
2.29: PROBLEM DEFINITION**Situation:**

SAE 10W30 motor oil.

$$T_o = 38^\circ\text{C}, \mu_o = 0.067 \text{ N s/m}^2.$$

$$T = 99^\circ\text{C}, \mu = 0.011 \text{ N s/m}^2.$$

Find:The viscosity of motor oil, $\mu(60^\circ\text{C})$, using the equation $\mu = Ce^{b/T}$.**PLAN**Use algebra and known values of viscosity (μ) to solve for the constant b . Then, solve for the unknown value of viscosity.**SOLUTION**Viscosity variation of a liquid can be expressed as $\mu = Ce^{b/T}$. Thus, evaluate μ at temperatures T and T_o and take the ratio:

$$\frac{\mu}{\mu_o} = \exp \left[b \left(\frac{1}{T} - \frac{1}{T_o} \right) \right]$$

Take the logarithm and solve for b .

$$b = \frac{\ln(\mu/\mu_o)}{\left(\frac{1}{T} - \frac{1}{T_o}\right)}$$

Data

$$\mu/\mu_o = \frac{0.011 \text{ N s/m}^2}{0.067 \text{ N s/m}^2} = 0.164$$

$$T = 372 \text{ K}$$

$$T_o = 311 \text{ K}$$

Solve for b

$$b = 3430 \text{ (K)}$$

Viscosity ratio at 60°C

$$\frac{\mu}{\mu_o} = \exp \left[3430 \left(\frac{1}{333 \text{ K}} - \frac{1}{311 \text{ K}} \right) \right]$$

$$= 0.4833$$

$$\mu = 0.4833 \times 0.067 \text{ N s/m}^2$$

$$\mu = \boxed{0.032 \text{ N} \cdot \text{s/m}^2}$$

2.31: PROBLEM DEFINITIONSituation:

Oil (SAE 10W30) fills the space between two plates.

$$\Delta y = 1/8 = 0.125 \text{ in, } u = 25 \text{ ft/s.}$$

Lower plate is at rest.

Find:

Shear stress in oil.

Properties:

Oil (SAE 10W30 @ 150°F) from Figure A.2: $\mu = 5.2 \times 10^{-4} \text{ lbf}\cdot\text{s}/\text{ft}^2$.

Assumptions:

- 1.) Assume oil is a Newtonian fluid.
- 2.) Assume Couette flow (linear velocity profile).

SOLUTION

Rate of strain

$$\begin{aligned}\frac{du}{dy} &= \frac{\Delta u}{\Delta y} \\ &= \frac{25 \text{ ft/s}}{(0.125/12) \text{ ft}} \\ \frac{du}{dy} &= 2400 \text{ s}^{-1}\end{aligned}$$

Newton's law of viscosity

$$\begin{aligned}\tau &= \mu \left(\frac{du}{dy} \right) \\ &= \left(5.2 \times 10^{-4} \frac{\text{lbf}\cdot\text{s}}{\text{ft}^2} \right) \times \left(2400 \frac{1}{\text{s}} \right) \\ &= 1.248 \frac{\text{lbf}}{\text{ft}^2}\end{aligned}$$

$$\boxed{\tau = 1.25 \frac{\text{lbf}}{\text{ft}^2}}$$

2.35: PROBLEM DEFINITION

Situation:

Velocity distribution of crude oil between two walls.

$$\mu = 8 \times 10^{-5} \text{ lbf s/ft}^2, B = 0.1 \text{ ft.}$$

$$u = 100y(0.1 - y) \text{ ft/s}, T = 100^\circ\text{F.}$$

Find:

Shear stress at walls.

