The Open University of Sri Lanka
B.Sc Degree Programme – Level 04
Final Examination – 2012/2013
PHU2145 – Thermodynamics and Radiation
Duration : 2 hours

Date : 18.12.2013 **Time:9.30 am- 11.30 am**

Answer any four questions only.

Q1 (a) Find the number of macroscopic states for an assembly of four identical particles distributed among two energy levels one of which is two-fold degenerate.

(b) Find the thermodynamic probability of each macroscopic state if there is no restriction on the number of particles in each energy state and,

(i) the particles are indistinguishable

(ii) the particles are distinguishable.

(c) What is the thermodynamic probability of each macroscopic state if there can be no more than one particle in each permitted energy state and the particles are indistinguishable.

(d) Calculate the thermodynamic probability of the assembly for parts (b) ~~(i) & (ii) and (c).~~

(You may assume $W_{M-B,K} = N_j!\Pi \frac{g_j^{N_j}}{N_j!}$

$W_{B-E,K} = \Pi \frac{(g_j + N_j - 1)}{(g_j - 1)!N_j!}$)

Q2. Write down Carnot's theorem and two corollaries.

(i) Two identical bodies of constant heat capacity c_p at temperature T_1 and T_2 respectively are used as reservoirs for a heat engine. If the bodies remain at constant pressure, show that the amount of work obtainable is

$$W = c_p(T_1 + T_2 - 2T_f)$$

where T_f is the final temperature attained by both bodies.

(ii) Show that if the most efficient engine is used

$$T_f^2 = T_1 T_2$$

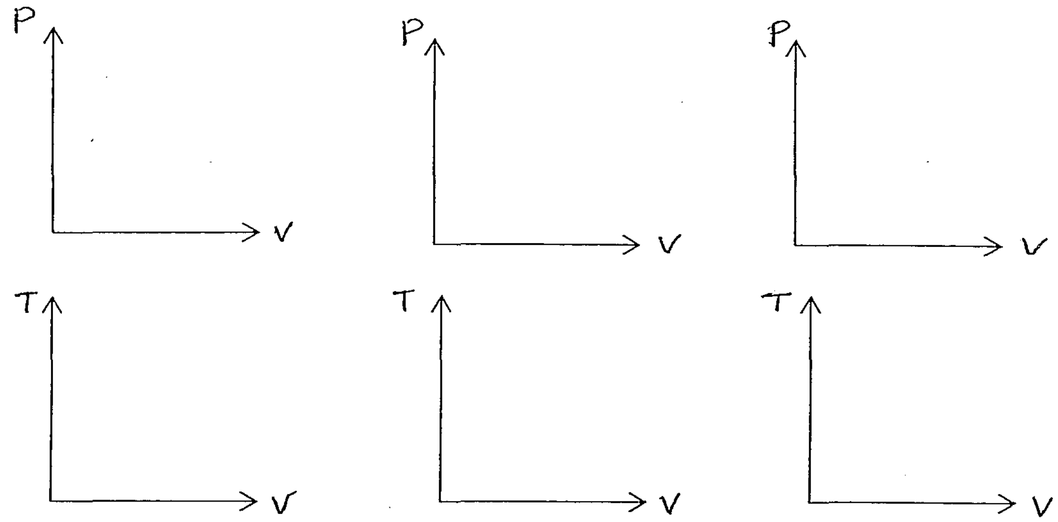
A building is maintained at a temperature T by means of an ideal heat pump which uses a river at temperature T_o as a source of heat. The heat pump consumes power W, and the building loses heat to its surroundings at a rate $\alpha(T - T_0)$, where α is a positive constant. Show that T is given by

$$T = T_0 + \frac{W}{2\alpha}\left[1 + \sqrt{1 - \frac{4\alpha T_0}{W}}\right]$$

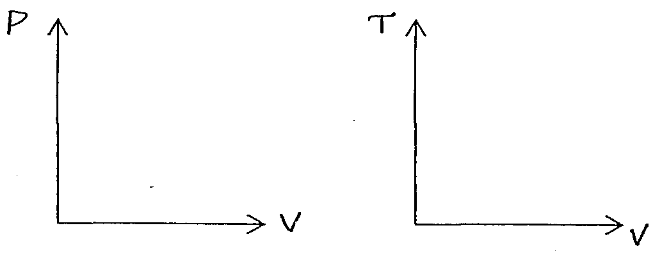
Q 3 (a) State the First Law of Thermodynamics.

(b) Copy down the following table which shows the process-relation for an ideal gas to your answer script and fill the blanks in it.

Process	P-V-T relation	ΔQ	$\Delta W = \int_1^2 P.dv$	$\Delta W = \int_1^2 V.dp$	ΔU
Constant volume	--------------	--------------	--------------	--------------	--------------
Constant pressure	--------------	--------------	--------------	--------------	--------------
Constant temperature	--------------	--------------	--------------	--------------	--------------
Reversible adiabatic	--------------	--------------	--------------	--------------	--------------



Constant Volume Constant Pressure Constant Temperature



Reversible Adiabatic

Q4. (i) Drive the $T.dS$ equation,

$$T.dS = c_v(\partial T/\partial P)_v\, dP + c_p(\partial T/\partial V)_p\, dV$$,where all the symbols have their usual meanings.

And show that the three $T.dS$ equations may be written as follows;

(a) $T.dS = c_v dT + \left(\frac{\beta T}{k}\right).dV$

(b) $T.dS = c_p dT - V\beta T.dP$

(c) $T.ds = \left(\frac{c_v k}{\beta}\right).dp + \left(\frac{c_P}{\beta V}\right).dV$

where the symbols, β - volume expansivity $\frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$ and

k - isothermal compressibility $\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$

Q5. State the first law of thermodynamics and write down the differential form of this law using the usual symbols.

(i) Explain why we can write the above law as
$dQ = c_p dT + AdP$ and
$dQ = c_v dT + BdV$
where A and B are constants

(ii) Subtract the above equations and show that
$(c_p - c_v)\, dT = BdV - AdP$ and
that at constant temperature
$$\left(\frac{\partial P}{\partial V}\right)_T = \frac{B}{A}$$

(iii) In an adiabatic change, show that
$$dP = -(c_p / A)dT$$
$$dV = -(c_v / B)dT$$
Hence show that in an adiabatic change we have that
$$\left(\frac{\partial P}{\partial V}\right)_{\text{adiabatic}} = \gamma\left(\frac{\partial P}{\partial V}\right)_T$$
$$\left(\frac{\partial V}{\partial T}\right)_{\text{adiabatic}} = \frac{1}{1-\gamma}\left(\frac{\partial V}{\partial T}\right)_P$$
$$\left(\frac{\partial P}{\partial T}\right)_{\text{adiabatic}} = \frac{\gamma}{\gamma - 1}\left(\frac{\partial P}{\partial T}\right)_V$$

Q6. Describe the Joule-Kelvin effect and explain why some gases show a cooling effect and the others show a heating effect when steamed through a porous plug.

(i) Show that the Joule- Kelvin coefficient is given by the expression

$$\frac{\Delta T}{\Delta P} = \frac{1}{c_p}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right]$$

where the symbols have their usual meanings