# November 5, 2012

1. A reducing elbow shown in Fig. 1 is used to deflect water ($\rho$ = 998 kg/m$^3$) flow at a rate of 0.03 m$^3$/s in a horizontal pipe upward by an angle $\theta$ = 45° from the flow direction while accelerating it. The elbow discharges water into the atmosphere. The cross-sectional area of the elbow is 150 cm$^2$ at the inlet and 25 cm$^2$ at the exit. The elevation difference between the centers of the exit and the inlet is 40 cm. Determine (a) the mass flow rate $\dot{m}$ and water velocity at sections (1) and (2), $V_1$ and $V_2$, respectively, (b) the pressure at section (1), $p_1$, and (c) the horizontal component of the anchoring force, $F_{Ax}$, needed to hold the elbow in place. Assume frictionless flow.

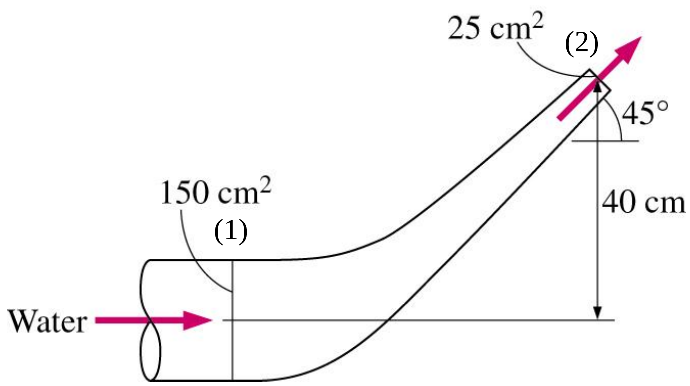


**Fig. 1**

2. Water ($\gamma$ = 62.4 lb/ft$^3$) is to be pumped from one large, open tank to a second large, open tank at a higher elevation as shown in Fig. 2. The pipe diameter throughout is 6 in. and the head loss associated is estimated as $h_L$ = 11 $\bar{V}^2$/2g, where $\bar{V}$ is the average velocity of water inside the pipe involved. If a flow rate of 1,600 gal/min is desired, find (a) the average velocity $\bar{V}$ and (b) the head loss $h_L$ and determine (c) the pump power $\dot{W}_p$ required in horse power. Note that 7.48 gal = 1 ft$^3$ and 1 hp = 550 ft·lb/s and g = 32.2 ft$^2$/s.

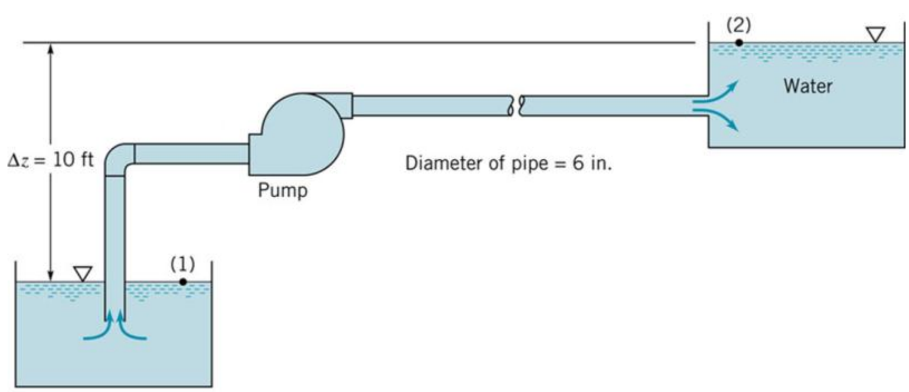


**Fig. 2**

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3. Two large, horizontal, infinite, parallel plates are in contact as shown in Fig.3. The top moving plate is sliding over the bottom fixed plate at a constant speed $V$. To reduce friction, the small gap of height $h$ between the plates is filled with an incompressible, viscous lubricant oil of viscosity $\mu$. The pressure gradient in the $x$-direction is zero and the only body force is due to the fluid weight. The flow is assumed steady, fully-developed, and laminar. (a) Use the following Navier-Stokes equation to derive an expression for the velocity distribution between the plates (*Show all your assumptions used*). (b) If the lubricant oil viscosity is $\mu$ = 0.38 N·s/m$^2$, top plate speed $V$ = 0.1 m/s, and the gap height $h$ = 0.1 mm, find the shear stress on the bottom fixed wall surface.

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)$$

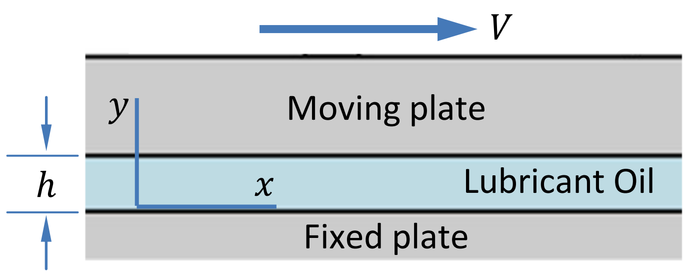


**Fig. 3**

4. The pressure drop per unit length, $\Delta p_\ell$, for the flow of blood through a horizontal small diameter tube shown in Fig. 4 is a function of the volume rate of flow, $Q$, the diameter, $D$, and the blood viscosity, $\mu$. By use of a dimensional analysis, develop a suitable set of dimensionless parameters for this problem.

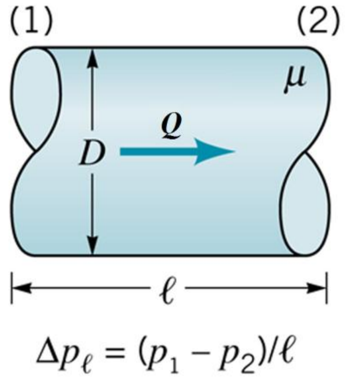


**Fig. 4**