CHAPTER 2 Fluid Properties and Basic Equations

$$\tau = \mu \frac{dV}{dy}$$

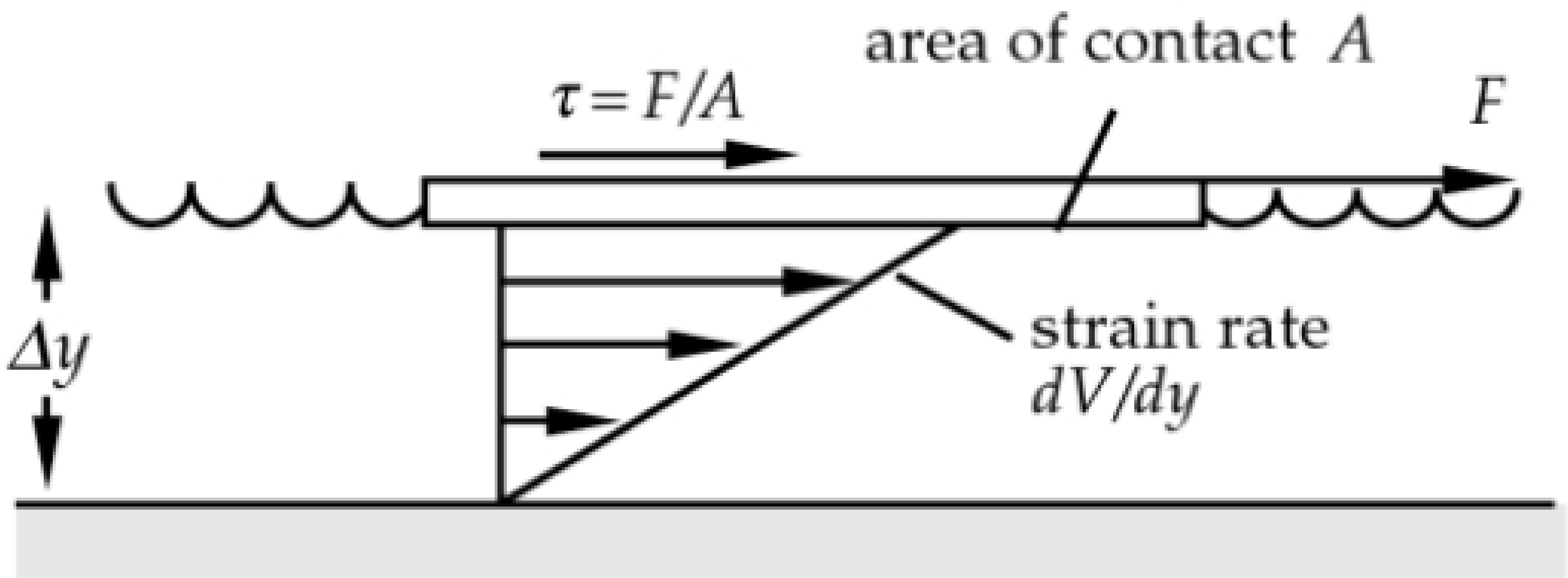


FIGURE 2.1. *Definition sketch for viscosity determination.*

$$\tau \int_0^y dy = \mu \int_0^V dV$$

$$\tau \Delta y = \mu \Delta V \qquad \tau = \mu \frac{\Delta V}{\Delta y}$$

Compressibility Factor

The compressibility factor is a property that describes the change in density experienced by a liquid during a change in pressure. The compressibility factor is given by

$$\beta = -\frac{1}{\text{V}\!\!\!-}\left(\frac{\partial \text{V}\!\!\!-}{\partial p}\right)_T \tag{2.8}$$

