MAE 101B, Spring 2009

Homework 1

Due Thursday, April 9, at 5 pm in EBU I office 2205

Guidelines: Please turn in a *neat* homework that gives all the formulae that you have used as well as details that are required for the grader to understand your solution. Required plots should be generated using computer software such as Matlab or Excel.
Please refrain from copying. Refer to the course outline for what constitutes copying

Use the following fluid properties:
water: $\rho = 1000\,kg/m^3$; $\mu = 0.001\,kg/m-s$.
kerosene: $\rho = 820\,kg/m^3$; $\mu = 0.0016\,kg/m-s$.
glycerin: $\rho = 1260\,kg/m^3$; $\mu = 1.49\,kg/m-s$.

1. The laminar fully-developed flow (low Reynolds number) in a channel between two infinite plates at $y = \pm h$ is:

$$u = \frac{h^2 \Delta p}{2\mu l}\left(1 - \frac{y^2}{h^2}\right) . \tag{1}$$

The flow is in the $+x$ direction, and the quantity, Δp, is defined to be positive.

a) Start from the incompressible Navier-Stokes equations to derive Eq. (1).

b) Start from Eq. (1) to derive a relationship between the friction factor, f, and the Reynolds number, $Re_h = Vh/\nu$.

2.

a) Glycerin flows with a given volume flow rate $Q = \int \vec{v} \cdot \vec{n} dA = \pi D^2 V/4$ through a horizontal pipe (1) of diameter D_1 that connects to pipe 2 of diameter D_2, as shown in figure 1. The pressure drop per unit length ($\Delta p/L$) in pipe 1 is measured to be 81 times smaller than in pipe 2. What is the diameter ratio D_2/D_1? Does your answer change if the fluid is water instead of glycerin? Why? Assume laminar flow in both cases.

b) Consider the same geometry as in part (a) and let $Q = 2\,m^3/s$. It is desired that the flow be laminar. What is the minimum value of D_1 given $D_2 = D_1/3$? What are the pressure drops per unit length under these conditions?

3. A fluid flows through a horizontal tube of length $20\,m$, and diameter $0.2\,mm$. The power delivered to the pipe by a pump is $W_s = 0.1\,hp$.

a) If laminar flow is desired, should the fluid be water? how about kerosene? Justify your answer.

b) Compute the wall shear stress if the flow with the fluid chosen in part (a) is at laminar transition point ($Re = 2300$).

4. Water flows upward at $10\,m/s$ in a $5\,cm$ diameter $5\,m$ long pipe from point 1 to point 2. The pipe is tilted upward at angle $\alpha = 30°$ to the horizontal plane. A pressure transducer reads $50\,kPa$ at point 1 and $30\,kPa$ at point 2. No power is being delivered to the pipe ($W_s = 0$).

a) Are the readings consistent? Justify your answer.

b) The correct reading at point 2 is $20\,kPa$. Compute the head loss and the friction factor.

5. Glycerin enters a diverging circular nozzle at contant volume rate $Q = 1\,m^3/s$. The diameter of the nozzle $D(x)$ is given (in m) by

$$\frac{D(x)}{L} = 0.5 + 0.1\frac{x}{L}\ ,$$

where L is length of the nozzle. The fluid exits the nozzle at laminar transition point ($Re = 2300$).

a) What is the length of the nozzle?

b) If the pressure is constant across the nozzle, what is the head loss?

Ungraded problems From text. 6.27