ME 118 - HW 2

Due October 15, 2004

Reading:

Sears & Salinger, Chapters 1-5

Problems:

2.1 Heating and cooling.

A heat pump heats a house in the winter and is then reversed to cool the house in the summer. The interior temperature is to be maintained at 20^oC in the winter and 25^oC in the summer. Heat transfer through the walls and roof is estimated to be 2400 kJ per hour per degree temperature difference between the inside and the outside.

a) If the outside temperature in the winter is 0^oC, what is the minimum power required to drive the heat pump?

b) If the power input is the same as in part a, what is the maximum outside summer temperature for which the inside of the house can be maintained at 25^oC?

2.2 Fundamental equations.

The following equations are purported to be fundamental equations of various thermodynamic systems for S(U, V, N). However, some are not consistent with the second law and the associated corollaries (Postulates II-IV in Callen).

a) For each, sketch the fundamental relationship between *S* and *U* while holding *N* and *V* constant.

b) Indicate if the equations are not physically permissible and indicate why. Use the following criteria.

- Entropy is extensive, $S(\lambda U, \lambda V, \lambda N) = \lambda S(U,V,N)$
- Entropy is continuous, differentiable, and monotonically increasing, $(\delta S/\delta U)_{V,N} > 0$.
- Entropy vanishes at absolute 0, at $(\delta U/\delta S)_{V,N} = 0$, $S=0$.

The quantities *A* and *C* are constants, which are different for each equation.

a) $S = A\,(NVU)^{1/3}$
b) $S = A(NU/V)^{2/3}$
c) $S = A(NU + CV^2)^{1/2}$
d) $S = A\,V^3/NU$
e) $S = A\,(NU)^{1/2}\exp(-CV^2/N^2)$
f) $U = A\,S^2/V\,\exp(CS/N)$

2.3. Euler equation.

For each of the physically possible fundamental thermodynamic equations from problem 2.1, determine the thermodynamic temperature, the pressure and the chemical potential. Verify that the representations for these properties are correct by inserting the results into the Euler equation.

2.4 Van der Waals gas.

Using the Van der Waals equation of state,

$$(P+a/v^2)(v-b)=RT$$

where *a* and *b* are constant,

a) Show that the specific heat at constant volume, c_v, depends only on temperature.

b) Use the general relations derived in class to find the change in internal energy and the change in entropy between a state of interest and a reference state. The results should be in terms of the specific heat at constant volume, the temperatures, the specific volume at the reference state, and the Van der Waals' coefficients *a* and *b*.