ChE 306: HEAT TRANSFER
FALL 2009
Homework #5: Chapters 7 & 8
(90 points)
DUE: MONDAY, OCTOBER 12

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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 ^{o}F over the 104 ^{o}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. An uninsulated steam pipe carries steam across a chemical plant. The pipe has a diameter of 0.5 m and has a surface temperature of 150 ^{o}C. In the winter it is exposed to -10 ^{o}C air moving in cross-flow across the pipe at 5m/s.
A. What is the total rate of heat loss for a 50 m pipe (in W)?
B. If the wind is in parallel flow over the pipe, the pipe is treated as a flat plate. Given the length of the pipe is 50 m, what is the heat loss per unit length (W) for this wind configuration?
C. Explain any difference in your answers.

3. Work Incropera and DeWitt Problem 7.68
B. What % of the light bulb energy is converted to thermal energy (in other words, what is the thermal inefficiency of the light bulb)?

4. Work Incropera and DeWitt Problem 7.83

5. Before an exhaust gas (which is primarily CO_2) is released from a chemical process, it is cooled by passing water on the exterior of the cylindrical pure aluminum pipe in cross-flow. The exhaust gas flowing at 0.080 kg/s enters the pipe at 94 ^{o}C and must be cooled to 40 ^{o}C when it leaves. The pipe has an outside diameter of 0.60 m and a wall thickness of 0.020 m. The water flowing outside the pipe maintains the inner surface at 34 ^{o}C.
A. Is the flow of exhaust CO_2 **laminar or turbulent**?
B. What total **rate of energy removal** (in W) is required to achieve an outlet temperature of 40 ^{o}C for the exhaust gas?
C. Using a Nu correlation, h_{CO_2} was determined to be 1.27 W/m^2-K. How **long** must the pipe be to reach an outlet temperature of 40 ^{o}C? (in m)

6. Ethylene glycol at 23 ^{o}F passes through a 1-inch schedule 40 steel pipe that has a constant inner surface temperature of 122 ^{o}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/m^2-K or Btu/h-ft^2-^{o}F)
D. The outlet temperature of ethylene glycol in ^{o}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 ^{o}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).

CONTINUED ON REVERSE

7. Repeat Problem 6 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?

8. Pharmaceutical products are often sterilized by heating prior to packaging. In this case, a liquid pharmaceutical product is heated from 25 to 75 ^oC by passing it through a 10 m long stainless steel tube with a 1/2 inch inner diameter. 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/m^3; 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 ^oC at the outlet?
B. What is the surface temperature on the inside of the pipe at the exit?

9. 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.