ChE 306: HEAT TRANSFER
FALL 2010
Homework #1
(80 points)
DUE: FRIDAY, AUGUST 27, 2010

Chapter 1 Problems

1. On a winter day, the inner surface of a glass window is 20 ^{o}C and the outer surface is 5 ^{o}C. The window is 7.5 mm thick, and measures 1 m by 3 m (length by width). Look up the thermal conductivity of plate glass in Appendix A3.

   A. What is the rate of heat loss through the window (in Watts)?
   B. Given the same thickness and dimensions of a slab of oak, with the same temperature conditions as the glass window, what is the heat loss (in Watts)? (Use Table A3 again) Compare your answer to (A) to see if your numbers make sense.
   C. Returning to the glass window, but on a summer day in Alabama, where the surface temperature on the outside surface of the glass is 104 ^{o}F and the inside surface temperature is 77 ^{o}F, what is the rate of heat transfer into the room through the glass (W)?

2. A rectangular slab of wood that is 50 mm thick has a known heat flux of 40 W/m^2. The surface temperatures on both sides of the wood slab are 40 and 20 ^{o}C, respectively.
   A. What is the thermal conductivity of the wood?
   B. What thickness of an aluminum slab would be required to achieve the same heat flux for the same temperatures?

3. Pressurized water at 50 ^{o}C flows inside a 5-cm inner diameter, 1 m long tube with the inside surface temperature maintained at 130 ^{o}C. The convective heat transfer coefficient between the water and the tube surface is 2000 W/m^2-^{o}C.
   A. What is the convective heat transfer coefficient in Engineering (English) units (Btu/h-ft^2-^{o}F)?
   B. What is the heat transfer rate, q, from the tube to the water (in kW)?
   C. Does the water exit the tube at 50 ^{o}C? If not, estimate the new exit temperature for a flow rate of 2.5 kg/s.

4. A computer chip must be cooled by the flow of air over its top surface. The chip is square and has a flat surface with 5 mm width. It is connected to the CPU by a plastic film so that it is well insulated on the bottom and the sides. The limiting (maximum) temperature to use the chip is 85 ^{o}C. Assume the air is at 15 ^{o}C and has a convection coefficient (h) of 50 W/m^2-K.
   A. What is the maximum rate of convective heat transfer (in W) from the chip?
   B. What is the maximum rate of convective heat transfer (in W) if the coolant is changed to a liquid with h = 300 W/m^2-K?
   C. If there were no convection, but radiation is considered as a way of cooling the chip, what is the maximum radiative cooling rate (in W) for the chip surface (which has an emissivity of 0.9)? You may assume that the temperature of the surroundings is 15^{o}C.
   D. Which situation would be better: combining air convection (part A) with radiative cooling (part C) or just using the liquid coolant (part B)?

(OVER)

5. A steam pipe at an oil refinery passes through the air-conditioned control room, which has an air temperature of 25 ^oC and walls also at 25 ^oC. The pipe is uninsulated (metal is exposed to air) and the surface of the pipe is 150 ^oC. The pipe is 25 m long and has an outside diameter of approximately 4 inches (10 cm). Given that the convection coefficient for natural convection from the steam pipe to the room air is h = 10 W/m^2-K, and that the surface emissivity, ε, of 0.8:

A. Determine the rate of heat loss (q) from the pipe due to convection.
B. Determine the rate of heat loss (q) from the pipe due to radiation.
C. What is the total rate of heat loss from the pipe?
D. What would your answers to (A) and (B) be if the pipe were made of a different material with emissivity of 0.7?

Chapter 2 Problems

6. Work Problem 2.6 in Incropera & DeWitt.

7. Work Problem 2.8 in Incropera & DeWitt.

8. Work Problem 2.16 in Incropera & DeWitt.
Determine the required thermal conductivity of the manufacturer's insulation, and use Appendix A3 (p 937-940) to determine what material the insulation might be made of.