Ref. No. EX/ET/Ph/T/1B/115/2018

B. E.T.C.E EXAMINATION 2018
(1^{st} year, 1^{st} Semester)
PHYSICS IB

Time : Three hours Full Marks: 100

Answer any five

1. (a) State zeroth law of thermodynamics. Establish the international scale of temperature? 1 + 4

   (b) Consider $dU = TdS - PdV$, where symbols have their usual meaning. Derive the expression for Helmholtz and Gibb's free energies and also the enthalpy the system 2 + 2

   (c) Obtain the Maxwell's thermodynamic relations from thermodynamic potentials. Using Maxwell's relation show that the ratio of adiabatic to isobaric volume expansion coefficient is $\frac{1}{1-\gamma}$, where, γ, the ratio of two specific heats $(\frac{C_P}{C_V})$. 7 + 4

2. (a) Describe the operation of Carnot's engine using a P-V diagram for an ideal gas and calculate its efficiency. Differentiate between a refrigerator and a heat pump. 10 + 3

   (b) Explain how one arrives at the idea of entropy as a state function. 2

   (c) A Carnot engine whose low temperature reservoir is at 27°C has an efficiency of 40%. What should be the temperature of high temperature reservoir ? What should be the temperature of the latter if the efficiency is to be raised by 60%? 5

3. (a) State the postulates of statistical mechanics. 3

   (b) There are 3 spin $\frac{1}{2}$ particles in a lattice each with magnetic moment $\vec{\mu}$, placed in an external magnetic field $\vec{B}$. Total energy of the system is $-\vec{\mu}.\vec{B}$. Calculate the number of accessible microstates. What is the average value of the magnetic moment of the 1^{st} spin? 6

   (c) Establish the statistical definition of temperature and hence entropy for a microcanonical ensemble. 5

   (d) what do you mean by equation of state? Derive the general expression for equation of state for a microcanonical ensemble. 6

4. (a) In a canonical ensemble, calculate the probability P_r that the system is in the energy E_r. Hence define the partition function Z. Derive the expression for average energy $\bar{E}$ and mean square energy fluctuation $(\Delta\bar{E}^2)$ 5+1+2+4

   (b) Consider $Z = Z(\beta, x)$, where , $\beta = \frac{1}{kT}$ and x is an extensive parameters, such as volume. Use first law of thermodynamic to establish the expression for entropy of a canonical system. 4

(c) The two canonical systems A and B have weak interaction. Show that the partition function of a composite system $Z_{AB} = Z_A.Z_B$. 4

5. (a) Calculate the partition function of an ideal monatomic gas. Hence derive the equation of state and obtain the expression for entropy. $6 + 2 + 3$

(b) What is Gibb's paradox? How was the paradox resolved? $2 + 4$

(c) A possible energy states of a canonical system are E_1, E_2 and E_3. What is the probability that the system will have energy E_1. 3

6. (a) A Particle moves along a curved path whose parametric equation are $x = e^{-t}, y = 2cos3t, z = 2sin3t$, where t is the time. Determine its velocity and acceleration at any time and at t=0. 5

(b) $\vec{A} = 5t^2\hat{i}+t\hat{j}-t^3\hat{k}$ and $\vec{B} = sint\hat{i}-cost\hat{j}$, find $(i)\frac{d}{dt}(\vec{A}.\vec{B}), (ii)\frac{d}{dt}(\vec{A}\times\vec{B}), (iii)\frac{d}{dt}(\vec{A}.\vec{A})$ $2\frac{1}{2} + 3 + 2\frac{1}{2}$

(c) Show that $\nabla r^n = nr^{n-2}\vec{r}$, where $\vec{r}$ is the position vector. 4

(d) $\vec{A} = x^2z\hat{i} - 2y^3z^2\hat{j} + xy^2z\hat{k}$. Find $\vec{\nabla} \times \vec{A}$ at point (1,1,1). 3

7. (a) Considering a system of particles and derive the Lagrangian of the system. State the boundary conditions and assumptions. 10

(b) Explain De- Alembertś principle with the mathematical expression. In reference to the above mentioned principle, explain the concept of virtual work. $4+2\frac{1}{2}$

(c) State what do you mean by degrees of freedom of a system of particles. A system contains 5 particles with 3 constraints to its motion, Calculate the degrees of freedom of the system. $2 + 1\frac{1}{2}$

8. (a) Consider two heavy weights W_1 and W_2. They are connected by inextensible string over a fixed smooth circular cylinder, such that they make a certain angle with the vertical. Derive the expression for the condition such that the system does virtual work. 5

(b) $A = xz^3\hat{i} - 2x^2yz\hat{j} + yz^4\hat{k}$ find $\vec{\nabla} \times (\vec{\nabla} \times \vec{A})$ 4

(c) What do you mean by a conservative force field. Show that for a conservative force field the curl of it is zero. $2 + 4$

(d) A particle of mass 2 units moves in a force field depending on time t. The force is given by $F = 24t^2\hat{i} + (36t - 16)\hat{j} - 12t\hat{k}$. Assuming that $t = 0$ the particle is located at $\vec{r_0} = 3\hat{i} - \hat{j} + 4\hat{k}$ and has velocity $\vec{v_0} = 6\hat{i} + 15\hat{j} - 8\hat{k}$. Find the velocity and position at any time t. 5