PHY 3513 – PROBLEM SET 3

1) It is desired to freeze 50 kg of water in a refrigerator operating at 0ºC. The heat leaving the refrigerator is expelled into a room that is at a temperature of 20ºC. Calculate the minimum power required to freeze all of the ice in one hour. Note that the heat of fusion of water is L=334 kJ/kg.

2) It is desired to increase the efficiency of a Carnot engine by either *increasing* the temperature of the high temperature reservoir by an amount ΔT or by *decreasing* the temperature of the low temperature reservoir by the same ΔT. Which choice will result in the greatest increase in efficiency? *Hint*: examine the ratio of the two new efficiencies.

3) **Text Problem 4.1 –** refer to problem 8 of homework set 1 (text problem 1.34). Note that Q_{in} is the sum of the two positive heat transfers calculated in that problem, In part b, to calculate the Carnot efficiency, use the highest and lowest temperatures that occur in the cycle.

4) **Text, problem 4.4** – note that the specific heat capacity of water is 4190 J/kg-K and that water has density ρ=1000 kg/m³.

5) A *heat pump* is a refrigerator that is used to heat the interior of an enclosure, rather than to cool it; i.e., it is used to remove heat from a low temperature reservoir and transfer it to a high temperature reservoir. Let T_C and T_H be the temperatures of the low and high temperature reservoirs and let Q_{out} and Q_{in} be the heat transferred *out of* the low temperature reservoir and the heat transferred *into* the high temperature reservoir (so that both Q's are positive).

a) Define the heat pump coefficient of performance by $K=Q_{in}/W$, where W is the work done by the refrigerator. Note that this definition of K is in accord with the general definition of coefficient of performance or efficiency as "what you get out" divided by "what you put in". Show that for a Carnot heat pump, K is given by $K=T_H/(T_H-T_C)$.

b) Suppose that on a cold winter day, the temperature outside is 0ºC (not Miami!), and it desired to maintain the temperature inside a house equipped with a Carnot heat pump at 20ºC. Calculate the coefficient of performance of this heat pump.

6) **Text Problem 3.10**

7) **Text Problem 3.11**

8) **Text Problem 3.28 –** note that air is mostly made up of diatomic molecules, and that increasing the volume at constant pressure also changes the temperature. Choose the initial temperature (room temperature) to be 20ºC.

9) Consider a thermally insulated resistor with resistance R=20 Ω and mass m=5.0 g. The resistor is made of a material with specific heat capacity c=850 J/(g-K) and carries a current of 2.0 A for a time period of 1.0 s.

a) Calculate the increase in the temperature of the resistor if it has initial temperature T_{in}=20ºC. Recall that the power dissipated by a resistor is given by $P=I^2R$.

b) Determine the increase in the resistor's entropy over the period that the current passes through it.

10) An ideal gas with adiabatic index γ is taken around a complete thermodynamic cycle consisting of three steps. Starting at point A, the pressure is increased at *constant volume* V_1 from P_1 to P_2 at point B. From point B to point C, the gas is allowed to expand *adiabatically* from volume V_1 and pressure P_2 to volume V_2 and the original pressure P_1. Finally, from point C to point A, the volume of the gas is decreased at *constant pressure* P_1 back to the original volume V_1.

a) Make a PV diagram of the complete cycle.

b) For each step of the cycle, determine the change in the entropy of the gas. Sum your results to find the total entropy change for the whole cycle. Note that every step is reversible.

c) Use the adiabatic relations to eliminate the pressure from your result for part b. Show that the resulting expression gives a total entropy change for the complete cycle equal to zero.

11) Suppose that the molar specific heat capacity of an ideal gas at constant volume is a linear function of temperature given by $C_V = A + BT$, where A and B are constants. Show that the change in entropy per mole in a process that takes the gas from volume V_{in} and temperature T_{in} to volume V_f and temperature T_f is given by

$$\Delta S/n = A \ln(T_f/T_{in}) + B(\Delta T) + R \ln(V_f/V_{in})$$