ME 3710 – Spring 2024
Homework 1
Due January 18 at 11:59pm – upload to files to Gradescope
26 points

1.2.13 WP The volume rate of flow, Q, through a pipe containing a slowly moving liquid is given by the equation

$$Q = \frac{\pi R^4 \Delta p}{8\mu \ell}$$

where R is the pipe radius, Δp the pressure drop along the pipe, μ a fluid property called viscosity $(FL^{-2}T)$, and ℓ the length of pipe. What are the dimensions of the constant $\pi/8$? Would you classify this equation as a general homogeneous equation? Explain.

1.4.9 WP A *hydrometer* is used to measure the specific gravity of liquids (see Video V2.8). For a certain liquid, a hydrometer reading indicates a specific gravity of 1.15. What is the liquid's density and specific weight? Express your answer in SI units.

1.6.4 WP Video One type of *capillary-tube viscometer* is shown in Video V1.5 and in Fig. P1.6.4. 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 $\nu = KR^4 t$, 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?

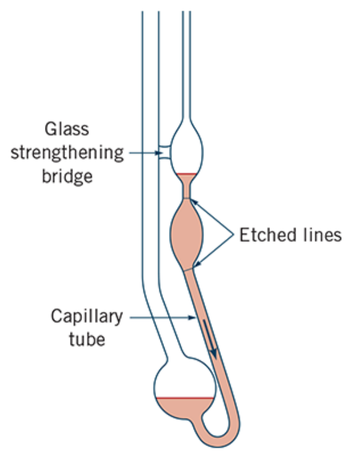


FIGURE P1.6.4

1.6.9 The kinematic viscosity of oxygen at 20 °C and a pressure of 150 kPa (abs) is 0.104 stokes. Determine the dynamic viscosity of oxygen at this temperature and pressure.

Problem 1.6.10 – Computational problem (Please submit your code with your solution)

For this problem use your favorite computational tool (Matlab, Python, C++, etc., but not Excel).

Fluids for which the shearing stress, τ, is not linearly related to the rate of shearing strain, $\dot{\gamma}$, are designated as non-Newtonian fluids. Such fluids are commonplace and can exhibit unusual behavior. Some experimental data obtained for a particular non-Newtonian fluid at 80 °F are shown below.

$\tau(\text{lb/ft}^2)$	0	2.11	7.82	18.5	31.7
$\dot{\gamma}(s^{-1})$	0	50	100	150	200

Plot these data and fit a second-order polynomial to the data using a suitable graphing program. What is the apparent viscosity of this fluid when the rate of shearing strain is 70 s^{-1}? Is this apparent viscosity larger or smaller than that for water at the same temperature?

1.6.21 WP Three large plates are separated by thin layers of ethylene glycol and water, as shown in Fig. P1.6.21. The top plate moves to the right at 2 m/s. At what speed and in what direction must the bottom plate be moved to hold the center plate stationary?

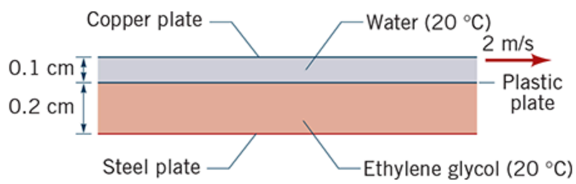


FIGURE P1.6.21

1.6.28 WP A layer of water flows down an inclined fixed surface with the velocity profile shown in Fig. P1.6.28. Determine the magnitude and direction of the shearing stress that the water exerts on the fixed surface for $U = 2$ m/s and $h = 0.1$ m.

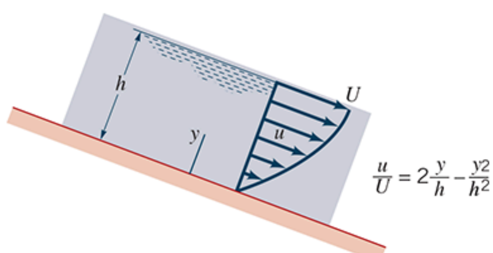
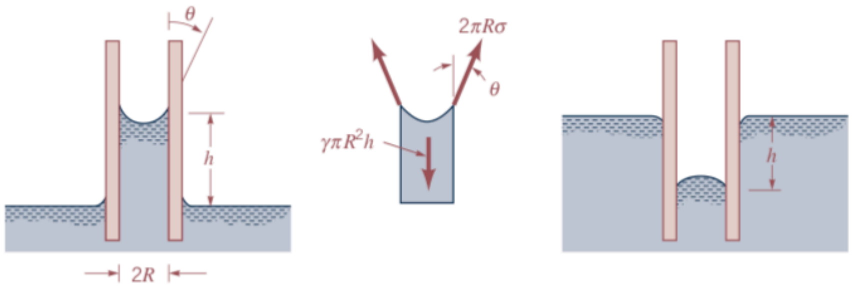


FIGURE P1.6.28

Problem 1.9.2 (See Video V1.10)

When a 2-mm-diameter tube is inserted into a liquid in an open tank, the liquid is observed to rise 10 mm above the free surface of the liquid. The contact angle between the liquid and the tube is zero, and the specific weight of the liquid is $1.2 \times 10^4 \text{ N/m}^3$. Determine the value of the surface tension for this liquid.



The action of surface tension in a tube inserted into a pool is to draw upward (or depress) the liquid in the tube a distance $h = \dfrac{2\sigma\cos\theta}{\gamma R}$ with respect to the elevation of the surrounding free surface.