish the relation

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$$

(c) The pressure p from an isotropic radiation field is 1/3 of its energy density :

$$p = u(T)/3 = U(T)/3V$$

Show that u obeys $u = \frac{1}{3}T\frac{du}{dT} - \frac{1}{3}u$

(You have to use the result of (b)). 4+2+4

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