Homework # 6

Problem #1
A room air conditioner operates as a Carnot cycle refrigerator between an outside temperature T_h and a room at a lower temperature T_l. The room gains heat from outdoors at a rate $A(T_h - T_l)$; this heat being removed by the air conditioner. The power supplied to the cooling unit is P.
(a) Show that the steady state temperature of the room is

$$T_l = \left(T_h - \frac{P}{2A}\right) - \left[\left(T_h + \frac{P}{2A}\right)^2 - T_h^2\right]^{1/2}$$

(b) If the outdoor temperature is at 37 ^{0}C and the room is maintained at 17 ^{0}C by a cooling power of 2 kW, find the heat loss coefficient A of the room in W K^{-1}. In a realistic unit the cooling coil may be at 282 K and the heat exchanger at 378 K.

Problem #2 (5.5)

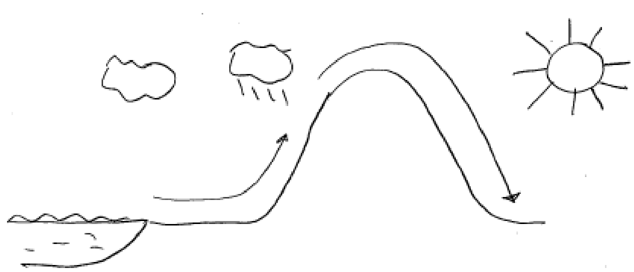
Consider a fuel cell that uses methane as fuel. The reaction is
$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$

a) Use the data at the end of this book to determine the values of ΔH and ΔG for this reaction for 1 mole of methane. Assume that the reaction takes place at room temperature and atmospheric pressure.
b) Assuming ideal performance, how much electrical work can you get out of the cell, for each mole of methane fuel?
c) How much waste heat is produced for each mole of methane fuel?
d) The steps of this reaction are

At - electrode: $CH_4 + 2H_2O \rightarrow CO_2 + 8H^+ + 8e^-$;
At + electrode: $2O_2 + 8H^+ + 8e^- \rightarrow 4H_2O$

What is the voltage of the cell?

Problem #3
Humid air coming from the Pacific Ocean ascends along the Rocky Mountains, expands and cools. In this process water vapor condenses and falls as a rain. Estimate the difference in temperatures of air at the base on both sides of the mountains. The humidity of air at the ocean coast is h=60 %, its temperature is 25 ^{o}C. At this temperature the pressure of the saturated water vapor is P_V=34 kPa. The latent heat of water evaporation is λ=2.5 kJ/kg. The atmospheric pressure at the base of the mountains is $P_0 = 10^5$



Problem# 4 (Problem 4.15 in textbook) (Extra credit 3 points)
In an absorption refrigerator, the energy driving the process is supplied not as work but as heat from a gas flame. (Such refrigerators are commonly use propane as fuel, and are used in locations where electricity is not available). Let us define the following symbols, all taken to be positive by definition:
Q_f=heat input from flame
Q_c=heat extracted from inside refrigerator

Q_r=waste heat expelled to room
T_f=temperature of flame
T_c=temperature inside refrigerator
T_r=room temperature

(a) Explain why the "coefficient of performance" (COP) for an absorption refrigerator should be defined as Q_c/Q_f.
(b) What relation among Q_f, Q_c, and Q_r is implied by energy conservation alone? Will energy conservation permit the COP to be greater than 1?

Use the second law of thermodynamics to derive an upper limit of the COP in terms of the temperatures T_f, T_c, and T_r alone.