63 (FY)SEM–3/MIN/PHYMIN2014

2025

PHYSICS

Paper : PHYMIN2014

(Thermal Physics and Statistical Mechanics)

Full Marks : 50

Pass Marks : 20

Time : Two hours

The figures in the margin indicate full marks for the questions.

1. Choose the correct answer : 1×5=5

   (i) The First Law of Thermodynamics is a statement of the conservation of :

   (a) Heat

   (b) Energy

   (c) Entropy

   (d) Temperature

(ii) The efficiency of a Carnot engine depends only on :

(a) The working substance

(b) The temperatures of source and sink

(c) The pressure of the gas used

(d) The type of cycle used

(iii) The enthalpy of a system is equal to :

(a) The total energy required to raise the temperature of the system

(b) The heat content of the system at constant pressure

(c) The work done by the system during expansion

(d) The kinetic energy of molecules

(iv) For a system with N number of particles, the phase space is a :

(a) 2 dimensional space

(b) 3 dimensional space

(c) $3N$ dimensional space

(d) $6N$ dimensional space

(v) In how many ways 2 balls can be arranged in 3 boxes (without any restriction) ?

(a) 6

(b) 9

(c) 8

(d) 5

2. Answer the following questions : ***(any five)*** 2×5=10

(i) Differentiate between an isothermal process and an adiabatic process.

(ii) Define internal energy of a system. How is it related to heat and work ?

(iii) What is Gibbs free energy ? State the condition for a spontaneous process at constant temperature and pressure.

(iv) State the main assumptions of the kinetic theory of a gases.

(v) What is the mean free path of gas molecules ? On which factors does it depend ?

(vi) Define macrostate and microstate of a thermodynamic system.

(vii) Differentiate between frequency of occurrence and probability.

(viii) What is an equilibrium state?

3. Answer the following questions : ***(any five)*** 5×5=25

(i) Show that the specific heats at constant pressure and constant volume for an ideal gas are related as

$$C_p - C_v = R$$

(ii) Define Gibbs free energy and derive the following thermodynamics relation

$$\left(\frac{\partial T}{\partial V}\right)_s = -\left(\frac{\partial P}{\partial S}\right)_V$$

(iii) State and explain the Second Law of Thermodynamics. A Carnot engine operates between two temperature reservoirs at 500 K and 300 K. If the engine absorbs 600 J of heat from the source, calculate the efficiency of the engine, and the work done per cycle. 2+3=5

(iv) Define an adiabatic process. One mole of an ideal gas expands adiabatically from a volume of 1 L to 3 L. The initial pressure is 2×10^5 Pa and $\gamma = 1.4$. Calculate the work done by the gas. 1+4=5

(v) Define phase space in statistical mechanics point of view and its characteristics. Draw the phase space diagram of a simple harmonic oscillator (oscillating in 1 diemnsion) 4+1=5

(vi) What is density function? For a system with fixed number of particles 'N' and fixed energy 'E', show that density function can be used to express thermodynamic parameters. 3+2=5

(vii) Show that entropy of a thermodynamic system is related to the number of microstates of the system through the relation $S = k_B ln\,\Omega(N,V,E)$

(viii) Establish the relation $PV^\gamma = constant$ for an adiabatic process.

4. Answer the following questions : ***(any one)*** 10×1=10

(i) What is a heat engine ? Explain in detail the working of a Carnot engine. Derive the expression for its efficiency in terms of the temperatures of the source and sink, and prove that no heat engine can be more efficient than a Carnot engine operating between the same two temperatures. Illustrate the Carnot cycle on a *P–V* diagram. 1+4+3+1+1=10

(ii) What is ensemble in statistical mechanics ? Describe three different types of ensembles with their characteristics and examples. 2+8=10