4.42 quiz 2
November 17, 2003
Open book

1 (50) The courtyard in the center of the Gardner Museum in Boston is enclosed with a glass roof. The glass is supported by a steel frame. The steel, 2 cm thick, extends in a solid piece from the inside to the outside as shown in the figure. The outside surface of the steel is painted black and has a convective heat transfer coefficient of 5 $W/m^2\ ^oK$. The outside air temperature is 0 ^oC. Assume the inside surface of the steel is painted with a silver paint that has an emissivity of 0.1. The inside convective heat transfer coefficient is 3 $W/m^2\ ^oK$. The inside air temperature is 20 ^oC and the relative humidity is 45 percent. Assume the steel surface on the inside radiates to a black body at 20 ^oC and the steel surface on the outside radiates to a black body at 0 ^oC.

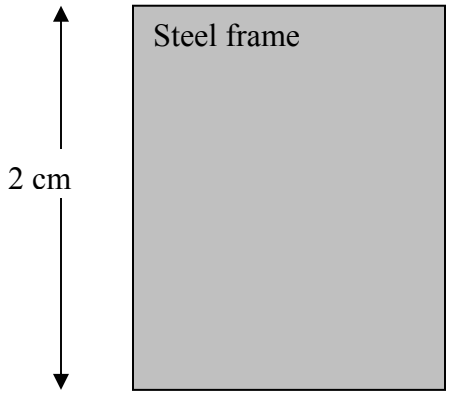
a) Draw the electric analogy for the heat transfer through the steel frame by using the linear form for radiation heat transfer (h_r).

b) What is the inside temperature of the steel frame?

c) Will water condense on the inside surface of the steel frame?

d) If the inside surface of the steel is painted black, will this cause worse condensation problems?

Outside air Tout = 0 C
Black surface, h(convection) = 5 $W/m^2\ ^oK$



Inside air Tin = 20 C, RH = 45%
Silver surface, emissivity = 0.1
h(convection) = 3 $W/m^2\ ^oK$

2 (50) The following figure shows an air conditioning system. Fresh air (T_1=35^{o}C, relative humidity RH_1=50%, flow rate m_1=3 kg/s) is mixed with the return air (T_2=25^{o}C, relative humidity RH_2=60%, m_2=7 kg/s) to achieve state 3 in front of the cooling heat exchanger A. The air reaches state 4 (T_4=14^{o}C, relative humidity RH_4=100%) after the mixed air (state 3) passes through the cooling heat exchanger A. Because the state 4's air temperature is too low, the air will be heated by an electrical heater B before it is supplied to the room at state 5 (T_5=18^{o}C). The exhaust air from room has same state as return air.

Assume that the ducts and room facades have no heat transfer and no air leakage. The energy consumed by the fan in this air conditioning system can be neglected. For air, Cp=1.01kJ/kg.^{o}C is constant in temperature range of 14^{o}C to 25^{o}C.

Questions:
a). Calculate the total energy consumption (kJ/s) of the cooling heat exchanger A and electrical heater B.
b). If the air conditioning system is running under steady sate, how much moisture (vapor) is generated in the room (in g/s)?
c). Draw the air conditioning system's air processing cycle on the psychometric chart. Please label states 1, 2, 3, 4 and 5 clearly.