$$\boxed{Q = \left(-\frac{dp}{dz}\right)\frac{\pi R^4}{8\mu}} \qquad (2.11)$$

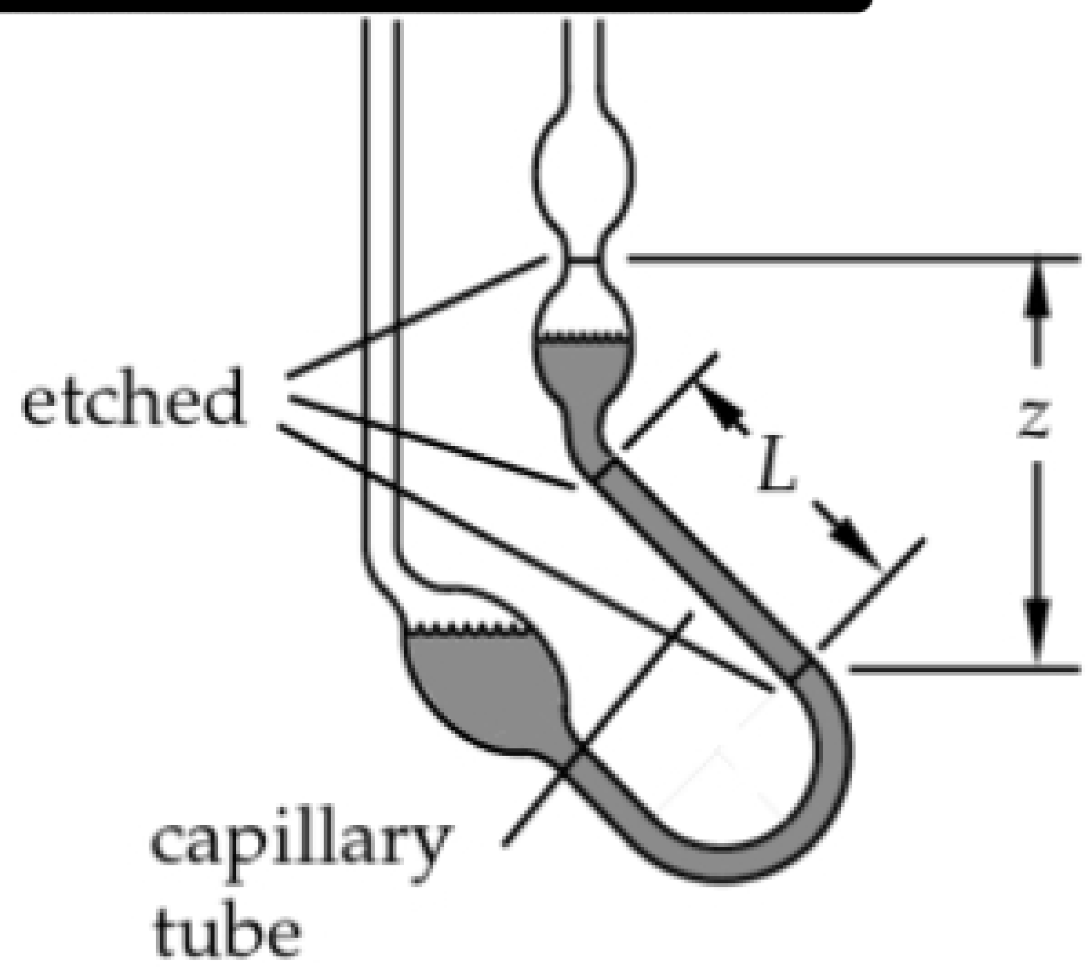
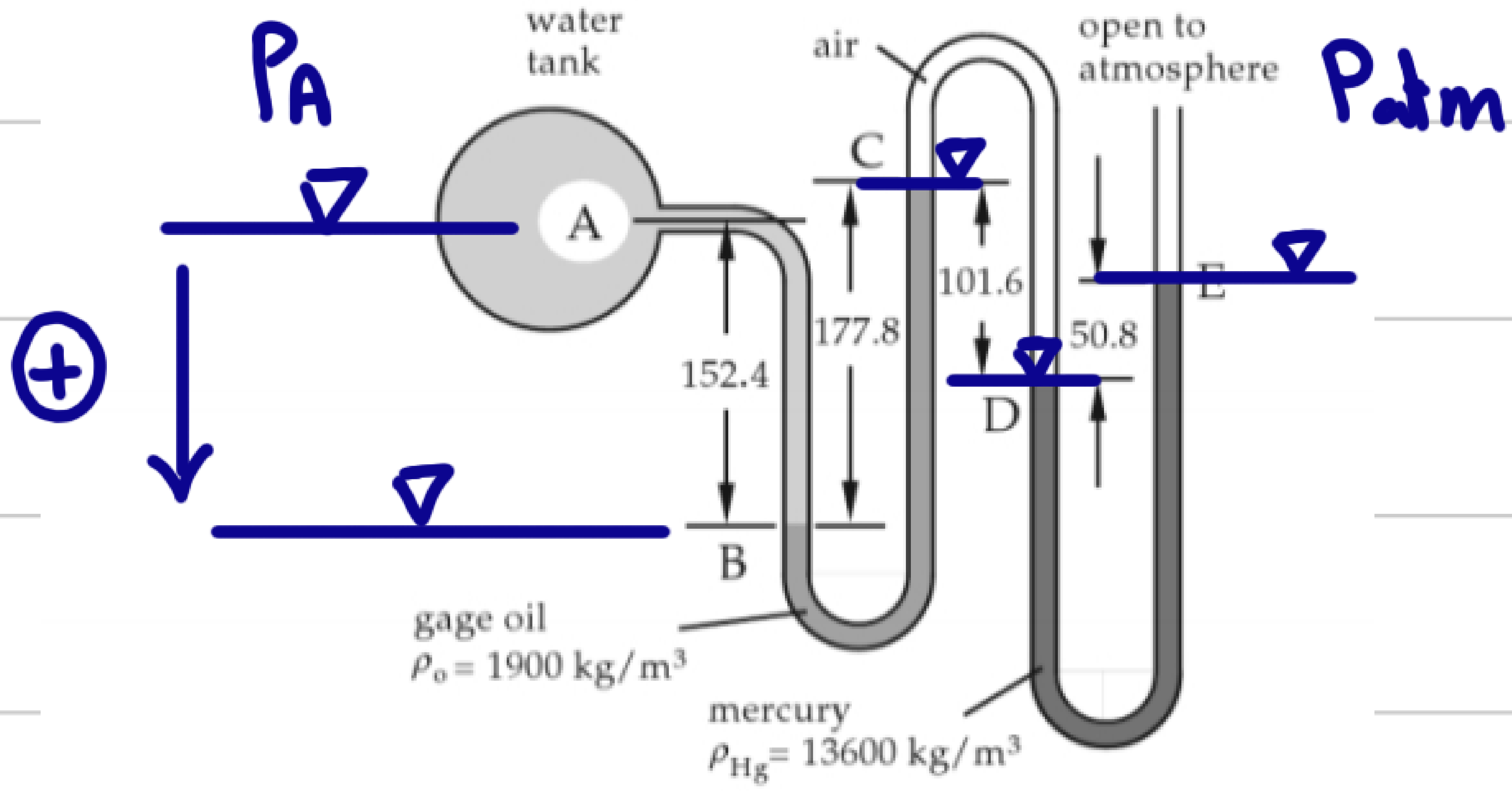


