ChE 306: HEAT TRANSFER
FALL 2010
Homework #2 (60 points)
DUE: FRIDAY, SEPTEMBER 3

Chapter 3 Problems

1. The defog dial in an automobile causes warm air to pass over the inside surface of the front windshield resulting in heat transfer from the inside (T_∞ = 40 °C) with a convective heat transfer coefficient of 30 W/m^2-K. Given: the windshield is made of plate glass and has a thickness of 0.4 cm, and the outside air is -10 °C with a convective heat transfer coefficient of 65 W/m^2-K.

A. **Determine the inner and outer surface temperatures** of the windshield.
Include a calculation of the total resistance of the air-window-air system.
B. The convective heat transfer coefficient is a function of fluid velocity (and Reynolds number); thus h increases as you drive faster. What would the **inner surface temperature** be for an outside convective heat transfer coefficient h_o = 100 W/m^2-K?

2. At companies like Radici-Spandex, the polymerization reactor room is kept at high temperatures because some of the reactants have high melting points. Thus, the air temperature in this room is typically 110 °F. At one end of the reactor room is the operator's office, which is kept at 76 °F by the air conditioning system. A stainless steel wall 8 feet tall and 14 feet wide separates the rooms. This wall is 0.5 inches thick. The air on both sides of the wall has a convective heat transfer coefficient, h = 5 Btu/h-ft^2-°F. Properties of stainless steel: Density = 7900 kg/m^3 = 493 lb$_m$/ft^3
Heat Capacity = 477 J/kg-K = 0.114 Btu/lb$_m$-°F
Thermal Conductivity = 14.9 W/m-K = 8.61 Btu/h-ft-°F

A. Draw a **sketch** of the problem, using an **arrow** to show the direction of heat transfer
B. Determine the **heat flux, q"**, in Btu/h-ft^2
C. You wish to save money on air conditioning the office by reducing the heat flux into the office to only 10 % of your answer in part B. You have polystyrene insulation that you can use to cover the entire surface of the wall. **How thick should this insulation be to achieve the required reduction in q" (q"$_{new}$ = 0.10 * q"$_{part\ B}$)?** Thermal conductivity of polystyrene insulation (k) = 0.016 Btu/h-ft-°F.
D. Should the insulation be placed on the office-side or reactor room side of the wall?

3. Pressurized liquid nitrogen at -80 °C passes through a 20-meter length of stainless steel pipe in an electronics factory at 12 kg/min. The pipe has an inner diameter of 1.0 cm and thickness of 0.20 cm. A layer of insulating urethane foam (2.0 cm thick) coats the outside of the pipe. The surface of the foam is exposed to the room air at 25 °C, which has a convective heat transfer coefficient of 12 W/m^2-K. Ignore radiation.

<u>Material Properties</u>

	LIQUID NITROGEN	STAINLESS STEEL	URETHANE FOAM
Density, ρ (kg/m^3)	1.69	7900	70
Thermal Conductivity, k (W/m-K)	0.0183	12.6	0.026
Heat Capacity, c_p (J/kg-K)	1.043	477	1045
Convective Heat Trans. Coeff., h (W/m^2-K)	32.0	---	---

A. Sketch the problem, **label** dimensions and **draw** an arrow to indicate the direction of heat transfer.
B. Draw a thermal resistance diagram indicating all resistances between the bulk temperatures (T_∞) of liquid nitrogen and room air.
C. Draw a rough qualitative graph to approximate temperature vs. radius starting from the liquid nitrogen temperature at r = 0 to the air temperature. Mark locations of the steel pipe and foam insulation.
D. What is the thermal resistance due to the urethane foam layer (in K/W)?
E. If the rate of heat transfer is -84.7 W, what is the surface temperature of the foam exposed to the room air?

4. A 6-inch inner diameter steel pipe carrying engine oil at 240 ^oF (h = 3.4 Btu/h-ft^2-^oF) loses heat to the outside air at 77 ^oF with h = 1.9 Btu/h-ft^2-^oF. The pipe is made of 1/4-inch thick steel (k = 33 Btu/h-ft-^oF), and is 150 ft long. It is coated with a 1/2-inch thick tube of foam insulation (k = 0.013 Btu/h-ft-^oF) to reduce heat loss.

What is the total rate of heat loss (q) from the pipe?

5. Work Problem 3.49.
NOTE: This problem will require a trial-and-error iterative solution.

6. Work Problem 3.64
Your answer may be counter-intuitive here. Try to explain your results in part C.