2017

PHYSICS

(Major)

Paper : 2.2

(Heat and Thermodynamics)

Full Marks : 60

Time : 3 hours

The figures in the margin indicate full marks for the questions

Symbols have their usual meanings

1. Answer the following questions : 1×7=7

(a) What is the magnitude of γ (the ratio of two specific heat) for a diatomic molecule?

(b) State the law of corresponding state of van der Waals' gas.

(c) Write down the relation between pressure and energy density of diffuse radiation.

(d) Under what condition will the efficiency of Carnot engine be 100%? Is it possible?

(e) Show that the energy of Planck's oscillator

$$\frac{h\nu}{e^{\frac{h\nu}{kT}}-1}$$

reduces to equipartition law of energy kT at high temperature.

(f) What is the magnitude of specific heat of water in SI system?

(g) A volume of a gas expands isothermally to four times its initial volume. Calculate the change of entropy in terms of gas constant.

2. Answer any *four* questions : 2×4=8

(a) Starting from the expression of pressure exerted by perfect gas, deduce Clapeyron's equation $p = nkT$.

(b) Using Maxwell's velocity distribution law, deduce an expression for most probable velocity of gas molecules of a perfect gas.

(c) Calculate the amount of work done during adiabatic expansion of a gas.

(d) If an spherical enclosure full of radiation is allowed to expand adiabatically, show that the radiation behave like a gas having $\gamma = \frac{4}{3}$.

(e) Using van der Waals' equation, show that at critical point, the volume of a gas V_c is equal to three times of van der Waals' constant b, i.e., $V_c = 3b$.

3. Answer any *three* questions : 5×3=15

(a) State and deduce the Kirchhoff's law regarding blackbody radiation.

(b) Show that the Joule-Thomson coefficient μ for an ideal gas is zero and for van der Waals' gas

$$\mu = \frac{1}{C_p}\left[\frac{2a}{RT} - b\right]$$

(c) Establish the relation $TV^{\gamma-1}$ = const., for adiabatic expansion of a perfect gas.

(d) The mean KE of a molecule of hydrogen gas at 0 °C is $5 \cdot 62 \times 10^{-21}$ J and molar gas constant $R = 8 \cdot 31$ JK^{-1}. Calculate Avogadro's number and Boltzmann constant k.

(e) Calculate the increase in entropy, when 1 gram ice at – 10 °C is converted into steam at 100 °C. Given specific heat of ice is 0·5 cal/gram/°C, latent heat of ice is 80 cal/gram and latent heat of steam is 540 cal/gram.

4. Answer any *three* of the following : 10×3=30

(a) State Stefan's law of blackbody radiation. Obtain this law from Planck's law of radiation . Given that

$$\int_0^\infty \frac{x^3}{e^x - 1} dx = \frac{\pi^4}{15}$$

(b) Establish the following relation :

(i) $C_p - C_v = R\left(1 + \frac{2a}{VRT}\right)$ for van der Waals' gas

(ii) $C_p - C_v = -TE\alpha^2 V$

(c) Using kinetic theory of gases, show that the number of molecules in the energy range E and $E + dE$ is given by

$$dN_E = 2N\left(\frac{E}{\pi}\right)^{\frac{1}{2}} (kT)^{\frac{3}{2}} e^{-E/kT} dE$$

(d) Discuss the Einstein's theory of translational Brownian motion and derive an expression for average displacement of a particle under Brownian motion.

(e) Deduce Fourier equation for heat conduction in a rectangular bar, when radiation loss is taken into account and hence find a solution of this equation. What is thermometric conductivity?

(f) Define Kelvin absolute scale of temperature. Show that this scale agree with that of perfect gas scale. Negative temperature is not possible on this scale. Discuss.

★★★