

2021
PHYSICS
[HONOURS]
Paper : IV

Full Marks : 75

Time : 4 Hours

*The figures in the right-hand margin indicate marks.**Candidates are required to give their answers in their own words as far as practicable.**Specify all symbols in your answer.*

1. Answer any **five** questions: 1×5=5
- a) State the Zeroth law of thermodynamics.
 - b) What is a second order phase transition?
 - c) Sketch the pressure versus volume graphs at constant temperatures of a vander Waals gas.
 - d) State the Kirchhoff's law of thermal radiation.
 - e) Define coefficient of viscosity of gas.
 - f) State Wiedemann-Franz's law.
 - g) State Maxwell's distribution law of velocities in a gas.

2. Answer any **six** questions: 2×6=12
- a) Calculate the work done in isothermal expansion of an ideal gas.
 - b) What is the physical significance of entropy?
 - c) Explain :
 - i) Degrees of freedom
 - ii) Equipartition energy
 - d) What is Joule-Thomson effect?
 - e) State Planck's law of blackbody radiation. What is radiation pressure?
 - f) Explain dependence of Maxwell's velocity distribution on temperature.
 - g) Find the diameter of a molecule of benzene if its mean free path is $2.2 \times 10^{-8} \text{m}$ and the number of benzene molecules per unit vol^{m} is 2.79×10^{25} molecules/ m^3 .
 - h) Using vander Waals equation of state, obtain the reduced equation of state.
 - i) What is Boyle temperature? How is it related to critical temperature?
 - j) How does the viscosity of a gas vary with pressure?

3. Answer any **three** questions: $6 \times 3 = 18$

- a) Draw the P-V diagram of a Carnot's cycle and explain its different steps. Calculate the efficiency of a Carnot's engine. $3+3$

b) Show that
$$\frac{Tds = C_v dT + T \left(\frac{\partial P}{\partial T} \right)_v dV}{Tds = C_p dT - T \left(\frac{\partial P}{\partial T} \right)_v dP}$$

Explain Nernst heat theorem. $2+2+2$

- c) State and derive Stefan-Boltzman law of radiation. Draw the curve showing the energy distribution in the spectrum of blackbody radiation. $1+4+1$

- d) Calculate the most probable velocity from Maxwell's velocity distribution. What is the ratio of mean velocity, root mean square velocity and most probable velocity? What is mean free path? $3+2+1$

- e) What are the critical constants of a gas? Deduce law of corresponding state. What is diffusion in gaseous system? $2+3+1$

4. Answer any **four** questions: $10 \times 4 = 40$

- a) Show 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 an isentropic transformation
$$\left(\frac{\partial V}{\partial T} \right)_s = \frac{C_v}{C_p - C_v} \left(\frac{\partial V}{\partial T} \right)_p$$
.

Write down the Kelvin-Planck and Clausius statements in context of the second law of thermodynamics. Calculate the temperature of the Sun from the following data: Radius of the Sun = $7 \times 10^8 \text{m}$, Distance of the Sun from the Earth = $1.5 \times 10^{11} \text{m}$, Solar constant = $1.36 \times 10^3 \text{J/m}^2 \text{s}$, Stefan's constant = $5.67 \times 10^{-8} \text{W/m}^2 \text{K}^4$.

$2+3+2+3$

- b) Discuss thermodynamically the equilibrium between a liquid and its vapour and hence deduce

Clapeyron's equation
$$\left(\frac{\partial P}{\partial T} \right)_v = \frac{L}{T(V_2 - V_1)}$$

(where the symbols have usual significance)

Show that in case of a throttling expansion Joule-Thomson coefficient can be expressed as

$$\mu = \frac{1}{C_p} \left[T \left(\frac{\partial V}{\partial T} \right)_p - V \right]$$
 State Wien's Distribution

law. $5+3+2$

c) Derive Cribbs-Helmholtz equation from Cribbs free energy equation. What is virial coefficient? Mention their significance in explaining the nature of the gas. Explain the principle of cooling of a system by adiabatic demagnetisation.

4+1+1+4

d) Show using kinetic theory of gases, that the pressure exerted by an ideal gas on the walls of its container is $P = \frac{1}{3}mn\bar{c}^2$ where m is the mass, n is the number density and \bar{c}^2 is the mean squared velocity of the gas molecules. What is Brownian motion? How do you distinguish between reversible and irreversible process.

6+2+2

e) Set up Fourier's equation for thermal conduction of a solid rod neglecting radiation loss. Solve this equation when one end is periodically heated and cooled in a simple harmonic manner in time. Distinguish between thermal conductivity and thermometric conductivity.

A refrigerator is working between the temperatures 7°C and 27°C. Calculate the maximum amount of heat that can be removed

per hour if energy is supplied to the refrigerator at the rate of 250 Watts.

2+3+2+3

f) Two identical bodies of constant heat capacity at temperature T_1 and T_2 are used as reservoir for a heat engine. If the bodies remain at constant pressure and undergo no change of phase, show that the amount of work obtainable is $W = C_v(T_1 + T_2 - 2T_f)$ where T_f is the final temperature. Show that for maximum W , $T_f = \sqrt{T_1 T_2}$.

Show how the second law of Thermodynamics enables us to define a scale of temperature independent of the properties of any working substance.

Explain Clausius inequality. 3+4+3
