

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Physics Department

8.044 Statistical Physics I

Spring Term 2004

Problem Set #4

Due by 1:10 PM: Monday, March 1

Problem 1: Thermal Equilibrium and the Concept of Temperature, I

This problem and the next are taken from **Heat and Thermodynamics** by Zemansky.

Systems A , B , and C are gases with coordinates P, V ; P', V' ; and P'', V'' . When A and C are in thermal equilibrium, the equation

$$PV - nbP - P''V'' = 0$$

is found to be satisfied. When B and C are in equilibrium, the relation

$$P'V' - P''V'' + \frac{nB'P''V''}{V'} = 0$$

holds. The symbols n , b , and B' represent constants.

- a) What are the three functions which are equal to one another at thermal equilibrium and each of which is equal to t where t is the empiric temperature?
- b) What is the relation expressing thermal equilibrium between A and B ?

Problem 2: Thermal Equilibrium and the Concept of Temperature, II

Systems A and B are paramagnetic salts with coordinates H, M and H', M' respectively. System C is a gas with coordinates P, V . When A and C are in thermal equilibrium, the equation

$$nRCH - MPV = 0$$

is found to hold. When B and C are in thermal equilibrium, we get

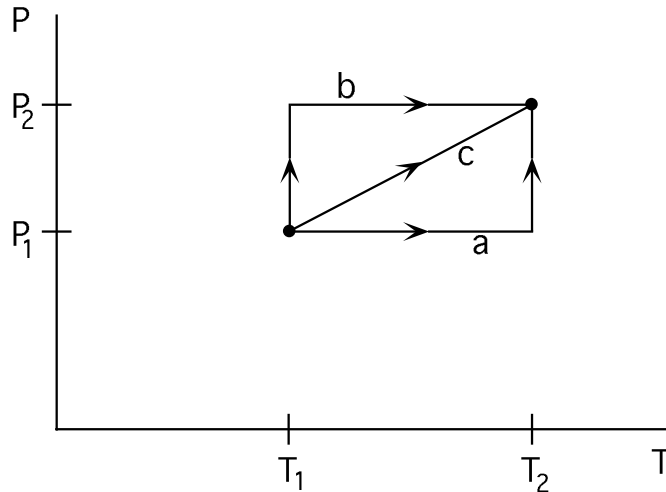
$$nR\Theta M' + nRC'H' - M'PV = 0$$

where n , R , C , C' , and Θ are constants.

- a) What are the three functions that are equal to one another at thermal equilibrium?

- b) Set each of these functions equal to the ideal gas temperature T and see if you recognize any of these equations of state.

Problem 3: Work in a Simple Solid



In the simplest model of an elastic solid

$$dV = -V\mathcal{K}_T dP + V\alpha dT$$

where \mathcal{K}_T is the isothermal compressibility and α is the thermal expansion coefficient. Find the work done on the solid as it is taken between state (P_1, T_1) and (P_2, T_2) by each of the three paths indicated in the sketch. Assume that the fractional volume change is small enough that the function $V(P, T)$ which enters the expression for dV can be taken to be constant at $V = V_1 = V(P_1, T_1)$ during the process.

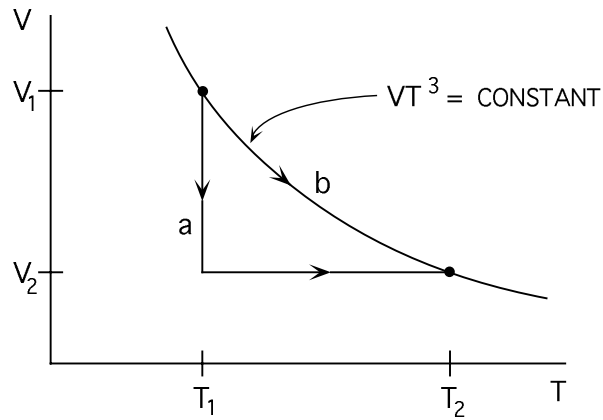
Problem 4: Work in a Non-Ideal Gas

An approximation to the equation of state for a real gas is

$$(P + a/V^2)(V - b) = NkT$$

where a , b , and k are constants. Calculate the work necessary to compress the gas isothermally from V_1 to $V_2 < V_1$.

Problem 5: Work and the Radiation Field



The pressure P due to the thermal equilibrium radiation field inside a cavity depends only on the temperature T of the cavity and not on its volume V ,

$$P = \frac{1}{3}\sigma T^4.$$

In this expression σ is a constant. Find the work done on the radiation field as the cavity is taken between states (V_1, T_1) and (V_2, T_2) along the two paths shown in the diagram.