2019

(October)

PHYSICS

(Elective/Honours)

[PHY-03(T)]

(Thermal Physics, Waves)

Marks : 56

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer Question No. **1** which is compulsory and *any* **four** from the rest

1. Answer any *four* of the following :

(a) A Carnot's engine takes 800 kilo-calories of heat from the reservoir at 527 °C and gives some heat to the sink at 27 °C. What is the efficiency? How much work in joules did it perform? 3

(b) Calculate the change in entropy when a body of mass 5 gm is heated from 100 K to 300 K. Given specific heat of the body to be $0{\cdot}1\,\text{cal gm}^{-1}\,\text{deg}^{-1}$. 3

(c) A mass of 1 kg is suspended from a spring of stiffness constant $25\ \text{Nm}^{-1}$. If the undamped frequency is $2\sqrt{3}$ times the damped frequency, calculate the damping factor. 3

(d) If the uncertainty in the location of a particle is equal to its de Broglie wavelength, then show that the uncertainty in the velocity is equal to its velocity. 3

(e) A blockbody at 1500 K emits the maximum energy at wavelength 2000 nm. What is the temperature of the sun, if it emits the maximum energy at wavelength 550 nm? 3

2. (a) Give reasons that led van der Waals to modify the gas equation of state. 2

(b) Deduce the van der Waals gas equation

$$\left(P+\frac{a}{V^2}\right)(V-b)=RT$$

What are the dimensions of a and b? 4+1=5

(c) What is meant by mean free path of the molecules of a gas? Show that the mean free path is proportional to the pressure. 1+3=4

3. (a) Discuss Carnot's reversible heat engine and obtain an expression for its efficiency. Plot a supporting P–V diagram. 2+4+1=7

(Continued)

(b) What is meant by entropy of a substance? Derive an expression for the entropy of one mole of a perfect gas in terms of pressure and temperature. 1+3=4

4. (a) What is temperature of inversion? Show that the temperature of inversion is $t_i=\frac{2a}{bR}$, where a and b are van der Waals constants and R the universal gas constant. 1+2=3

(b) What is Stefan's law? Give its thermodynamical deduction. 1+4=5

(c) What is phase space? State the difference between microcanonical and canonical ensembles. 1+2=3

5. (a) What are Lissajous figures? Find the Lissajous figures formed by the superposition of two simple harmonic vibrations at right angles when their time periods are in the ratio of 1 : 2 and there is a phase difference of 0 or $\frac{\pi}{2}$. 1+3=4

(b) Write down the differential equation of a damped harmonic oscillator. Show that in case of a damped harmonic oscillator, the rate of loss of energy is equal to the rate of doing work against the resistive force. 1+3=4

(c) Define quality factor. Show that for a large quality factor, damping has little or no effect on the frequency. 1+2=3

(Turn Over)

6. (a) What are plane waves and spherical waves? Show that the amplitude of a spherical wave varies inversely with distance. 2+2=4

(b) What are transverse and longitudinal waves? Derive an expression for the displacement of a progressive wave of wavelength λ and amplitude A, moving with a velocity v along the positive x-direction. 2+3=5

(c) Define group velocity and phase velocity. 2

7. (a) Obtain an expression for the energy of a transversely vibrating string. Hence derive the expression for the rate of flow of energy along the stretched string. 3+2=5

(b) Obtain the Fourier series for the function $f(x) = x^2$ defined in the interval $-\pi \le x \le \pi$. 4

(c) State the de Broglie hypothesis of matter waves. 2

8. (a) State Heisenberg's uncertainty principle. Using this principle, explain the non-existence of electrons in the atomic nucleus. 1+4=5

(b) What do you understand by the wave-function Ψ of a moving particle? Give its physical significance. 1+2=3

(c) Derive the one-dimensional time-dependent Schrödinger equation. 3

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