2017

(October)

PHYSICS

(Elective/Honours)

(Thermal Physics, Waves)

[PHY–03 (T)]

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. *(a)* The efficiency of a Carnot engine is $\frac{1}{6}$. On reducing the temperature of the sink by 65 °C the efficiency becomes $\frac{1}{3}$. Find the temperature between which the engine initially work. 3

(b) A blackbody at 1227 °C emits maximum energy of wavelength 2000 nm. If the sun emits maximum energy of wavelength 550 nm, what is the temperature of the sun? 3

(c) A string of length 0·4 m and mass 10^{-2} kg is tightly fixed at its ends. Identical wave pulses are produced at one end at equal interval of time Δt. Find the minimum value of Δt for constructive interference between successive pulses if the tension on the string is 1·6 N. 3

(d) The de Broglie wavelength of a non-relativistic electrons is 2·0 Å. What is its energy? 3

2. (a) What are transport phenomena? 1

(b) Derive an expression for the viscosity η of a gas in terms of mean free path of its molecules. 5

(c) Discuss the effect of temperature and pressure on the coefficient of viscosity of a gas. 1½+1½=3

(d) Calculate the mean free path of a gas molecule. Given that the molecular diameter is 2×10^{-8} cm and the number of molecules per cc is 3×10^{19}. 2

3. (a) What is entropy? 1

(b) Show that for an irreversible process the entropy increases. 4

(c) Explain thermodynamic scale of temperature. 6

4. (a) Define Boyle temperature and inversion temperature. 1+1=2

(b) Explain regenerative cooling for liquefaction of gases. 6

(c) Show that the volume of a phase cell in quantum statistics cannot be less than h^3, where h is Planck's constant. 3

5. (a) State Planck's postulates on quantum theory of radiation. 2

(b) Derive Planck's radiation law. 7

(c) Explain the distribution of energy of a blackbody radiation at two different temperatures by drawing the graph. 2

6. (a) Define simple harmonic motion. Set up the differential equation of motion of a simple harmonic oscillator and solve the equation. 1+1+2=4

(b) What are damped and forced oscillations? Obtain an expression for the energy of a damped SHM. 1+1+2=4

(c) Distinguish between ansient' and 'steady state' oscillations. Define 'sharpness of resonance' and 'quality factor'. 1+1+1=3

7. (a) What are spherical waves? Show that the amplitude of a spherical wave falls off as $\frac{1}{r}$ with distance. 1+3=4

(b) State the conditions that a function must satisfy so that it can be expanded in Fourier series. 2

(c) A function $f(t)$ is given by

$$f(t) = A\frac{t}{T} \quad \text{for} \quad 0 < t < T$$

$$f(t+T) = f(t)$$

Find the Fourier expansion of $f(t)$. 5

8. (a) State uncertainty principle and explain its significance. 1+3=4

(b) For which pair of dynamical variables is the principle valid? 1

(c) Discuss the normalization of a wave function with an example. 6

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2018

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Marks : 56

Time : 3 hours

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

1. *(a)* A 100 gm piece of ice at 0 °C is dropped into a container containing 200 gm of water at 30 °C. Calculate the net change in entropy of the system when the final equilibrium state is reached. Latent heat of fusion of ice = 80 cal. 3

(b) A particle executes SHM with time period 8 s and amplitude 4 cm. Calculate the velocity and acceleration when the particle is 2 cm from central position and also calculate their maximum values. 3

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

(d) The uncertainty in the velocity of an electron moving with a speed of 500 m/s is 0·004%. Calculate the uncertainty in the position of an electron. 3

2. (a) State and prove the law of equipartition of energy. 1+2=3

(b) Define the critical constants of a gas. Obtain the expressions for the critical constants in terms of the constants a and b of the van der Waals equation. 1½+3½=5

(c) What are the essential features of Brownian motion? Explain why the motions of particles in Brownian motion are random and irregular. 1½+1½=3

3. (a) State and prove Carnot's theorem. 1+3=4

(b) Show that the work done in an adiabatic process depends only on the initial and final temperatures. 3

(c) Explain what you understand by the terms reversible process and irreversible process. 1+1=2

(d) Define Boyle temperature and obtain an expression for it. 2

4. (a) Show that the rate of energy emitted by a blackbody per unit area is proportional to the fourth power of its absolute temperature. 3

(b) Show that Planck radiation law reduces to Rayleigh-Jeans law in the long wavelength limit. 3

(c) What is phase space? Calculate the number of states per unit volume in phase space. 1+2=3

(d) What is a canonical ensemble? For which type of system, it is suitable? 1+1=2

5. (a) Discuss the resultant due to two mutually perpendicular SHMs which are represented by equations $x = 3\sin\omega t$ and $y = 4\cos\omega t$. 4

(b) Graphically represent the displacement, velocity and acceleration of the particle executing SHM. 2

