Phys 741
Statistical Mechanics
Problem Set # 1

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1. Starting from $dE = dQ - PdV$ and for an adiabatic process show that

$$C_P \left(\frac{\partial T}{\partial V}\right)_P dV + C_V \left(\frac{\partial T}{\partial P}\right)_V dP = 0$$

   and verify that for an ideal gas this reduces to $PV^\gamma = const$, where $\gamma = \frac{C_P}{C_V}$

2. Show that

$$\left(\frac{\partial C_P}{\partial P}\right)_T = -T\left(\frac{\partial^2 V}{\partial T^2}\right)_P$$

   and

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

3. Pathria 1.2

4. (a) Starting form $dE = TdS - PdV$, show that for an ideal gas, the internal energy depends only on T, i.e. $E = E(T)$
   (b) Write down a general expression for the equation of state that is consistent with $E = E(T)$
   (c) Show that for a van der Waals gas C_V is a function of temperature alone

5. Three distinguishable particles can each occupy energy levels 0, ε, and 3ε. Calculate the entropy of the system if the total energy is $a)E = 2\varepsilon$, $b)E = 3\varepsilon$, $c)E = 9\varepsilon$

6. Consider a particle of mass m moving freely in a 1D box of size L. Find the eigenvalues and the normalized eigenvectors $\phi_n(x)$. Now consider a system of 3 non-interacting particles of mass m placed in such 1D box. If the energy of the system equals to $E = 38\varepsilon_0$, where $\varepsilon_0 = \frac{\hbar^2\pi^2}{2mL^2}$ is the lowest eigenvalue, find the entropy of the following three cases where the system is composed of:
   (a) 3 distinguishable spinless particles
   (b) 3 indistinguishable spinless bosons
   (c) 3 indistinguishable spin-1/2 fermions

Good Luck