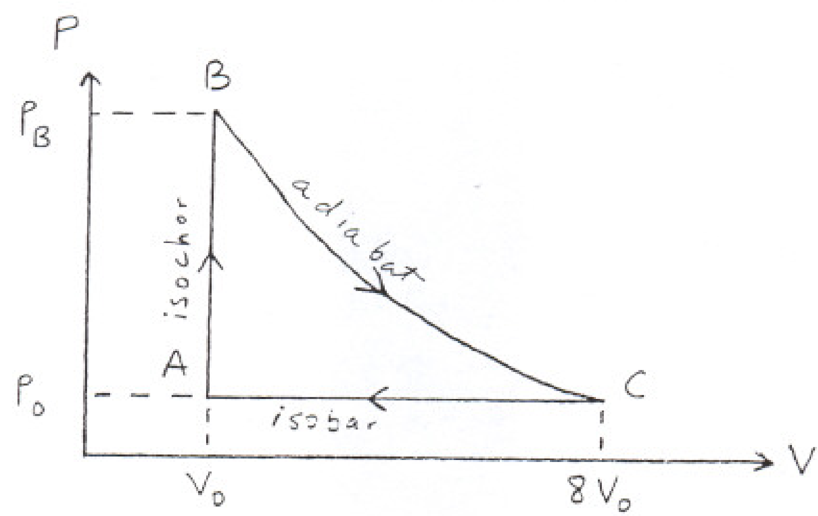
Thermodynamics

Directions: Do problem 1 and two of the remaining three problems.

1. (40 pts) One mole of a monatomic ideal gas undergoes the following reversible cyclic process:



(a) On the adiabat PV^{γ} is constant and $\gamma = 5/3$. Find the pressure P_B at point *B*.

(b) Find the change in internal energy ΔU from *B* to *C* (i.e., on the adiabat). You may want to express your answer in units of RT_0, where T_0 is the temperature at point *A*.

(c) Find the total work *W* done on the system, in units of RT_0, over one cycle.

(d) The total ΔS of the universe is zero since the cycle is reversible. However, suppose the isochor is made irreversible: the system at *A* is suddenly placed in contact with a heat reservoir at the temperature, T_B, of point *B*. The other processes remain reversible. In this case, what is ΔS of the universe, in units of *R*, for one cycle?

2. (30 pts) Calculate the equation of state $P = P(V,T)$ for a closed system whose entropy is given by $S(U,V) = A(NUV)^{1/3}$, where A is a constant and N is the (fixed) number of particles.
Hint: Use the First law of thermodynamics to obtain expressions for relevant derivatives of S.

3. (30 points) Consider a typical hydrostatic system with a first order liquid – gas phase transition.

   (a) On a *P-V* diagram, sketch an isotherm that passes through the liquid – gas coexistence region, the critical isotherm, and a high temperature isotherm. Indicate the coexistence region with a dashed curve, and label the critical point *C*. Put labels *L* (liquid), *G* (gas), and *L*+*G* (coexisting liquid and gas) in appropriate places.

   (b) Across the coexistence region (i.e., between points of equal pressure on either side of coexistence), which of the potentials *H* (enthalpy), *A* (Helmholtz), and *G* (Gibbs) of the combined *L*+*G* system change? (Recall $H = U + PV$, $A = U - TS$, $G = U + PV - TS$.)

4. (30 points) An ideal gas contains *N* identical molecules, each of which is triatomic and linear. In addition to center of mass translations, each molecule has four vibrational and two rotational normal modes. Determine the heat capacity C_P of the gas, assuming all modes are activated, the atoms within the molecules interact through a harmonic potential, but there are no intermolecular interactions.