FIGURE 2.5. *A capillary tube viscometer.*

EXAMPLE 2.5. Figure 2.16 shows several manometers containing different fluids and attached together. For the configuration shown, determine the pressure in the water tank at A. (All dimensions are in mm.)



$$P_A + \rho_{water}\, g\,[152.4\times10^{-3}] - \rho_{oil}\, g\,[177.8\times10^{-3}]$$

$$+ \rho_{air}\, g\,[101.6\times10^{-3}] - \rho_{mercury}\, g\,[50.8\times10^{-3}] - P_{atm} = 0$$

$$P_A - P_{atm} = -\rho_{water}\, g\,[152.4\times10^{-3}] + \rho_{oil}\, g\,[177.8\times10^{-3}]$$

$$-\rho_{air}\, g\,[101.6\times10^{-3}] + \rho_{mercury}\, g\,[50.8\times10^{-3}]$$

We can neglect the effect of air because it is very small

$$P_A - P_{atm} = -\rho_{water}\, g\,[152.4\times10^{-3}] + \rho_{oil}\, g\,[177.8\times10^{-3}]$$

$$\cancel{-\rho_{air}\, g\,[101.6\times10^{-3}]} + \rho_{mercury}\, g\,[50.8\times10^{-3}]$$

$$P_A = [-1000 * 9.8 * 152.4 * 10^{-3}] + [1900 * 9.81 * 177.8\times10^{-3}]$$

$$+\left[13600 * 9.81 * 50.8 * 10^{-3}\right] + \left[101.35 * 10^{3}\right]$$

$$= 109946.5 \quad Pa$$

$$= 109.9 \quad kPa \simeq 110 \quad kPa$$

EXAMPLE 2.7. Figure 2.18 shows a tank being filled with kerosene issuing from two pipes, while a third pipe is simultaneously draining the tank. The pipe at A (ID = 52.5 mm) discharges kerosene at 1.83 m/s. The pipe at B (ID = 26.6 mm) discharges kerosene into the tank at a velocity of 1.98 m/s. The kerosene velocity in the discharge pipe (ID = 40.9 mm) is 0.305 m/s. Under these conditions, determine the time it takes for the kerosene level to change from a depth of 0.305 to 1.22 m. The tank diameter is 3.05 m.

