

Physics II
ISI B.Math
Mid Semestral Exam : March 2, 2009

Total Marks: 100

Answer any five questions

1. For the following multiple choice questions indicate your answers by the appropriate letters (a), (b), (c) or (d).

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 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) An exact differential expression relating thermodynamic variables is given by

$$dB = CdE - FdG + HdJ$$

Which of the following would not be a new thermodynamic potential function consistent with the above expression?

(a) $B - CE$

(b) $B - HJ$

(c) $B - FG - CE$

(d) $B - HJ + FG - CE$.

iii) Given the same exact differential expression as in (ii) we conclude that

(a) $\left(\frac{\partial C}{\partial G}\right)_E = \left(\frac{\partial F}{\partial E}\right)_G$

(b) $\left(\frac{\partial C}{\partial J}\right)_{E,G} = \left(\frac{\partial H}{\partial E}\right)_{J,G}$

(c) $\left(\frac{\partial F}{\partial G}\right)_{E,J} = -\left(\frac{\partial E}{\partial C}\right)_{G,J}$

(d) None of the above.

iv) For a PVT system,

$$T \left(\frac{\partial S}{\partial T} \right)_P - T \left(\frac{\partial S}{\partial T} \right)_V$$

is *always* equal to

- (a) zero
- (b) $\gamma = \frac{C_P}{C_V}$
- (c) R
- (d) $T \left(\frac{\partial P}{\partial T} \right)_V \left(\frac{\partial V}{\partial T} \right)_P$

v) The expression $\left(\frac{\partial P}{\partial V} \right)_T \left(\frac{\partial T}{\partial P} \right)_S \left(\frac{\partial S}{\partial T} \right)_P$ is equivalent to

- (a) $\left(\frac{\partial S}{\partial V} \right)_T$
- (b) $\left(\frac{\partial P}{\partial T} \right)_V$
- (c) $\left(\frac{\partial V}{\partial T} \right)_S$
- (d) $-\left(\frac{\partial P}{\partial T} \right)_V$

2. Consider the earth's atmosphere as an ideal gas of molecular weight μ in a uniform gravitational field. Let g denote the acceleration due to gravity.

(a) If z denotes the height above sea level, show that the change in atmospheric pressure with height is given by

$$\frac{dp}{p} = -\frac{\mu g}{RT} dz$$

where T is the absolute temperature at height z .(4)

(b) If the decrease in pressure in (a) is due to adiabatic expansion, show that(4)

$$\frac{dp}{p} = \frac{\gamma}{\gamma - 1} \frac{dT}{T}$$

(c) From (a) and (b) calculate $\frac{dT}{dz}$ in degrees per kilometre. Assume the atmosphere to consist of mostly nitrogen, for which $\gamma = 1.4$.(4)

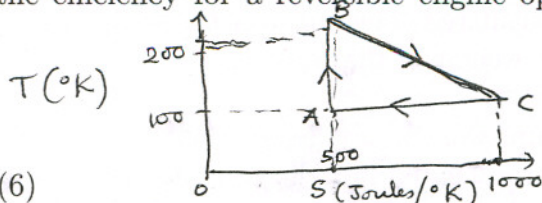
(d) In an isothermal atmosphere at temperature T , express the pressure p at height z in terms of the pressure at sea level.(4)

(e) If the sea level pressure and temperature are p_0 and T_0 respectively, and the atmosphere is regarded as adiabatic as in part (b), find again the pressure

p at height z . (4)

3.(a) Show that if two quasi-static adiabatic curves intersect, the second law of thermodynamics is violated. (5)

(b) Find the efficiency for a reversible engine operating around the cycle



illustrated. (6)

(c) Prove that the slope on a T - S diagram of an isochoric (const. volume) curve is T/C_V . Why does an isochoric curve plotted on a TS diagram have a greater slope than an isobaric (const. pressure) curve at the same temperature? (6)

(d) Two equal volume bulbs containing 1 mole each of a certain ideal gas at the same temperature are connected by a valve. What is the entropy change when the valve is opened? (3)

4. (a) By considering a Carnot engine operating in the region of equilibrium coexistence of a liquid and its saturated vapour, derive the Clausius-Clapeyron equation given below. [Hint: On the P - V diagram for this system, draw two neighbouring isothermals at temperatures T and $T + dT$ respectively and operate the engine between these two isothermals by connecting them with adiabatic curves]

$$\left(\frac{dP}{dT} \right) = \frac{\lambda}{T(v_2 - v_1)}$$

where λ is the latent heat of the liquid - vapour phase transition, v_2 , v_1 are the specific volumes of the vapour and water respectively at the transition temperature. (8)

(b) During the above phase transition, state which of the following quantities remain constant and which change. - molar entropy (s), molar Gibbs potential (g), molar Helmholtz potential (f), molar heat capacity (c_p). Give a brief explanation accompanying your answer. (5)

(c) Using the result in part (a) show that the saturated vapour pressure p_s of a liquid is given by

$$p_s \propto \exp(-\lambda M/RT)$$

provided the vapour can be approximated as an ideal gas and the latent heat λ of vaporization may be considered constant over the temperature range of interest. M is the molecular weight of the vapour.(7)

5. (a) Calculate the maximum work in Joules obtainable from a heat reservoir consisting of 200 kg of iron heated initially to a temperature of 1500 C, using the ocean , at 12 C, as the second heat reservoir. Assume that the specific heat capacity of the iron is constant and equal to 0.60 joules/gram-deg. (7)

(b) Calculate the entropy change of the universe in this process.(6)

(c) The Joule-Thomson coefficient $\mu = \left(\frac{\partial T}{\partial P}\right)_H = -\frac{T\left(\frac{\partial S}{\partial P}\right)_T + V}{C_P}$, where H is the enthalpy and C_p is the heat capacity at constant pressure. Show that $\mu = 0$ for an ideal gas. Can one achieve cooling by throttling an ideal gas? Find the entropy change when an ideal gas at temperature T is throttled from pressure P_1 to a lower pressure P_2 .(7)

6.(a) For a PVT system show that(5)

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

(b) A gas which obeys the van der Waals equation $\left(p + \frac{a}{V^2}\right) \times (V - b) = RT$ has a molar specific heat at constant volume C_V which is constant and independent of temperature. Consider a thermally insulated rigid container which is divided into two compartments (of volumes V_1 and V_2 respectively) separated by a valve which is initially closed. One mole of the above gas is introduced into the chamber of volume V_1 and its temperature T_1 noted. The valve is then opened and the gas expands to fill both the compartments.

(i) Find the final temperature T_2 of the gas after the valve is opened. (7)

(ii) What would be the final temperature if the real gas were replaced by an ideal gas? (2)

(iii) If the valve were replaced by a piston and the gas was quasistatically expanded to volume $V_1 + V_2$ what would be the final temperature ?(6)

Information you may (or may not) need

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

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

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

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