Physics II
ISI B.Math
Mid Semestral Exam: September 11, 2013

Total Marks: 60
Time: 3 hours
Answer question 1 and any 4 from the rest.

1. **(Marks : $4 \times 3 = 12$)**

For the following multiple choice questions indicate your answers by the appropriate letters (a), (b), (c) or (d).There is only one correct answer.

i) A system is changed from an initial equilibrium state to the same final equilibrium state by two different processes - one reversible, and one irreversible. Which of the following is true, where ΔS refers to the change of entropy of the system?

(a) $\Delta S_{irr} = \Delta S_{rev}$
(b) $\Delta S_{irr} > \Delta S_{rev}$
(c) $\Delta S_{irr} < \Delta S_{rev}$
(d) No decision is possible with respect to (a), (b) or (c).

ii) Two Carnot refrigerators R_1 and R_2 operate between the temperatures T_l and T_h where $T_l < T_h$. The working material for R_1 is a photon gas, with equation of state $P = \frac{1}{3}\sigma T^4$ where σ is a positive constant . The working material for R_2 is an ideal gas with the usual equation of state. If the coefficient of performance C of a refrigerator is defined as the ratio of the heat extracted at T_l to the work input, then if C_1 and C_2 are the coefficients of performance for R_1 and R_2 respectively, then

(a) $C_1 > C_2$
(b)$C_1 < C_2$
(c) $C_1 = C_2$
(d) It is not possible to conclude (a), (b) or (c) from the data given.

iii) A liquid in equilibrium with its saturated vapour is enclosed in an cylinder attached to a piston. The piston is slowly raised to a final position. As a result 5 gms of the liquid gets converted to 5gms of vapour while the temperature and pressure remain constant. If G is the Gibbs potential and S the entropy of the liquid vapour system, in this process

(a) G decreases and S increases.
(b) G and S remain unchanged.
(c) G remains unchanged and S increases.
(d) G and S both increase.

iv) Which of the following statements is FALSE ?

(a) The internal energy of a fixed mass of gas obeying van-der Waals equation remains unchanged when it undergoes adiabatic free expansion.
(b) The entropy of a system always increases when it undergoes an irreversible transformation.

(c) $dQ = TdS$ is only true for an infinitesimal quasistatic reversible transformation.
(d) C_p is always greater than C_v.

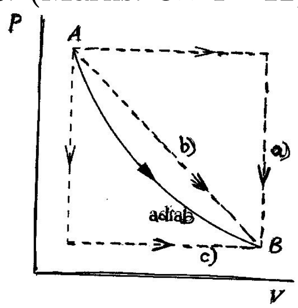
2. **(Marks: 4 + 8)**

i) A 100 W light bulb is left burning inside a refrigerator that draws 100W of electricity to do work. Can the refrigerator cool below room temperature? Justify your answer.

ii) A room air conditioner operates as a Carnot cycle refrigerator between an outside temperature T_h and a room at lower temperature T_i. The room gains heat from the outside at the rate $A(T_h - T_i)$; this heat is removed by the air conditioner. The power supplied to the cooling unit is P. Show that the steady state temperature of the room is

$$T_i = (T_h + P/2A) - [(T_h + P/2A)^2 - {T_h}^2]^{\frac{1}{2}}$$

3. **(Marks: 3× 4 =12)**



During a quasistatic reversible transformation from $A \rightarrow B$ during which no heat is exchanged with the environment, the pressure of a certain amount of gas is found to change with the volume according to the equation $P = \alpha V^{-\frac{5}{3}}$ where α is a constant. Find the work done on the system and the net amount of heat absorbed by the gas in each of the following three transformations which take the system from state A to state B as indicated in the diagram by a) , b) and c). You may assume that the transformations are quasi-static and reversible. Express your results in terms of P_A, P_B, V_A and V_B (the constant α should not appear in your results.)

4. **(Marks: 7 + 5)**

i) If the specific heat of an ideal gas for a process where x is kept constant is c_x, show that $pv^f =$ constant for this process, where $f = \frac{c_x - c_p}{c_x - c_v}$, where v is the specific volume, p is the pressure and c_p and c_v are the (constant) specific heats at constant pressure and constant volume.

ii) Use the first law of thermodynamics and the fact that dS is an exact differential to show that the internal energy of an ideal gas is independent of volume.

5. **(Marks: 6 + 6)**

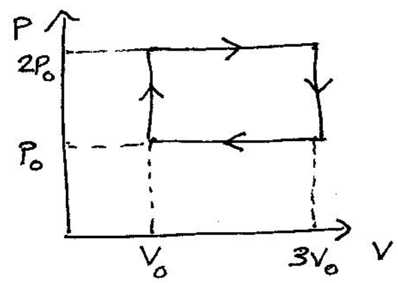
i) It is experimentally found that for a solid of volume expansion coefficient β at constant pressure P

$$\beta V = a + bP + cP^2$$

where a, b and c are constants for $P_A \leq P \leq P_B$. How much will the entropy increase when the solid is compressed from a pressure P_A to P_B at constant temperature ?

ii) Show that the Joule-Thomson coefficient $\mu = \left(\frac{\partial T}{\partial P}\right)_H = -\frac{T\left(\frac{\partial S}{\partial P}\right)_T + V}{C_P} = 0$ for an ideal gas. (Recall $H = U + PV$).

6. **(Marks: 7 + 2 + 3)**



An ideal monatomic gas is taken around the above rectangular cycle shown in the above $P - V$ diagram. Let this operate as a heat engine to convert the heat added to mechanical work.
(i) Evaluate the efficiency of the engine
(ii) Calculate the efficiency of an "ideal" engine operating between the same temperature extremes.
(iii) Sketch the above $P - V$ cycle on a $T - S$ plot.

Information you may (or may not) need

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

$$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

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

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