Homework set 1

Due: 2:10 PM – September 7, 2018

Problem 1

Froude number is an important dimensionless parameter, widely used for certain types of fluid flow problems. It is defined as $\text{Fr} = V/\sqrt{gL}$, where V is a velocity, g the acceleration of gravity, and L is a length. Determine value of the Froude number for $V = 20\ ft/s$, $g = 32.2\ ft/s^2$, and $L = 8\ ft$. Recalculate the Froude number using SI units for the same V, g, and L. Explain significance of the results you found from these calculations.

Problem 2

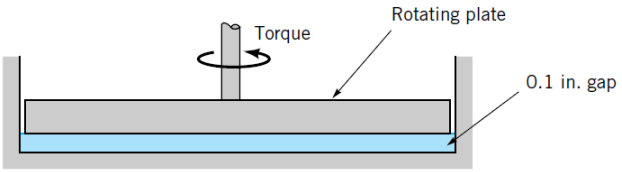
The local governing equation for a fluid can be reduced to the Navier-Stokes equation of motion under certain assumptions. The one-dimensional form of this equation has been written below, but with the ρ distributed incorrectly.

$$\frac{\partial v}{\partial t} + \rho v \frac{\partial v}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial y} - \rho g + \frac{\mu}{\rho^2}\frac{\partial^2 v}{\partial y^2} \tag{1}$$

First, find the dimension of each term in the equation as shown above. Can you find how to multiply or divide each of the 5 terms by ρ to get a dimensionally correct relation?

Problem 3

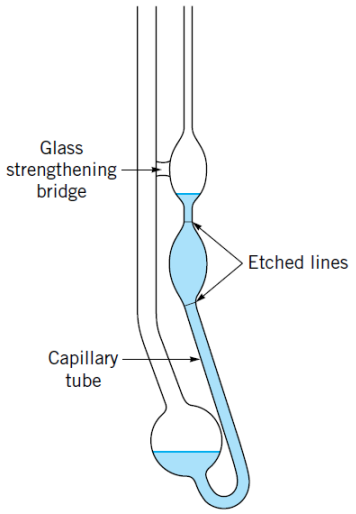
A circular plate (with radius of 6 inch) is placed over a fixed bottom plate with a 0.1-inch gap between the two plates filled with glycerin as shown. Determine the torque required to rotate the circular plate slowly at 2 rpm. Assume that the velocity distribution in the gap is linear and that the shear stress on the edge of the rotating plate is negligible.



Problem 4

One type of capillary-tube viscometer is shown in the figure below. For this device the liquid to be tested is drawn into the tube to a level above the top etched line. The time is then

obtained for the liquid to drain to the bottom etched line. The kinematic viscosity, ν in m^2/s is then obtained from the equation where $\nu = KR^4t$ where K is a constant, R is the radius of the capillary tube in mm, and t is the drain time in seconds. When glycerin at 20°C is used as a calibration fluid in a particular viscometer, the drain time is 1430 s. When a liquid having a density of 970 kg/m^3 is tested in the same viscometer the drain time is 900 s. What is the dynamic viscosity of this liquid?



Problem 5

Water has a surface tension of 0.4 N/m. In a 3 mm diameter vertical tube if the liquid rises 6 mm above the liquid outside the tube, calculate the contact angle.

Problem 6

Air is introduced through a nozzle into a tank of water to form a stream of bubbles. If the bubbles are intended to have a diameter of 2 mm, calculate how much the pressure of the air at the tip of the nozzle must exceed that of the surrounding water. Assume that the value of surface tension between air and water as 72.7×10^{-3} N/m.

TEXTBOOK

Munson, B.R., Okiishi, T.H., Huebsch, W.W., and Rothmayer, A.P., "Fundamentals of Fluid Mechanics", 7th Edition, 2013, John Wiley & Sons.