The Open University of Sri Lanka
B.Sc. Degree Programme - Level 04
Final Examination – 2006/2007
PHU 2145 / PHE 4145 – Thermodynamics & Radiation
Duration: Two and Half (2 ½) hours

Date: 19th June 2007 **Time: 1.30 pm to 4.00 pm**

ANSWER FOUR QUESTIONS ONLY (R = 8.31 J/mole K)

1. A system consisting of fix number of identical particles is generally called an assembly and description of the assembly depends on whether the particles are distinguishable or indistinguishable.

   (a) Explain what is meant by macroscopic state and microscopic state of a system.
   (b) How do you define the thermodynamic probability?
   (c) State the three statistics found in statistical mechanics and write down the conditions impose on particles and energy states under each statistic.
   (d) A certain assembly consists of four particles distributed in two energy levels E_1 and E_2 having degeneracy $g_1 = 5$ and $g_2 = 3$ respectively. A macroscopic state of the assembly is distinguished by the number of particles N_1 and N_2 in each of the energy levels E_1 and E_2 respectively. Calculate the number of complexions associated with the macroscopic states of the following two cases for the three statistics.

   (i) $N_1 = 2$ and $N_2 = 2$
   (ii) $N_1 = 4$ and $N_2 = 0$

2. The surrounding can exert force on a system to do work on the system or vise versa and the system will go through a thermodynamic equilibrium states in a quasi statistic process. The process is reversible if the system and the surrounding restore to their initial state.

   (a) How do you define a system at thermodynamic equilibrium?
   (b) Write down the equation of state of an ideal gas defining all the thermodynamic coordinates.
   (c) Show that the work done by change of volume, dv of a constant mass of gas in a cylinder of a piston is given by $w = \int P\,dv$.
   (d) A thermodynamic system consisting of 3 moles of an ideal gas undergoes a reversible process. First, the temperature of the system changes from 300 K to 500 K by an isobaric process at 1×10^6 Pascal. Then its volume is reduced to its initial value by compressing the gas isothermally. Finally the gas is cooled to 300 K by isochoric process. Draw this process in a P-V diagram and calculate the work done at each step.

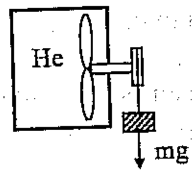
3. The total internal energy of a system changes in a process due to absorbance of heat and by doing work, in such away to conserve the total energy as given by the first law of thermodynamics.

(a) Write down the first law of thermodynamics in differential form. What are the exact differentials (path functions) of the above equation?

(b) How do you use the above equation to describe a hydrostatic system?

Hence show that $dQ = \left(\frac{\partial U}{\partial \theta}\right)_v d\theta + \left[\left(\frac{\partial U}{\partial v}\right)_\theta + P\right] dv$, when the internal energy of the system, U is a function of temperature, θ and volume, v.

(c) Define specific heat capacity of a system and show that at constant volume $\Delta U = m\int C_v dT$, where m is the mass and C_v is the thermal capacity at constant volume.



(d) An insulated rigid container of 1 m^3 volume contains helium gas at 20 °C and 100 kPa pressure. A paddle wheel rotates inside the container when a mass of 1 kg is released to fall under gravity as shown in the figure. Calculate the depth of fall of the mass to raise the temperature of helium gas to 25 °C, assuming helium behave as an ideal gas and C_v = 12.5 kJ/kmol K for helium.

4. The second law of thermodynamics is important to identify the processes, which are spontaneous.

(a) Write down the Kelvin-Plank statement and the Clausius statement of the second law of thermodynamics? Give one example of practical application for each statement.

(b) The Carnot engine of a perfect gas works in connection with two heat reservoirs at high and low temperatures, θ_1 and θ_2 respectively. Write down the steps that the system must go through to complete a Carnot cycle with the help of a P-V diagram.

(c) Write down the Carnot theorem and show that the efficiency of a Carnot engine is given by $\eta = 1 - \frac{\theta 2}{\theta_1}$

(d) A automobile industry personal claims that the engines of their company operates at one kW power which produce by burning fuel at the rate of 65 kJ per minute which make 1127 °C inside the cylinder of the piston when the surrounding is at 27 °C. Could you agree with what he claims.

5. The internal energy of a real gas depends upon the thermodynamic coordinates such as P, V and T that leads to the Joule–Kelvin effect.

   (a) What is meant by the Joule-Kelvin effect of a gas? Briefly explain how you observe this effect experimentally.
   (b) What is an isenthalpic curve of a gas?
   (c) Show that the Joule-Kelvin coefficient is given by the expression $\frac{\Delta T}{\Delta P} = \frac{1}{C_P}\left[T\left(\frac{\partial v}{\partial T}\right)_P - V\right]$
   (d) Explain why a hydrogen gas cylinder, which kept open its valve, set the gas fire and nitrogen gas cylinder that kept open the valve leads to condensation of ice on the neck of the valve considering the Joule-Kelvin coefficient of those two gases.

6. In most thermodynamic processes heat transfer occurs between the system and the surrounding by conduction where radiation is also a possible mechanism.

   (a) What does a black body mean?
   (b) Define the terms absorptive power and emissive power of a radiative body.
   (c) State the Stefan's law of radiation.
   (d) A polished copper sphere of radius 1 cm is suspended in an evacuated enclosure whose wall temperature is maintained at 27 °C. The emissivity of the polished copper surface is 0.02 from room temperature to 270 °C. If the sphere loses heat by radiation what would be its rate of cooling at 250 °C? How would the rate of cooling be altered if the copper surface is coated with lamp soot, assuming the sphere to be a perfect black body?

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