1. Make use of Tables 1.3 in the text book (See the last page in this assignment) to express the following quantities in SI units: (a) 10.2 in./min, (b) 4.81 slugs, (c) 3.02 lb, (d) 73.1 ft/s², (e) 0.0234 lb·s/ft².

Sol) (a) \(10.2 \frac{\text{in.}}{\text{min}} \cdot \left(\frac{2.54 \times 10^{-2} \text{ m}}{1 \text{ in.}}\right) \cdot \left(\frac{1 \text{ min}}{60 \text{ s}}\right) = 4.32 \times 10^{-3} \text{ m/s}\)

(b) 4.81 slugs \(\cdot \left(\frac{14.59 \text{ kg}}{1 \text{ slug}}\right) = 70.2 \text{ kg}\)

(c) 3.02 lb \(\cdot \left(\frac{4.45 \text{ N}}{1 \text{ lb}}\right) = 13.4 \text{ N}\)

(d) \(73.1 \frac{\text{ft}}{s^2} \cdot \left(\frac{0.305 \text{ m}}{1 \text{ ft}}\right) = 22.3 \text{ m/s}^2\)

(e) 0.0234 \(\frac{\text{lb} \cdot \text{s}}{\text{ft}^2} \cdot \left(\frac{4.45 \text{ N}}{1 \text{ lb}}\right) \cdot \left(\frac{1 \text{ ft}}{0.305 \text{ m}}\right)^2 = 1.12 \text{ N/s/m}^2\)

2. Make use of Tables 1.4 in the text book (See the last page in this assignment) to express the following quantities in BG units: (a) 14.2 km, (b) 8.14 N/m³, (c) 1.61 kg/m³, (d) 0.0320 N·m/s, (e) 5.67 mm/hr.

Sol) (a) 14.2 km \(\cdot \left(\frac{3281 \text{ ft}}{1 \text{ km}}\right) = 46590 \text{ ft}\)

(b) 8.14 \(\frac{\text{N}}{\text{m}^3} \cdot \left(\frac{0.225 \text{ lb}}{1 \text{ N}}\right) \cdot \left(\frac{1 \text{ m}}{3.28 \text{ ft}}\right)^3 = 0.0519 \text{ lb/ft}^3\)

(c) 1.61 \(\frac{\text{kg}}{\text{m}^3} \cdot \left(\frac{0.0685 \text{ slug}}{1 \text{ kg}}\right) \cdot \left(\frac{1 \text{ m}}{3.28 \text{ ft}}\right)^3 = 0.003125 \text{ slugs/ft}^3\)

(d) 0.0320 \(\frac{\text{N} \cdot \text{m}}{\text{s}} \cdot \left(\frac{0.225 \text{ lb}}{1 \text{ N}}\right) \cdot \left(\frac{3.28 \text{ ft}}{1 \text{ m}}\right)= 0.0236 \text{ lb·ft/s}\)

(e) 5.67 \(\frac{\text{mm}}{\text{hr}} \cdot \left(\frac{0.00328 \text{ ft}}{1 \text{ mm}}\right) \cdot \left(\frac{1 \text{ hr}}{3600 \text{ s}}\right) = 5.17 \times 10^{-6} \text{ ft/s}\)
3. The information on a can of pop indicates that the can contains 355 mL. The mass of a full can of pop is 0.369 kg while an empty can weighs 0.153 N. Determine the specific weight, density, and specific gravity of the pop and compare your results with the corresponding values of for water at 20 °C. Express your results in SI units.

Sol) * Information from the description

Volume, \( V = 355 \text{ mL} = 355 \times 10^{-3} \text{ L} = 355 \times 10^{-3} \times (10^{-3} \text{ m}^3) = 355 \times 10^{-6} \text{ m}^3 \)

Total mass of full can, \( m_{\text{total}} = 0.369 \text{ kg} \)

Weight of an empty can \( W_{\text{can}} = 0.153 \text{ N} \)

From the information, we can determine the net mass of pop and then the density.

\[
m_{\text{pop}} = m_{\text{total}} - \frac{W_{\text{can}}}{g} = 0.369 - \frac{0.153}{9.81} = 0.353 \text{ kg}
\]

Then, (1) Density: \( \rho_{\text{pop}} = \frac{m_{\text{pop}}}{V} = \frac{0.353}{355 \times 10^{-6}} = 994.37 \text{ kg/m}^3 \)  

\( \text{c.f. } \rho_{\text{H}_2\text{O}@20^\circ\text{C}} = 998 \text{ kg/m}^3 \) (Because the textbook provides only the properties of water at 15.6 °C, you can use those values for comparison.)

