Franklin W. Olin College of Engineering
ENGR 3310: Transport Phenomena

Problem Set 5

Assigned: 10/14/04 Fall 2004
Due: 10/21/04 by 5:00 pm

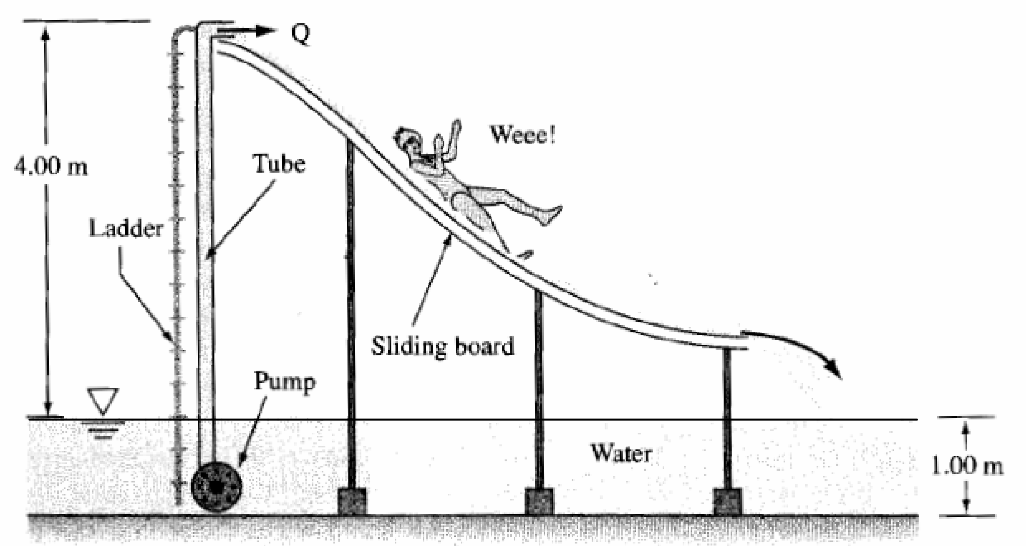
Problem 1: Slurp!
Human lungs can develop approximately 3 kPa of vacuum pressure, which comes in handy when sucking liquid through a straw. Based on this information, answer the following questions:

(a) What is the longest straw you could drink a chocolate milkshake through? (Density of chocolate milkshake = 1200 kg/m^3). Assume that the straw is vertical.
(b) If the straw is 15 cm long, how many gallons of chocolate milkshake could you drink in a minute? For this part of the problem, you can assume that the flow is laminar and the friction factor $f = 0.1$.
(c) If you are drinking water out of the same straw, how many gallons of water could you drink in a minute? (Use a friction factor of 0.01).

Problem 2: He Said – She Said
The designer of a machine has incorporated in his rough sketches a long, circular tube of diameter D_A and length L_A through which a viscous liquid will flow steadily at a volume flow rate Q_A, supplied by a positive displacement pump. The designer determines that the flow will be laminar and calculates the pressure drop is P_A, which is within acceptable limits. Subsequently, another designer finds a way to reduce the length of the tube by a factor of 2 so that $L_B = L_A/2$, but she must use a tube of rectangular cross-section of height b and width $10b$, yet having a flow area equal to that of the circular tube of diameter D_A. Because design B has the same flow area but only half the length, the second designer believes its pressure drop ΔP_B will be less than ΔP_A. Is the second designer correct?

Problem 3: Weeeeee!

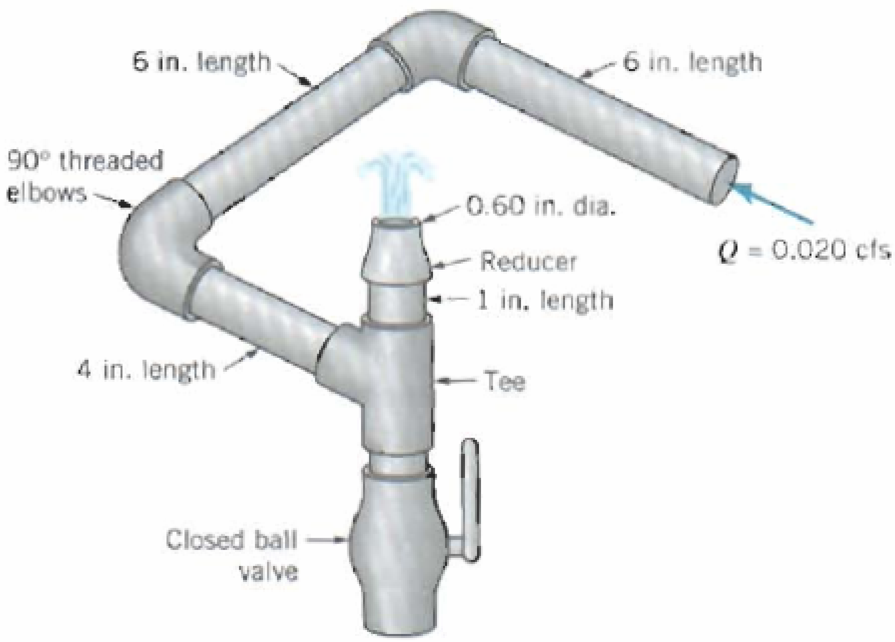
A small water slide is to be installed inside a swimming pool. The slide manufacturer recommends a continuous water flow rate Q of 1.39×10^{-3} m^3/s (about 22 gal/min) to ensure that the customers do not burn their bottoms. A pump is to be installed under the slide, with a 5.0 m long, 4.0 cm diameter hose supplying swimming pool water for the slide. The pump is 80% efficient and will rest fully submerged 1.0 m below the surface. The roughness inside the hose is ε = 0.008 cm. The hose discharges the water at the top of the slide as a free jet open to atmosphere. The hose outlet is 4.0 m above the water surface. For fully developed turbulent pipe flow, the kinetic energy correction factor is about 1.06. Ignore any minor losses here. Assume that ρ = 998 kg/m^3 and the kinematic viscosity is $\nu = 1.00\times10^{-6}$ m^2/s for the pool water. Find the brake horsepower (that is, the actual shaft power in Watts) required to drive the pump.



C6.3

Problem 4: Old School

8.66 Water flows steadily through the 0.75-in-diameter galvanized iron pipe system shown in **Video V8.6** and Fig. P8.66 at a rate of 0.020 cfs. Your boss suggests that friction losses in the straight pipe sections are negligible compared to losses in the threaded elbows and fittings of the system. Do you agree or disagree with your boss? Support your answer with appropriate calculations.



■ FIGURE P8.66

Problem 5: Blood

Consider the process of donating blood. Blood flows through a vein in which the pressure is greater than atmospheric, through a long small-diameter tube, and into a plastic bag that is essentially at atmospheric pressure. Based on fluid mechanics principles, estimate the amount of time it takes to donate a pint of blood. List all assumptions and show calculations.

Some hints for getting started:

1. From your own experience giving blood, or from talking to someone that has, make an estimate of the approximate geometry (length of tube, diameter of tube).
2. To get an estimate of the pressure in a blood vessel, use the internet or some other reference to get a better understanding of what a blood pressure measurement is actually measuring.
3. You may have to guess/estimate whether the flow is laminar or turbulent and the friction factor is. This may require some iteration to eventually get a good estimate. (Example: choose laminar flow and some value of f, solve for the velocity in the tube, then calculate Reynolds number to see if your assumption of laminar flow was correct.)
4. Please write down your assumptions as you go. Since there is no one right answer, I will need to be able to follow your work.