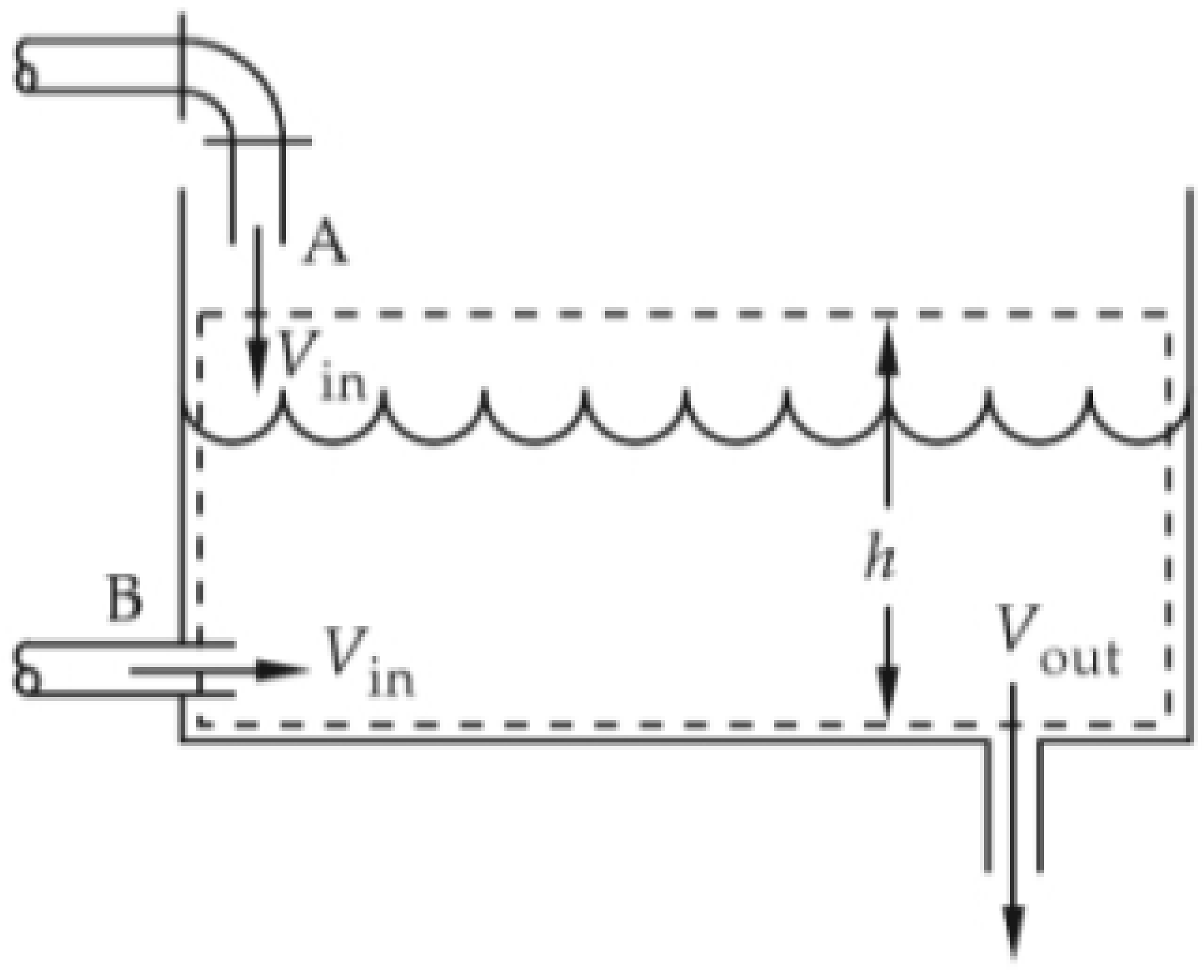


FIGURE 2.18. *A tank with two inlets and one drain.*

By using Continuity equation

$$\left.\frac{\partial m}{\partial t}\right|_{cv} + \iint_{cs} \rho V_n \, dA = 0$$

$$m = \rho \forall$$

$$\forall = \frac{\pi}{4} D^2 . h = 7.306\, h$$

$$m = 823 \times 7.306\, h$$

$$m = 6013\, h$$

$$\left.\frac{\partial m}{\partial t}\right|_{cv} = 6013 \frac{dh}{dt}$$

$$\iint_{cs} \rho V_n \, dA = \iint_{out} \rho V_n \, dA - \iint_{in} \rho V_n \, dA$$

$$= [\rho V A]_{out} = 823 \times \frac{\pi [0.0409]^2}{4} \times 0.305 = 0.33 \ \frac{kg}{sec}$$

$$(\rho A V)_A = 823 \times \frac{\pi}{4} [0.0525]^2 \times 1.83$$

$$= 3.25 \ kg/sec$$

$$(\rho A V)_B = 823 \times \frac{\pi}{4} [0.0266]^2 \times 1.98$$

$$= 0.909 \ kg/sec$$

By substituting in Continuity eqn.