(c) What is sharpness of resonance in forced vibration? Discuss the effect of damping on the sharpness of resonance. 1½+1½=3

(d) Write down a differential equation representing damped simple harmonic equation explaining the various terms. 1+1=2

6. (a) What are normal modes of vibration? 1

(b) A perfectly elastic string of length l which is under tension T and fixed at both ends is plucked at a point $x = a$ to a height h and released. Find the different normal modes of vibration. 6

(c) Show that the KE and PE of the plane progressive wave are equal. 4

7. (a) Find the Fourier expansion of a square wave which is given by

$$y(t) = A \quad \text{for} \quad 0 < t < \frac{T}{2}$$

$$y(t) = -A \quad \text{for} \quad \frac{T}{2} < t < T$$ 3

(b) Discuss at least two phenomena that classical physics failed to explain. 3

(c) Illustrate the uncertainty principle by using Heisenberg's microscope. 5

8. (a) An object of mass 100 gm is moving with a velocity of 200 m/sec. Find the de Broglie wavelength of the object. 2

(b) Explain why the wave nature of larger object is hard to detect. 2

(c) Derive the one-dimensional time-dependent and time-independent Schrödinger equations. 4

(d) What is a wave function? Give its physical interpretation. 1+2=3

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2016

(October)

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(Elective/Honours)

(Thermal Physics, Waves)

[PHY–03 (T)]

Marks : 56

Time : 3 hours

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

1. *(a)* At what temperature the molecular velocity (r.m.s.) of oxygen will become half that of hydrogen at NTP? 3

(b) Calculate the total change of entropy when 1 g of water at 0 °C is converted into 1 g of steam at 100 °C. 3

(c) Calculate the maximum amount of heat which may be lost per second by the radiation from a sphere of 10×10^{-2} m diameter at a temperature of 227 °C when placed in an enclosure at a temperature of 27 °C. 3

(d) On the basis of Heisenberg uncertainty principle, show that electron cannot exist within the atomic nucleus. 3

2. (a) State the principle of equipartition of energy. 1

(b) Prove the above principle and hence obtain the ratio of specific heats of an ideal gas. 6+4=10

3. (a) Give a brief explanation of emission of radiation from a blackbody. 3

(b) State Stefan-Boltzmann law of radiation. 1

(c) Deduce this law from thermodynamical consideration. 7

4. (a) Explain Brownian motion. 4

(b) Give the Einstein's approach on the theory of Brownian motion. 7

5. (a) What are Lissajous figures? 1

(b) Obtain the resultant of two simple harmonic vibrations (of same amplitude) at right angles to each other when their frequencies are in the ratio 1 : 2 and with a phase difference of zero and $\frac{\pi}{2}$. Draw the Lissajous figures of the above two cases. (4+4)+(1+1)=10

6. Write down the differential equation of damped simple harmonic oscillation with the significance of the symbols used therein and hence obtain the general solution of this equation. Discuss fully the case of damped simple harmonic motion. 2+3+6=11

7. (a) Define the terms 'wave velocity' and 'group velocity'. 2

(b) Establish the relation connecting the wave velocity and group velocity. 5

(c) Derive an expression for the de Broglie wavelength associated with an electron accelerated under a potential difference of V volts. 4

8. (a) Define wave function. Give the physical significance of the wave function. 1+4=5

(b) Without using operators, deduce the one-dimensional time-independent Schrödinger equation. 6

9. *(a)* Find the Fourier series for a square wave function. 6

(b) Normalize the one-dimensional wave function $\psi(x) = A \sin \frac{n\pi x}{l}$, where l = constant having dimension of length, n = integer and A = constant. 5

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Values of important physical constants are given below :

Electronic charge, $e = 1{\cdot}6 \times 10^{-19}$ C

Mass of electron, $m_e = 9{\cdot}11 \times 10^{-31}$ kg

Mass of proton, $m_p = 1{\cdot}67 \times 10^{-27}$ kg

Universal gas constant, $R = 8{\cdot}31$ J mole^{-1} K^{-1}

van der Waals constants for 1 gm molecule of a gas are : $a = 0{\cdot}245$ atm-litre^2 mole^{-2}

$b = 2{\cdot}67 \times 10^{-2}$ litre-mole^{-1}

Latent heat of fusion of ice = 80 cal/gm

Latent heat of condensation of steam = 540 cal/gm

Specific heat of water = 1 cal gm^{-1} K^{-1}

Boltzmann's constant, $k = 1{\cdot}38 \times 10^{-23}$ JK^{-1}

Avogadro number, $N = 6{\cdot}02 \times 10^{23}$ mole^{-1}

Planck's constant, $h = 6{\cdot}63 \times 10^{-34}$ Js

Stefan's constant, $\sigma = 5{\cdot}7 \times 10^{-12}$ watts cm^{-2} K^{-4}

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

(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

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 $-\pi \leq x \leq \pi$. 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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