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ENCH 501: Transport Processes Quiz #7 **November 25, 2003**

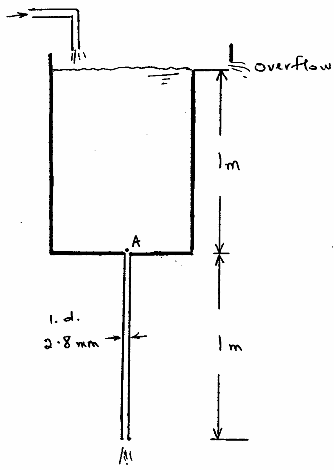
Time Allowed: 45 mins. **Name:**

A liquid (density = 930 kg/m^3) flows by gravity through a tube attached to the bottom of a large tank, as shown in the sketch below. The volume rate of the liquid out of the tube is measured as 0.048 m^3/hour. Neglecting entrance effects (i.e. assuming the flow is fully developed within the tube),

(a) estimate the viscosity (μ) for the fluid.

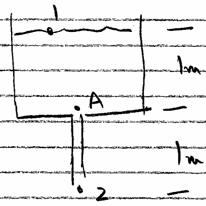
(b) Estimate the gauge pressure at point A (inlet of the tube).

Hint: Use Bernoulli equation with frictional losses allowed for. Also assume that the flow in the tube is laminar. Check this assumption.



ENCH 501 Solution Quiz 7 , Nov. 25, 2003

Bernoulli equation



$$\frac{P_1}{\rho g} + z_1 + \frac{V_1^2}{2g} = \frac{P_2}{\rho g} + z_2 + \frac{V_2^2}{2g} + h_f$$

where h_f is head loss due to friction.

For the problem, the average velocity at exit, point 2 is

$$V_2 = \frac{Q}{A_2} = \frac{Q}{\pi R^2} = \frac{0.048/3600}{\pi (1.4)^2 (10^{-6})} = 2.1654 \text{ m/s}$$

$P_1 = P_2 = P_{atm.}$; large tank $\Rightarrow V_1 \simeq 0$

$z_1 - z_2 = 2\text{m}$ + (ρ = const.)

Substitute into Bernoulli equation

$$2 = \frac{(2.1654)^2}{2(9.81)} + h_f \quad \text{or} \quad h_f = 1.761 \text{ m}$$

For laminar flow within the tube,

$$h_f = 64 \left(\frac{\mu}{D\bar{u}\rho}\right)\left(\frac{L}{D}\right)\left(\frac{\bar{u}^2}{2g}\right)$$

$$1.761 = 64 \left(\frac{\mu}{D\bar{u}\rho}\right)\left(\frac{1}{2.8(10^{-3})}\right)\left(\frac{2.1654^2}{2(9.81)}\right)$$

$$\therefore \frac{\mu}{D\bar{u}\rho} = 3.22(10^{-4}) \quad \text{or} \quad Re = 3102$$

(turbulent flow)

(a) $\mu = 2.8(10^{-3})(2.1654)(930)(3.22)(10^{-4})$

$= 0.001818$ Pa.s or 1.82 mPa.s

(b) For P_A, use Hagen - Poiseuille equation

Equation 6.30 (Notes)

$$Q = - \frac{\pi \left[\frac{dP}{dz} + \rho g \sin\beta \right] R^4}{8\mu}$$

$$= \frac{\pi \left[P_A - P_2 - \rho g L \sin\beta \right] R^4}{8 L \mu} \quad \text{and } \beta = -\frac{\pi}{2}$$

$$Q = \frac{\pi \left[(P_A - P_2) + \rho g L \right] R^4}{8 \mu L} \quad ; \; P_A - P_2 \text{ is gauge pressure at A}$$

substitute numbers

$$\frac{0.048}{3600} = \frac{\pi \left[P_{A_G} + 930(9.81)(1) \right] (4.4)^4 (10^{-12})}{8(1.818)(10^{-3})(1)}$$

$$P_{A_G} = 6,942.7 \text{ Pa}$$

$$= \frac{6.942}{101.325} \text{ ~~atm~~ } = \text{ ~~0.0685 atm.~~}$$

$\longrightarrow$

Note : The hydrostatic head at A = $h\rho g$

$$= 1(930)(9.81) = 9,123.3 \text{ Pa.}$$

$\therefore$ P_{A_G} is $<$ hydrostatic head.