(2) Specific weight: \( \gamma_{\text{pop}} = \rho_{\text{pop}} g = 9754.7 \text{ N/m}^3 \)  

\( \text{c.f. } \gamma_{\text{H}_2\text{O}@20^\circ\text{C}} = 9790 \text{ N/m}^3 \)

(3) Specific gravity: \( SG_{\text{pop}} = \frac{\rho_{\text{pop}}}{\rho_{\text{H}_2\text{O}@4^\circ\text{C}}} = \frac{994.37}{1000} = 0.994 \)  

\( \text{c.f. } SG_{\text{H}_2\text{O}@20^\circ\text{C}} = 0.998 \)
4. If 1 cup of cream having a density of 1005 kg/m³ is turned into 3 cups of whipped cream, determine the specific gravity and specific weight of the whipped cream.

Sol) Mass of 1 cup of cream, \( m_{\text{cream}} = (1005 \frac{kg}{m^3}) \times (\text{Volume of cup}, V_{\text{cup}}) \)

Since there is no change in total mass of cream, i.e. \( m_{\text{cream}} = m_{\text{whipped cream}} \)

Density of 3 cups of whipped cream,

\[
\rho_{\text{whipped cream}} = \frac{m_{\text{whipped cream}}}{3V_{\text{cup}}} = \frac{(1005 \frac{kg}{m^3}) \times (V_{\text{cup}})}{3V_{\text{cup}}} = \frac{1005 \frac{kg}{m^3}}{3} = 335 \frac{kg}{m^3}
\]

Then

(1) Specific gravity,

\[
SG = \frac{\rho_{\text{whipped cream}}}{\rho_{H_2O @ 4^\circ C}} = \frac{335 \frac{kg}{m^3}}{1000 \frac{kg}{m^3}} = 0.335 \quad \text{(Answer)}
\]

(2) Specific weight,

\[
\gamma_{\text{whipped cream}} = \rho_{\text{whipped cream}} \times g = (335 \frac{kg}{m^3}) \times (9.81 \frac{m}{s^2}) = 3290 \frac{N}{m^3} \quad \text{(Answer)}
\]
5. A Newtonian fluid having a specific gravity of 0.92 and a kinematic viscosity of $4 \times 10^{-4} \text{ m}^2/\text{s}$ flows past a fixed surface. Due to the no-slip condition (*The fluid sticks to a plate surface*), the velocity at the fixed surface is zero, and the velocity profile near the surface is shown in figure. Determine the magnitude and direction of the shearing stress developed on the plate. Express your answer in terms of $U$ and $\delta$, with $U$ and $\delta$ expressed in units of meters per second and meters, respectively.

**Sol)** Because the situation is related with the viscosity of oil, let’s use the following eq.

$$\tau = \mu \frac{du}{dy}$$

By using the information from the description,

$$\tau = \mu \frac{du}{dy} = \mu U \left[ \frac{3}{2\delta} \frac{3}{2} \left( \frac{y^2}{\delta^3} \right) \right] \quad \text{(because } u = U \left[ \frac{3}{2} \left( \frac{y}{\delta} \right) - \frac{1}{2} \left( \frac{y}{\delta} \right)^3 \right] \text{)}$$

Please note that the problem provides a kinematic viscosity $\nu$, not (dynamic) viscosity $\mu$ and thus we have to use,

$$\mu = \nu \rho = 4 \times 10^{-4} \cdot \left( SG \times \rho_{H_2O@4\text{C}} \right) = 4 \times 10^{-4} \cdot (0.92 \times 1000) = 0.368 \text{ N}\cdot\text{s}/\text{m}^2$$

Then, $\tau = \mu U \left[ \frac{3}{2\delta} \frac{3}{2} \left( \frac{y^2}{\delta^3} \right) \right] = 0.368 U \left[ \frac{3}{2\delta} \frac{3}{2} \left( \frac{y^2}{\delta^3} \right) \right] = 0.552 \frac{U}{\delta} \text{ N/m}^2 \quad \text{(Answer)}$

: because we need the shearing stress at the plate ($y = 0$)

Direction of shearing stress ($\tau$) **exerting on the plate due to motion of the fluid**

$\rightarrow$ Left \quad \text{(Answer)}
6. 3. The viscosity of liquids can be measured through the use of a rotating cylinder viscometer of the type shown in Fig. In this device the outer cylinder is fixed. The inner cylinder has a diameter \((R_i)\) of 40 cm and the gap between the inner and outer cylinder is 0.1 cm. The experiment reveals that the torque of 1.0 N-m is required in order to develop the angular velocity of inner cylinder \((\omega)\) of 100 rpm.

