2022

(CBCS)

(6th Semester)

PHYSICS

SIXTEENTH PAPER

(Thermal and Statistical Physics)

Full Marks : 75

Time : 3 hours

The figures in the margin indicate full marks for the questions

(SECTION : A—OBJECTIVE)

(*Marks* : 10)

Tick (✓) the correct answer in the brackets provided : 1×10=10

1. According to kinetic theory of gases, energy associated with a molecule of a monoatomic gas at temperature T is

(a) $\frac{3}{2}K_BT$ ( )

(b) $\frac{3}{2}RT$ ( )

(c) $\frac{5}{2}K_BT$ ( )

(d) $\frac{5}{2}RT$ ( )

2. At what temperature will the average speed of hydrogen molecules be four times the average speed of oxygen molecules at 300 K?

(a) 75 K ( )

(b) 150 K ( )

(c) 273 K ( )

(d) 300 K ( )

3. During an isochoric adiabatic process, the _____ of a system remains constant.

(a) enthalpy ( )

(b) internal energy ( )

(c) entropy ( )

(d) Gibbs free energy ( )

4. At very high pressure, the coefficient of viscosity increases as density is increased. This is due to the fact that at high pressure, the mean free path becomes

(a) zero ( )

(b) constant ( )

(c) comparable to molecular diameter ( )

(d) infinitely large ( )

5. The dimensions of phase space volume are

(i) $(\text{length} \times \text{momentum})^3$

(ii) $(\text{work} \times \text{time})^3$

(iii) $(\text{length})^3$

(iv) $(\text{angular momentum})^3$

(a) *(i)*, *(ii)* and *(iv)* ( )

(b) *(ii)*, *(iii)* and *(iv)* ( )

(c) *(i)*, *(iii)* and *(iv)* ( )

(d) *(i)*, *(ii)* and *(iii)* ( )

6. According to fundamental concepts of statistical mechanics

(a) total energy of the system does not remain constant ( )

(b) total energy of the system remains constant ( )

(c) total volume of the system does not remain constant ( )

(d) total volume of the system remains constant ( )

7. In micro-canonical ensemble, exchange of _____ takes place.

(a) energy and mass ( )

(b) energy and temperature ( )

(c) temperature and mass ( )

(d) energy, mass and temperature ( )

8. According to Boltzmann canonical distribution law

(a) low energy cells contain more particles ( )

(b) high energy cells contain more particles ( )

(c) particles with zero energy are greater than any other energy ( )

(d) particles with zero energy are zero ( )

9. Photons obey

(a) M-B statistics ( )

(b) F-D statistics ( )

(c) B-E statistics ( )

(d) All of the above ( )

10. Particles obeying M-B statistics are

(a) indistinguishable ( )

(b) distinguishable and identical ( )

(c) distinguishable ( )

(d) distinguishable but not identical ( )

(SECTION : B—SHORT ANSWER)

(*Marks* : 15)

Answer the following questions in brief : 3×5=15

UNIT—I

1. Discuss the essential features of Brownian motion.

OR

2. Show that for a gas with f degrees of freedom, the molar specific heat ratio $1 \frac{2}{f}$.

UNIT—II

3. Show that enthalpy remains constant during an isobaric adiabatic process.

OR

4. State Gibbs phase rule. Show that the maximum number of phases that can co-exist at equilibrium for 1-component system is 3.

UNIT—III

5. Explain the terms 'macrostate' and 'microstate' with the help of an example.

OR

6. Explain the term 'constraints', hence define accessible and inaccessible states.

UNIT—IV

7. Discuss the law of increase of entropy.

OR

8. Show that for thermodynamical equilibrium of any two systems in contact, the parameter of the two systems must be identical.

UNIT—V

9. State three points of difference between classical and quantum statistics.

OR

10. Applying M-B distribution law, show that the internal energy of an ideal monoatomic gas depends only on its temperature.

(SECTION : C—DESCRIPTIVE)

(*Marks* : 50)

Answer the following questions : 10×5=50

UNIT—I

1. *(a)* State the postulates of kinetic theory of gases. Based on kinetic theory of gases, obtain an expression for pressure of an ideal gas. 3+4

(b) If the r.m.s. velocity of oxygen is 0 46 10^3 m/s, calculate the r.m.s. velocity of hydrogen. 3

OR

2. *(a)* Define mean free path. Derive an expression for mean free path in terms of temperature and pressure of the gas. 2+4

(b) If the diameter of the molecules of a gas is 3 10^{-8} cm, calculate the mean free path of the gas molecules at NTP. 2

(c) Obtain an expression for average velocity of the gas molecules. 2

UNIT—II

3. *(a)* Define thermal conductivity. Deduce an expression for the coefficient of thermal conductivity of a gas. Hence, show that the coefficient of thermal conductivity is greatest for hydrogen among all diatomic gases. 1+5+1

(b) The viscosity of hydrogen gas at 27 °C is 100 micro poise. Calculate the diameter of the hydrogen molecule. 3

OR

4. *(a)* Using Maxwell's thermodynamic relations, show that

$$C_P \quad C_V \quad T \left(\frac{P}{T}\right)_V \left(\frac{V}{T}\right)_P$$

Hence show that for a van der Waals gas

$$C_P \quad C_V \quad R\ 1 \quad \frac{2a}{RTV}$$

3+3

(b) Using Maxwell's thermodynamic relations, discuss the variation of C_P with pressure. Hence, show that for a perfect gas C_P is independent of pressure during an isothermal process. 3+1

UNIT—III

5. *(a)* Define probability. State and explain the principle of equal a priori probability. 1+2

(b) Discuss the additive and multiplicative law of probability. 2+2

(c) A card is drawn from a well-shuffled pack of 52 cards. Calculate the probability for the drawn card to be either a King, a Queen or a Jack. 3

OR

6. *(a)* Discuss phase space and quantum states. Derive an expression for the number of states in a six-dimensional phase space. 2+4

(b) For a particle of mass m enclosed in a volume V, calculate the number of accessible microstates in the energy range E and $E \quad dE$. 4

UNIT—IV

7. *(a)* Derive the probability distribution function in a grand canonical ensemble. 5

(b) Discuss the thermodynamic quantities in canonical ensemble and hence derive an expression for Helmholtz free energy in terms of partition function. 5

OR

8. *(a)* What do you mean by partition function? Deduce an expression for the partition function for a system in thermal equilibrium. 1+3

(b) State and prove equipartition theorem by the method of momentoids. 1+5

UNIT—V

9. *(a)* Derive the F-D distribution law. 6

(b) Compare the basic postulates of M-B, B-E and F-D statistics. 4

OR

10. *(a)* State the basic postulates of Bose-Einstein statistics, hence deduce the B-E distribution law. 2+5

(b) Using F-D distribution law, deduce the expression for energy distribution of free electrons in a metal. 3

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