SOLUTION

Velocity distribution

$$u = 100y(0.1 - y) = 10y - 100y^2$$

Rate of strain

$$\begin{aligned} du/dy &= 10 - 200y \\ (du/dy)_{y=0} &= 10 \text{ s}^{-2} \quad (du/dy)_{y=0.1} = -10 \text{ s}^{-2} \end{aligned}$$

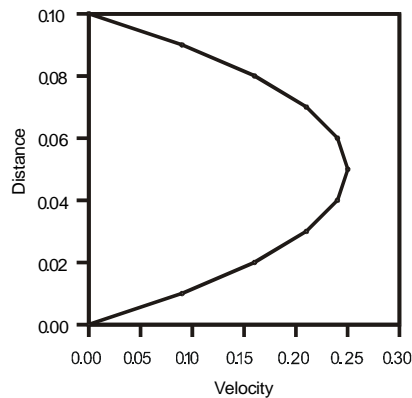
Shear stress

$$\tau_0 = \mu \frac{du}{dy} = (8 \times 10^{-5}) \times 10$$

$$\tau_0 = 8 \times 10^{-4} \text{ lbf/ft}^2$$

$$\tau_{0.1} = 8 \times 10^{-4} \text{ lbf/ft}^2$$

Plot



2.46: PROBLEM DEFINITION

Situation:

Water is subjected to an increase in pressure.

Find:

Pressure increase needed to reduce volume by 2%.

Properties:

From Table A.5, $E = 2.2 \times 10^9$ Pa.

PLAN

Use modulus of elasticity equation to calculate pressure change required to achieve the desired volume change.

SOLUTION

Modulus of elasticity equation

$$\begin{aligned} E &= -\Delta p \frac{V}{\Delta V} \\ \Delta p &= E \frac{\Delta V}{V} \\ &= -(2.2 \times 10^9 \text{ Pa}) \left(\frac{-0.01 \times V}{V} \right) \\ &= (2.2 \times 10^9 \text{ Pa}) (0.02) \\ &= 4.4 \times 10^7 \text{ Pa} \end{aligned}$$

$$\boxed{\Delta p = 44 \text{ MPa}}$$

2.53: PROBLEM DEFINITION

Situation:

Two vertical glass plates

$$y = 1 \text{ mm}$$

Find:

Capillary rise (h) between the plates.

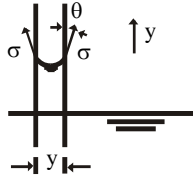
Properties:

From Table A.4, surface tension of water is $7.3 \times 10^{-2} \text{ N/m}$.

PLAN

Apply equilibrium, then the surface tension force equation.

SOLUTION



Equilibrium

$$\sum F_y = 0$$

Force due to surface tension = Weight of fluid that has been pulled upward

$$(2\ell)\sigma = (h\ell t)\gamma$$

Solve for capillary rise (h)

$$2\sigma\ell - h\ell t\gamma = 0$$

$$h = \frac{2\sigma}{\gamma t}$$

$$h = \frac{2 \times (7.3 \times 10^{-2} \text{ N/m})}{9810 \text{ N/m}^3 \times 0.001 \text{ m}}$$

$$= 0.0149 \text{ m}$$

$$h = \boxed{14.9 \text{ mm}}$$

2.61: PROBLEM DEFINITION

Situation:

Water at 60 °F

Find:

The pressure that must be imposed for water to boil

Properties:

Water (60 °F), Table A.5: $P_v = 0.363$ psia

SOLUTION

The pressure to which the fluid must be exposed is $P = 0.363$ psia. This is lower than atmospheric pressure. Therefore, assuming atmospheric pressure is 14.7 psia gage, or 14.7 psig, the pressure needed could also be reported as $P = -14.34$ psig.

2.63: PROBLEM DEFINITION**Situation:**

Water in a closed tank
 $T = 20\text{ }^\circ\text{C}$, $p = 10400\text{ Pa}$

Find:

Whether water will bubble into the vapor phase (boil).

Properties:

From Table A.5, at $T = 20\text{ }^\circ\text{C}$, $P_v = 2340\text{ Pa abs}$

SOLUTION

The tank pressure is 10,400 Pa abs, and $P_v = 2340\text{ Pa abs}$. So the tank pressure is higher than the P_v . Therefore the **water will not boil**.

REVIEW

The water can be made to boil at this temperature only if the pressure is reduced to 2340 Pa abs. Or, the water can be made to boil at this pressure only if the temperature is raised to approximately 50 °C.