CHEN.3030 Fluid Mechanics

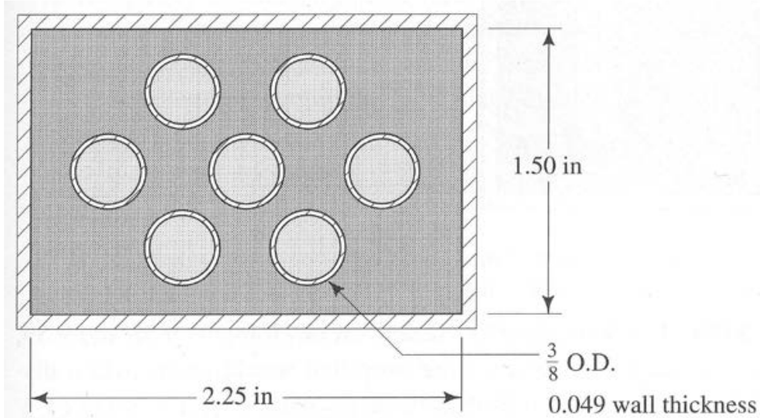
Homework Assignment #9 Spring 2017

Internal Viscous Flows

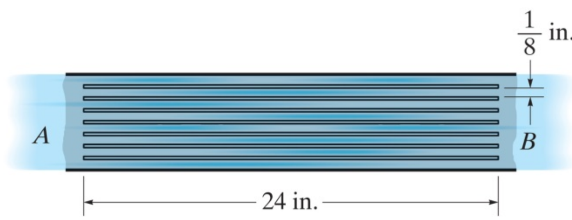
1. In the figure, ethylene glycol (sg = 1.10 and μ = 0.011 lbm/ft-s) at 77 F flows around the 3/8 inch tubes inside the rectangular channel (i.e. the flow area is the grey area outside the tubes and inside the channel walls).

a. Calculate the volume flow rate of ethylene glycol in gal/min (gpm) required for the flow to have a Reynolds number of 1200.

b. With the conditions of Part a, estimate the energy loss per unit length of channel using Darcy's equation. State any assumptions.

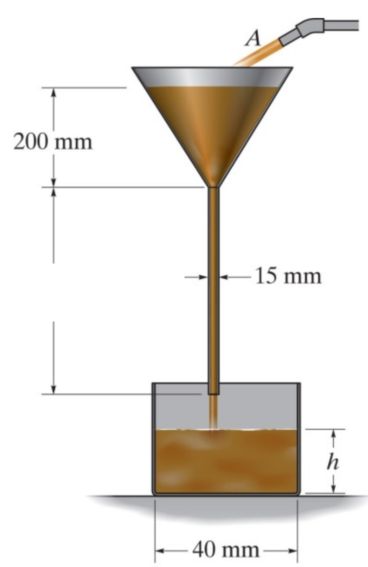


2. Air at T = 80° F flows with an average velocity of 20 ft/s through the parallel plates as shown in the sketch. The plates are each 15 in. wide, and the gap between them is 1/8 in. Assuming fully developed flow, determine the pressure difference $\Delta P = P_A - P_B$ (in psi) between the inlet A and the outlet B. Also, for the 8-channel system shown, determine the total discharge.

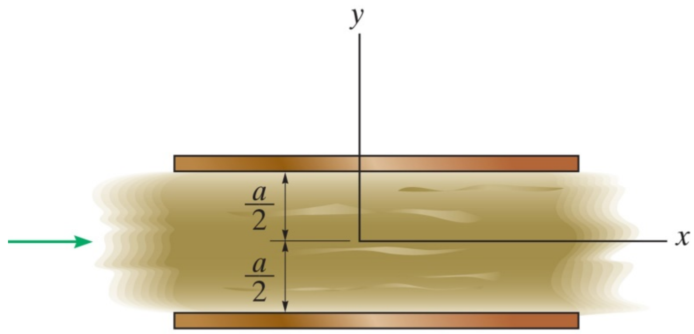


3. The setup in the sketch can be used to measure the viscosity of the fluid. In a particular situation, oil (sg = 0.92) is poured steadily into the funnel so that the level of 200 mm is maintained. The oil flows through the stem at a steady rate and accumulates in the cylindrical container. If it takes 6 seconds to fill the container to a depth of h = 180 mm, determine the viscosity of the oil.

Hint: Assume laminar flow conditions for this problem, but be sure to verify that this assumption is correct before problem completion.



4. The liquid flows between the two fixed horizontal plates due to a pressure gradient dP/dx. The width, b, of the plates into the page is large compared to the gap thickness, a. Using the coordinate system shown in the sketch, develop analytical expressions for the shear-stress distribution, $\tau(y)$, and the velocity profile, v(y), within the liquid. Assume laminar flow of a Newtonian fluid with viscosity μ. Be formal…



5. A 2 inch diameter horizontal pipe has a smooth interior surface and transports kerosene at 68°F. If the pressure drops 17 lbf/ft^2 in 15 feet, determine the maximum velocity of the flow. Also estimate the thickness of the viscous sublayer. **Hint:** Use the turbulent flow correlations given in Chapter 9 pf your text by Hibbeler then, at the end, always check the Reynolds number to make sure that the flow is really turbulent.

Extra Credit (up to 5 points): In class, we developed a relationship for the head loss, h_L, for laminar flow in a smooth circular pipe in terms of the pipe geometry (D and L), the fluid properties (ρ and μ), and the flow rate (Q or v). The result for laminar flow in a smooth circular pipe was

$$h_L = \frac{128\mu LQ}{\pi\rho g D^4} = \frac{32\mu L v}{\rho g D^2} = (32)(2)\frac{\mu}{\rho v D}\frac{L}{D}\frac{v^2}{2g} = \frac{64}{Re}\frac{L}{D}\frac{v^2}{2g} = f\,\frac{L}{D}\frac{v^2}{2g}$$

where the last expression gives Darcy's equation for the head loss in a circular pipe with the friction factor explicity defined as f = 64/Re for this case.

Your challenge for this extra credit problem is to do a similar development for laminar flow in a smooth rectangular channel of height a and width b. Your starting point should be the general energy equation and the expression for the velocity profile, u(y), for this situation as developed in your text.

Be formal and systematic in your development and be sure to show all the steps. An outline of the process and the final result are given in the class notes -- so your job here is to fill in the details!!!