(a) The applied torque will create the shearing stress \((\tau)\) on the surface of inner cylinder. Determine the shearing stress due to the torque of 1.0 N-m.

(b) Determine the velocity at the surface of inner cylinder.

(c) Using the results from Questions (a) and (b), determine the viscosity of fluid. Assume that the fluid is Newtonian, i.e. the velocity distribution \((du/\,dy)\) in the gap is linear.

Sol) (a) Shearing stress, \(\tau = \frac{(\text{Force parallel to the surface})}{(\text{Surface Area})} = \frac{F_C}{A}\)

\[ F_C: \text{Force due to the measured torque} \]
\[ F_C = \frac{M}{R_i} = \frac{(1.0 \text{ N} \cdot \text{m})}{(0.4 \text{ m})} = 2.5 \text{ N} \]

\[ A: \text{Area of the outer surface of the inner cylinder} \] \[ A = 2\pi (0.4 \text{ m}) \cdot (0.5 \text{ m}) = 1.26 \text{ m}^2 \]

Then, \(\tau = \frac{F_C}{A} = \frac{2.5}{1.26} = 1.98 \text{ N/m}^2\) \(\text{(ANSWER)}\)

(b) Velocity at the surface of inner cylinder,

\[ u_{inner} = R_i\omega = (0.4 \text{ m}) \cdot (100 \text{ rev/min}) \cdot \frac{2\pi \text{ rad}}{1 \text{ rev}} \cdot \frac{60 \text{ sec}}{1 \text{ min}} \]

\[ = (0.4) \cdot (10.47) = 4.19 \text{ m/s} \] \(\text{(ANSWER)}\)

(c) Velocity of the outer cylinder, \(u_{outer} = 0\) (Stationary cylinder)

Because the fluid is Newtonian, the distribution of fluid velocity is linear.

\[ \frac{du}{dy} = \frac{u_{inner} - u_{outer}}{\text{gap}} = \frac{4.19}{0.001} = 4190 \text{ s}^{-1} \]

Then, \(\tau = \mu \frac{du}{dy} \propto 1.98 = \mu(4190) \propto \mu = \frac{1.98}{4190} = 4.73 \times 10^{-4} \text{ N} \cdot \text{s/m}^2\) \(\text{(ANSWER)}\)
7. In a test to determine the bulk modulus of a liquid it was found that as the absolute pressure was changed from 15 to 3000 psi the volume decreased from 10.240 to 10.138 in³. Determine the bulk modulus for this liquid.

Sol) Let’s use the definition of bulk modulus

\[ E_V = -\frac{dp}{dV/V} = \frac{3000 - 15}{10.138 - 10.240} \times 10^5 \text{ psi} \]  

(Answer)

8. As shown in Figure, surface tension forces can be strong enough to allow a double-edge steel razor blade to “float” on water, but a single-edge blade will sink. Assume that the surface tension forces act at an angle \( \theta \) relative to the water surface. (The mass of the double-edge blade is \( 0.64 \times 10^{-3} \) kg, and the total length of its sides is 206 mm. Determine the value of \( \theta \) required to maintain equilibrium between the blade weight and the resultant surface tension force. (b) The mass of the single-edge blade is \( 2.61 \times 10^{-3} \) kg, and the total length of its side is 154 mm. Explain why this blade sinks. Support your answer with the necessary calculation.

Sol)

(a) From the definition of the surface tension force,

\[ F_\sigma = \sigma_{\text{water}} \times (206 \times 10^{-3} \text{ m}) \]  

(From Table 1.6, \( \sigma_{\text{water}} = 7.34 \times 10^{-2} \) N/m)

\[ = (7.34 \times 10^{-2}) \times (206 \times 10^{-3}) = 0.0151 \text{ N} \]

Then, the vertical component of \( F_\sigma \) should be balanced by the weight of a double-edge blade.

\[ F_\sigma \sin \theta = mg \quad \Leftrightarrow \quad \sin \theta = \frac{(0.64 \times 10^{-3})(9.81)}{0.0151} = 0.416 \]

\[ \therefore \theta = 24.6^\circ \]

(b) For a single-edge blade with the mass and the total length of its side of \( 2.61 \times 10^{-3} \) kg and 154 mm, respectively,

\[ F_\sigma = (7.34 \times 10^{-2}) \times (154 \times 10^{-3}) = 0.0113 \text{ N} \]

and by the same manner,

\[ F_\sigma \sin \theta = mg \quad \Leftrightarrow \quad \sin \theta = \frac{(2.61 \times 10^{-3})(9.81)}{0.0113} = 2.26 > 1 \quad \text{(Impossible)} \]

\[ \therefore \text{The surface tension cannot maintain equilibrium with a single-edge blade.} \]