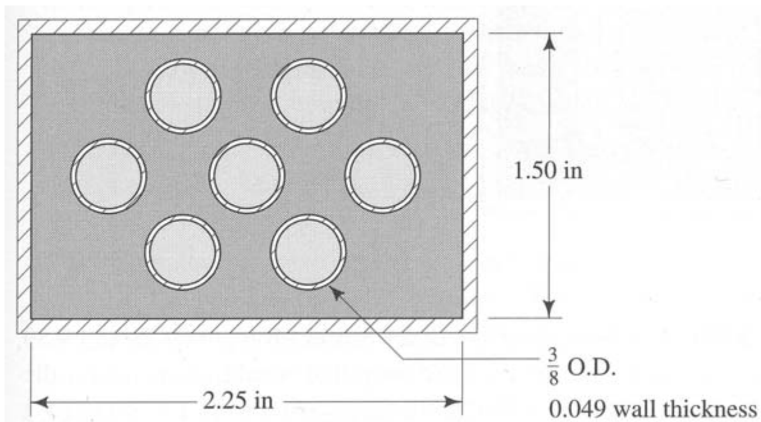
10.303 & 14.301 Fluid Mechanics

Homework Assignment #10 Fall 2006

Internal Viscous Flows

1. In the figure, ethylene glycol (sg = 1.10 and μ = 0.011 lbm/ft-s) at 77 F flows around the 3/8 inch tubes inside the rectangular channel.



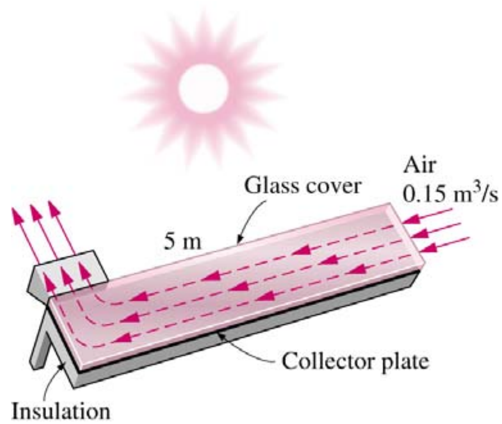
a. Calculate the volume flow rate of ethylene glycol in gal/min required for the flow to have a Reynolds number of 8000.

b. With the conditions of Part a, compute the energy loss per unit length of channel if all surfaces are smooth.

c. Redo Part b using your favorite computational software package (Matlab, Excel, etc.). In particular, given the geometry parameters, fluid properties, and flow rate, Q, you should compute the average velocity, v, the Reynolds number, Re, the friction factor, f, the velocity head, $v^2/2g$, and the head loss, h_L, in the channel (here L = 1 ft). This sequence of calculations is so common that it makes sense to have this capability readily available on the computer. Include a copy of your Matlab program or Excel spreadsheet, etc. to document this portion of the problem.

2. Consider a solar collector that is 1 m wide and 5 m long and has a constant spacing of 3 cm between the glass cover and the collector plate. Air flows within the rectangular channel at an average temperature of 45 C at a rate of 0.15 m^3/s as shown in the sketch.

Disregarding the entrance and roughness effects, estimate the pressure drop in the collector.



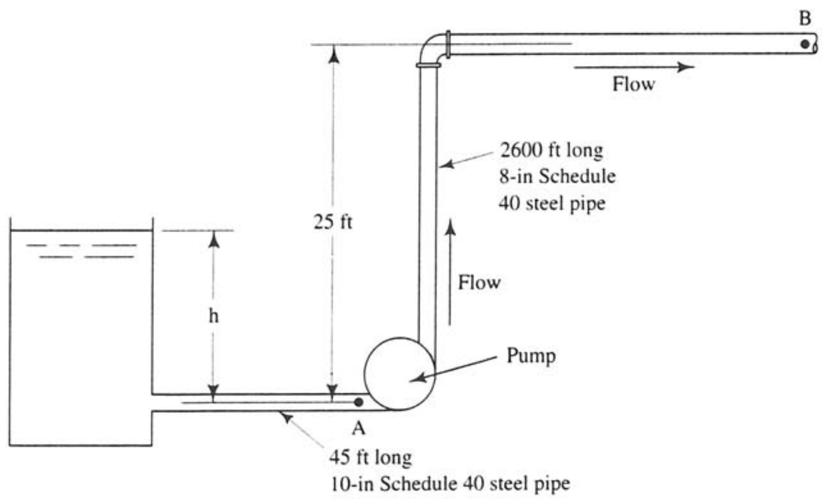
3. A positive displacement pump delivers an essentially constant discharge flow rate independent of the discharge pressure. In a particular flow system, with the suction pressure of the pump fixed at 10 psig, the desired water flow rate is 250 gal/min. The water temperature is 60 F and the horizontal Schedule 40 discharge line is 200 ft long. The pipe exit is open to the atmosphere. Assume that the suction line has a relatively short 3½" Schedule 40 commercial steel pipe (D = 3.5484 inches).

a. Compute the power added by the pump if the discharge line is a 2" Schedule 40 steel pipe.

b. Now, redo the calculation from Part a using your favorite computer analysis tool (Excel, Matlab, Mathcad, etc.). Validate the computer calculations using your hand calculations for the 2" Schedule 40 discharge line as a benchmark.

   Once you get this working, redo the calculations using both 2½" and 3" Schedule 40 commercial steel pipes. With these data, discuss how the power delivered by the pump changes versus discharge line size.

4. The figure below shows a portion of a fire protection system in which a pump draws water at 60 F from a reservoir and delivers it to point B at a flow rate of 1500 gal/min.



a. Calculate the required height, h, of water in the tank in order to maintain the pressure at point A at 5 psig. Neglect minor losses.

b. Assuming that the pressure at A is 5 psig, calculate the power (in hp) delivered by the pump to the water in order to maintain the pressure at B at 85 psig. Again, you can neglect minor losses since the pipe lengths are so long.

5. A vented tanker is to be filled with fuel oil (ρ = 920 kg/m^3 and μ = 0.045 kg/m-s) from a vented underground reservoir using a 20 m long, 5 cm diameter, smooth plastic hose. The connection to the reservoir has a slightly rounded entrance (K = 0.12) and the hose to the tanker has two smooth 90^o bends (K = 0.3 for each bend). The elevation difference between the oil level in the reservoir and the top of the tanker where the hose is connected is 5 m. A pump in the system between the reservoir and the tanker provides a constant flow rate of 0.01 m^3/s.

   Taking the kinetic energy correction factor at the hose discharge (note that this is a free jet) to be 1.05, and assuming an overall pump efficiency of 82 percent, determine the required power input to the pump to operate this system.