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.

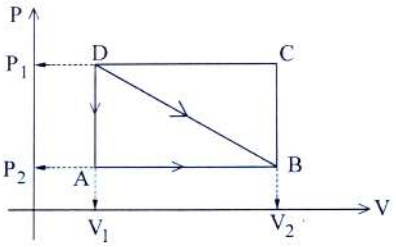
Answer ***question no.* 1** and ***any four*** questions from the rest.

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

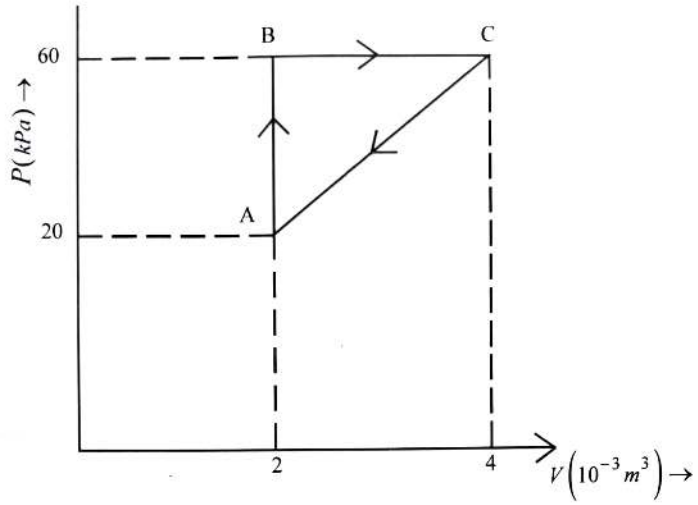
$$S=Nk_B \ln\left[V\left(\frac{E}{N}\right)^{3/2}\left(\frac{4\pi m}{3h^2}\right)^{3/2}\right]+\frac{3Nk_B}{2},$$

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