CHEN.3030 Fluid Mechanics (Section 202)

Homework Assignment #2 Spring 2017

More Fluid Properties

1. The Reynolds number is a dimensionless quantity that plays an important role in characterizing fluid flow phenomena. Within the context of viscous flow through pipes, the Reynolds number, Re, is defined as

$$Re = \frac{\rho v D}{\mu} = \frac{vD}{\nu}$$

where ρ is the fluid density, v is the mean fluid velocity, D is the pipe diameter, μ is the fluid dynamic viscosity, and ν is the kinematic viscosity.

a. If the mean velocity is 3 m/s and the fluid temperature is 30 C, compute Re for water flowing through a 3 mm diameter tube.

b. Re-compute Re for air as the working fluid in the system described in Part a. Assume standard atmospheric pressure. Can you explain the difference in values (note that the transition from laminar to turbulent flow occurs in the range of $2300 < Re < 4000$)?

2. The variation with temperature of the viscosity of air is represented well by the empirical Sutherland correlation,

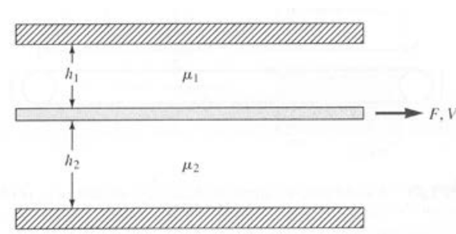
$$\mu = \frac{a_1 T^{3/2}}{T + a_2}$$

where the regression coefficients are approximately $a_1 = 1.357\text{x}10^{-6}$ N-s/m^2-K$^{1/2}$ and a_2 = 78.84 K, and μ is given in N-s/m^2 with T in K.

Assuming air as a perfect gas, compute and plot the dynamic viscosity (N-s/m^2 or Pa-s) and kinematic viscosity (m^2/s) versus T (^{o}C) over a range of temperatures from –20 ^{o}C to 120 ^{o}C at atmospheric pressure. These should be computer-generated plots (either Excel or Matlab) and both curves, μ(T) and ν(T), should be plotted on the same axes (with proper annotation). Do your results agree reasonably well with the data in your text? For example, pick 0 ^{o}C and 100 ^{o}C to do a quantitative comparison here.

Note: Be sure to show the equations and data used, and to identify how you generated the desired curves.

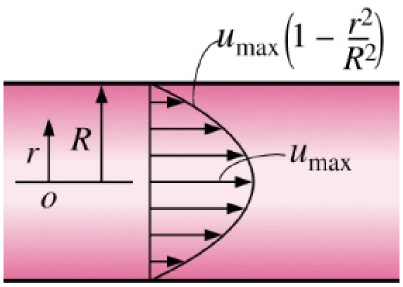
3. A thin plate is separated from two fixed plates by viscous liquids (with viscosities μ_1 and μ_2, respectively) as shown in the sketch. The plate spacings, h_1 and h_2, may be unequal. The contact area between the central plate and each fluid is A.



a. Assuming a linear velocity distribution within each fluid gap, derive an expression for the force F required to pull the plate with steady velocity v.

b. For a specific situation, h_1 = 6 mm and h_2 = 4 mm, and the two fluids have viscosities of μ_1 = 0.04 N-s/m^2 and μ_2 = 0.08 N-s/m^2. If the area of the top plate is 1.2 m^2, determine the force needed to move the plate at a steady state velocity of 1 cm/s.

4. In regions far from the entrance, fluid flow through a circular pipe is one-dimensional, and the velocity profile for laminar flow is given by $u(r) = u_{max}(1 - r^2/R^2)$, where R is the radius of the pipe, r is the radial distance from the center, and u_{max} is the maximum flow velocity, which occurs at the center of the pipe (see sketch).



a. Obtain a relation for the drag force applied by the fluid on a section of pipe of length L.

b. Determine the value of the drag force for water flow at 20 C with R = 0.08 m, L = 15 m, u_{max} = 3 m/s and μ = 0.0010 N-s/m^2.

5. A solid cylindrical needle of diameter D, length L, and density ρ may float on a liquid of surface tension σ.

a. Neglecting buoyancy effects, derive a formula for the maximum diameter needle able to float on the liquid. **Hint:** Simply compare the upward surface tension force with the downward gravity force.

b. Determine D_{max} for a steel needle (sg = 7.84) and water at 20 C. Assume a contact angle of zero degrees. Does your result appear reasonable?