

ChE 306: HEAT TRANSFER
FALL 2010
Homework #5 Ch 7 & 8 (80 points)
DUE: FRIDAY, OCTOBER 8

1. Water is flowing over all of the surfaces of a 3-inch diameter, 50 foot long cylinder in cross-flow such that equation 7.52 applies to determine the Nusselt number. The water is flowing at 1.0 mph at a bulk temperature of 68 °F over the 104 °F cylinder surface at steady state.
 - A. What is the heat loss rate in W?
 - B. Evaluate the heat loss rate using Equation 7.53 and 7.54. Compare your answers to (A).
 - C. Returning to Equation 7.52, what velocity of water is required to double the heat loss rate?

2. Air at 25 °C passes over a 50-W light bulb at 0.5 m/s. The light bulb may be approximated as a sphere with a 5 cm diameter and surface temperature of 140 °C.
 - A. What is the rate of heat loss by convection to the air?
 - B. If the surroundings temperature is also 25 °C and the emissivity of the light bulb is 0.89, what is the rate of heat loss by radiation to the air (again, you may assume the light bulb is a sphere and ignore the threaded base in your calculation)?
 - C. What total fraction of the light bulb energy (50-W) is lost as heat?

3. Air flowing at 5 m/s at 25 °C and 1 atm is used on the outside of a tube bank to condense steam at 100 °C flowing through the tubes. The outer surface temperature of the tubes can be assumed to be 100 °C. The tubes are 1m long and have an outside diameter of 10 mm and inside diameter of 8 mm. The tube bank has 196 total tubes arranged in a square, aligned array with $S_T = S_L = 15$ mm.
 - A. Use Equation 7.64 to determine the total rate of heat transfer to the air.
 - B. Use Figure 7.13 to find the friction factor and estimate the pressure drop associated with the airflow.

4. Consider the tube bank in problem 3.
 - A. If the 196 tubes were replaced with a single pipe to transport the steam, what (inside) diameter pipe would be required to give the same cross-sectional area as all of the tubes?
 - B. Assuming this pipe has a 1 mm-thick wall (the same as the tubes above), how long must this pipe be to have the same total heat loss rate as the tube bank in part A? (Use Eq. 7.53) Assume the air is in cross-flow over the pipe, which has a surface T of 100 °C.

5. Ethylene glycol at 23 °F passes through a 1-inch schedule 40 steel pipe that has a constant inner surface temperature of 122 °F. The pipe is 60 feet long.

For a flow rate of 3 g/s, determine:

 - A. The hydrodynamic entry length for fully developed flow ($x_{FD,h}$)
 - B. The thermal entry length for fully developed flow ($x_{FD,t}$)
 - C. The convective heat transfer coefficient, h (in either W/m²-K or Btu/h-ft²-°F)
 - D. The outlet temperature of ethylene glycol in °F (using eq. 8.41 b)
 - E. The total heat transfer rate in Btu/h. (using eq. 8.34)

Notes: To avoid iterations, you may use 62.6 °F to determine the fluid properties. Also, schedule 40 refers to a specific pipe size; you will need to look up the actual diameter in a piping table (use Perry's Handbook or perhaps your fluid dynamics book or on-line resources).

6. Repeat Problem 5 for ethylene glycol flow rates of

- A. 200 g/s, and
- B. 60 kg/s.

Note: if you need to evaluate a fluid property at the surface temperature, use 350 K.

C. For all three flowrates (3 g/s, 200g/s, and 60kg/s), if you were asked to run a second iteration for each problem, what temperature would you use to look up fluid properties?

7. Pharmaceutical products are often sterilized by heating prior to packaging. In this case, the pharmaceutical product is heated from 25 to 75 °C by passing it through a 10 m long stainless steel tube with a diameter of 12.7 mm. The tube is wrapped with electrical tape to deliver a constant heat flux into the tube. The fluid enters the tube with a fully developed velocity profile and a uniform temperature at a flowrate of 0.2 m/s.

Fluid properties: density = 1000 kg/m³; heat capacity = 4000 J/kg-K, viscosity (μ) = 0.002 kg/s-m, thermal conductivity = 0.8 W/m-K, Pr = 10.

- A. What heat flux is required to reach 75 °C at the outlet?
- B. What is the surface temperature on the inside of the pipe at the exit?

8. Work Incropera and DeWitt Problem 8.51.

Note: “thin-walled” in the problem means that the thermal resistance due to conduction through the pipe can be ignored. This is often the case in heat exchanger-type problems, because the thermal conductivity of the metal pipe is usually not a significant barrier to heat transfer compared to the convection terms on both sides of the pipe. Also, note that “slowly flowing” can be used to mean that the flow is laminar; assume that the pipe is long enough that the flow is fully developed.