End Semester Examination, 2021

Semester - III

Physics

PAPER - CC6T

Full Marks : 40

Time : 2 Hours

<u>Gr - A</u>

1. ***Answer any <u>five</u> questions :-*** **5x2=10**

a) A Carnot engine is working in between 500 K and 400 K temperature. Calculate its efficiency.

b) If 1g of water freezes into ice, the change in its specific volume is 0.091 cc. Calculate the pressure to be applied to freeze 10g of water at $-1^0 C$.

c) When a gas expands adiabatically, its volume is doubled while its absolute temperature is decreased by a factor 1.32. Compute the number of degrees of freedom for the gas molecules.

d) Prove that the ratio of the adiabatic to the isobaric pressure coefficient of expansion is $\frac{1}{1-\gamma}$.

e) Two finite, identical, solid bodies of constant total heat capacity per body, C, are used as heat sources to drive heat engine. Their initial temperatures are T_1 and T_2 respectively. Find the maximum work obtainable from the system.

f) The density of Hydrogen at N.T.P. is $8.96\times10^{-5} g/c.c$. Calculate the r.m.s velocity for an oxygen molecule at N.T.P.

g) Show that Maxwell's law of distribution of molecular speed is independent of temperature if the most probable speed is taken as the unit of measuring.

h) Show that at critical temperature, the departure of the van der Waals' gas law from that of the ideal gas $\frac{p_c V_c}{T_c} = R$ measures 62%.

<u>Gr - B</u>

Answer any <u>four</u> questions :- **4x5=20**

2. One kilogram of water is heated by an electrical resistor from 20^0C to 99^0C at constant (atmospheric) pressure. Estimate :

   a) The change in internal energy of the water.

   b) The entropy change of the water.

   c) The factor by which the number of accessible quantum states of the water is increased.

   d) The maximum mechanical work achievable by using this water as heat reservoir to run an engine whose heat sink is at 20^0C. 1+1+1+2

3. a) Deduce the Clausius-Clapeyron equation :

   $\frac{dp}{dt} = \frac{L}{T(V_2 - V_1)}$, Where the symbols have their usual significance.

b) Mention the characteristics of a first order phase transitions. 3+2

4. Consider an arbitrary heat engine which operates between two reservoirs, each of which has the same finite temperature-independent heat capacity *c*. The reservoirs have initial temperatures T_1 and T_2, Where $T_2 > T_1$, and the engine operates until both reservoirs have the same final temperature T_3.

   a) Give the argument which shows that $T_3 > \sqrt{T_1 T_2}$.

   b) What is the maximum amount of work obtainable from the engine ? 2+3

5. a) Obtain the following Tds equation :

$$Tds = C_V dT + T\alpha E_T dV$$

where, $E_T = -V\left(\frac{\partial P}{\partial V}\right)_T$ is the isothermal elasticity and $\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$ is the volume coefficient of expansion, S is the entropy and T the Kelvin temperature.

   b) If U is the internal energy then show that for an ideal gas $\left(\frac{\partial U}{\partial V}\right)_T$. 3+2

6.a) What do you mean by 'Degrees of Freedom' of a dynamical system ?

b) A shower of 10^4 molecules, each originally moving with the same velocity, traverses a gas. Find the number of molecules which will not be deflected even after traversing a length twice the mean free path.

c) Calculate the fraction of gas molecules will have free paths lying between λ and 2λ. 2+2+1

7.a) Write down Maxwell's speed distribution of a gas molecule. Show it graphically :

i) For two different temperature T_1 and T_2 ($T_1 > T_2$)

ii) For two different molecules, say O_2 and H_2.

b) If c be the speed of sound in a gaseous medium $(\gamma = 1.4)$, show that the r.m.s. speed v of the gas molecules is $v = \left(\frac{15}{7}\right)^{\frac{1}{2}} c$ 3+2

Gr - C

Answer any <u>one</u> question :- **1x10=10**

8.a) State and prove Carnot's theorem.

b) What is Helmholtz function ? Show that it represents the free energy of the system in a reversible isothermal process or the energy available for work.

c) Consider an ideal gas whose entropy is given by :

$$S = \frac{n}{2}\left[\sigma + 5RIn\frac{U}{n} \_ 2RIn\frac{V}{n}\right]$$

Where n = number of moles, R = universal gas constant, U=internal energy, V=volume, and σ=constant.

Calculate C_P and C_v, the specific heats at constant pressure and volume. 4+4+2

9.a) What are the critical constants of a gas ? Obtain their values in terms of the constants of van der Waals' equation.

b) Define Boyle's temperature and find it's relation with critical temperature.

c) The critical temperature of CO_2 is 31^0C and the critical pressure 73 atmos. Assuming that CO_2 obeys van der Waals' equation, estimate the diameter of its molecule. (2+3)+3+2