$$0 = 6013 \frac{dh}{dt} + 0.33 - [3.25 + 0.909]$$

$$\therefore \frac{dh}{dt} = 6.37 \times 10^{-4}$$

$$\int_{0.305}^{1.22} dh = 6.37 \times 10^{-4} \int_{0}^{t} dt$$

$$(1.22 - 0.305) = 6.37 \times 10^{-4} \ t$$

$$\therefore t = 1437 \ sec \quad = 23.9 \ min \quad = 0.4 \ hr$$

EXAMPLE 2.9. A water jet impacts a flat surface, as shown in Figure 2.19. At section 1, the liquid jet has a diameter of 25.4 mm and a velocity of 4.57 m/s. Determine the force exerted on the surface by the jet.

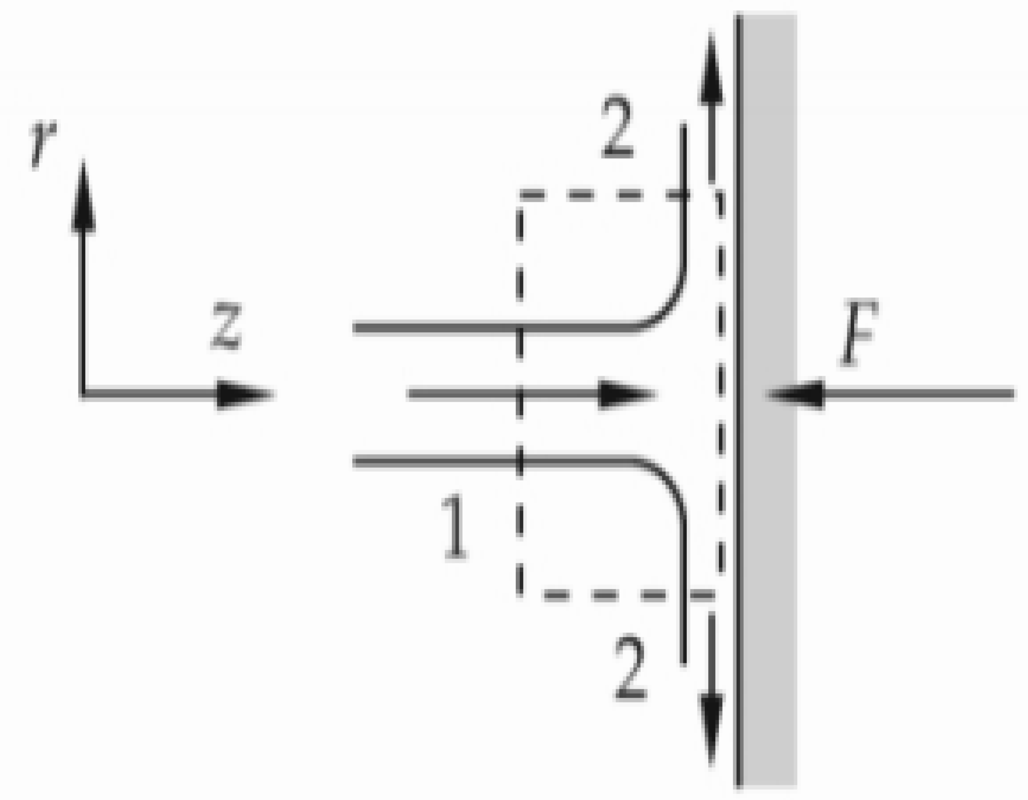


FIGURE 2.19. *A jet of liquid impacting a flat plate.*

$$\mathring{m} = \rho A V$$

$$A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4}[0.0254]^2 = 5.067 \times 10^{-4}\ m^2$$

$$\mathring{m} = \rho A V = 1000 * 5.067 * 10^{-4} * 4.57 = 2.32\ \frac{kg}{sec}$$

using momentum eqn

$$\overrightarrow{\sum F} = \sum_{out} \mathring{m} V - \sum_{in} \mathring{m} V$$

Take X - direction only because the Force directed along X-axis

$$-F = \mathring{m}[\cancel{V_{out}} - V_{in}]_x$$

$$-F = -\mathring{m} V_{in}$$

$\therefore F = \dot{m} V$

$= 2.32 \times 4.57$

$= 10.58 \text{ N}$