**Problem 1.** (15 pts) Consider the residential plumbing system shown. A pump drives water at $60^\circ F$ through a pipe of length $L = 15$ ft, through a standard tee where the branch leads to a bathroom, then through another pipe of length $L$, then through another standard tee, then through another pipe of length $L$, then straight out into the atmosphere. All of the pipes are made of drawn tubing and have inner diameter 0.5 in. Assume that the density of the water is constant. The flow to each bathroom can be represented as a pipe with length $L/2$ that empties into the atmosphere.

![Diagram of the plumbing system]

a) Suppose that flow to the bathrooms is shut off, so there is no flow through the branches of the two tees (that is, the flow is through the ‘run’ only). The volume flow rate out the end of the last pipe is 0.7 gal/s. What gage pressure does the pump produce at its exit? Account for all major and minor loss terms, except you can neglect any minor losses at the exit of the last pipe and the exit of the pump.

b) Now suppose that you want to have more flexibility in controlling the system, so you install globe valves at location ‘B’ (mid-way along the last pipe) and at location ‘A’. What does the pump’s exit pressure need to be now to keep the same flow rate as in a), again assuming that neither bathroom is in use and the valves are fully open?

c) Now, suppose that the valves are in place as in b), and the total flow rate out of the pump is still 0.7 gal/s, but now the flow to the first bathroom is open. What’s the flow rate out of the last pipe?

**Problem 2.** (10 pts) Text, problem 8.158.

(over)
Problem 3. (15 pts) The pumping system shown takes water (at 15°C) from the reservoir at the left and deposits it in the elevated tank on the right. The reservoir on the left is large enough that the water level is fixed at $H_1 = 5$ m. Water from the reservoir passes through a square-edged entrance into a horizontal galvanized iron pipe with diameter $D_1 = 10$ cm and length $L_1 = 2$ m; passes through a pump that imposes a pressure gain $\Delta p$; passes through another galvanized iron pipe, with diameter $D_1$ and length $L_2 = 5$ ft; goes through a 45° bend; goes through another galvanized iron pipe, with diameter $D_1$ and length $L_3 = L_2$; goes through a sudden expansion into a commercial steel pipe with diameter $D_s = 20$ cm and length $L_4 = 10$ m; goes through a sudden contraction into a galvanized iron pipe with diameter $D_1$ and length $L_5 = L_2$; passes through another 45° bend; goes through a galvanized iron pipe with diameter $D_1$ and length $L_6 = 5$ m; then enters the upper tank through a square-edged exit. The upper tank is cylindrical in cross-section, with diameter $D = 4$ m. What pressure rise does the pump have to provide in order that the liquid level in the upper tank rise by 4 cm per second at the instant when $H_2 = 4$ m?