3–127 The pressure of water flowing through a pipe is measured by the arrangement shown in Fig. P3–127. For the values given, calculate the pressure in the pipe.

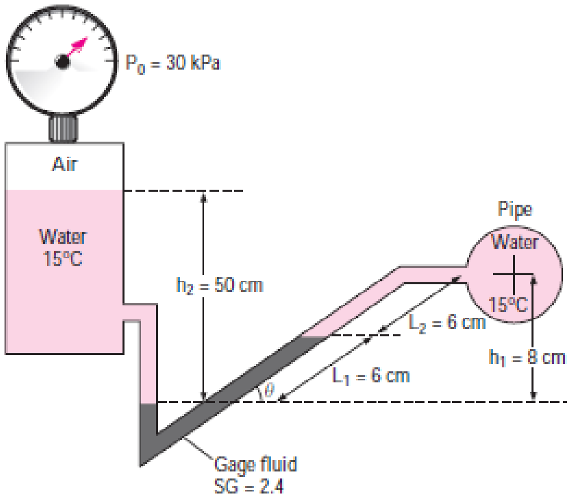


FIGURE P3–127

Analysis Starting with the pressure indicated by the pressure gage and moving along the tube by adding (as we go down) or subtracting (as we go up) the ρgh terms until we reach the water pipe, and setting the result equal to P_{water} give

$$P_{gage} + \rho_w g h_{w1} - \rho_{gage} g h_{gage} - \rho_w g h_{w2} = P_{water}$$

Rearranging,

$$P_{water} = P_{gage} + \rho_w g(h_{w1} - SG_{gage} h_{gage} - h_{w2}) = P_{gage} + \rho_w g(h_2 - SG_{gage} L_1 \sin\theta - L_2 \sin\theta)$$

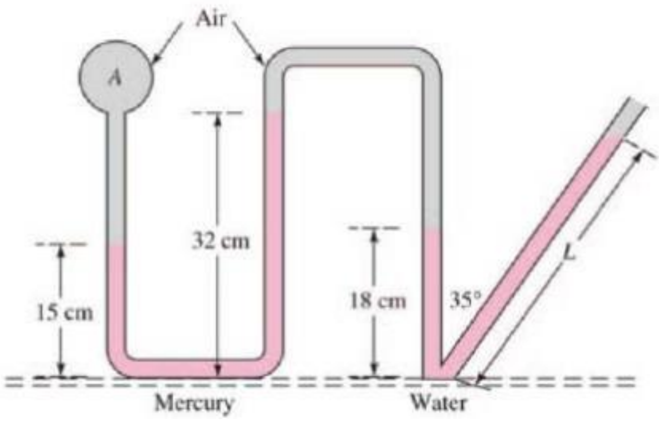
Noting that $\sin\theta = 8/12 = 0.6667$ and substituting,

$$P_{water} = 30\text{ kPa} + (1000\text{ kg/m}^3)(9.81\text{ m/s}^2)[(0.50\text{ m}) - 2.4(0.06\text{ m})0.6667 - (0.06\text{ m})0.6667]$$
$$\times\left(\frac{1\text{ kN}}{1000\text{ kg}\cdot\text{m/s}^2}\right)\left(\frac{1\text{ kPa}}{1\text{ kN/m}^2}\right)$$
$$= \mathbf{33.6\ kPa}$$

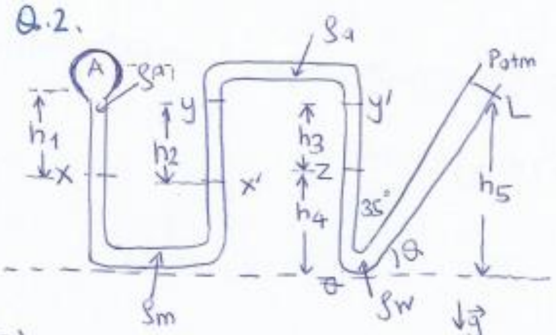
The system below (Figure 2) is open to atmospheric pressure (10^5 Pa) on its right side

a) If L = 120 cm, what is the air pressure in Container A? (10 Points)

b) Conversely, if P_A = 135 kPa, what is the length L? Assume the density of water and mercury are 1000 kg/m^3 and 13600 kg/m^3, respectively (15 points) The density of the air is 1.2 kg/m^3.



Q.2.



$h_1 = 32-15 = 17 cm = 0.17 m$

$h_2 = 32-15 = 17 cm = 0.17 m$

$h_3 = 32-18 = 14 cm = 0.14 m$

$h_4 = 18 cm = 0.18 m$

$h_5 = L . \sin\theta = 1.2^m \times \sin 55^\circ = 0.98 m$

$\rho_a = 1.2 kg/m^3$

$\rho_w = 1000 kg/m^3$

$\rho_m = 13600 kg/m^3$

a)

$P_A + \rho_a g h_1 = P_x$

$P_x = P_{x'}$

$P_A + \rho_a g h_1 - \rho_m g h_2 = P_y$

$P_y = P_{y'}$

$P_A + \rho_a g h_1 - \rho_m g h_2 + \rho_a g h_3 = P_z$

$P_A + \rho_a g h_1 - \rho_m g h_2 + \rho_a g h_3 + \rho_w g h_4 = P_\theta$

$P_A + \rho_a g h_1 - \rho_m g h_2 + \rho_a g h_3 + \rho_w g h_4 - \rho_w g h_5 = P_{atm}$

$*$ $P_A + \rho_a g h_1 - \rho_m g h_2 + \rho_a g h_3 + \rho_w g h_4 - \rho_w g h_5$

Solve the final equation for P_A.

$$P_A + (1.2 kg/m^3)(9.81 \tfrac{N}{kg})(0.17 m) - (13600 \tfrac{kg}{m^3})(9.81 \tfrac{N}{kg}).(0.17 m) +$$
$$(1.2 kg/m^3)(9.81 \tfrac{N}{kg})(0.14 m) + (1000 \tfrac{kg}{m^3}).(9.81 \tfrac{N}{kg}).(0.18 m)$$
$$- (1000 kg/m^3).(9.81 \tfrac{N}{kg}).(0.98 m) = 10^5 Pa$$

$P_A \cong 130\,500$ Pa (absolute pressure)

$P_A \cong 30\,500$ Pa (gage pressure)

Q.2 continues

$P_A = 135\ kPa = 135\,000\ Pa$ given

Use the same final equation above

$$P_A + (1.2\ kg/m^3)(9.81\ \frac{N}{kg}) \cdot (0.17m) - (13600\ kg/m^3)(9.81\ N/kg)(0.17m)$$
$(=135\,000\ Pa)$

$$+ (1.2\ \frac{kg}{m^3})(9.81\ \frac{N}{kg})(0.14m) + (1000\ \frac{kg}{m^3})(9.81\ \frac{N}{kg})(0.18m)$$

$$- (1000\ \frac{kg}{m^3}) \cdot (9.81\ \frac{N}{kg}) \cdot L \cdot \sin 55^\circ = 100\,000\ Pa$$

From here L is found as a value of 1.75 m

$(L = 1.75m = 175\ cm)$

2-7 The pressure in an automobile tire depends on the temperature of the air in the tire. When the air temperature is 25°C, the pressure gage reads 210 kPa. If the volume of the tire is 0.025 m^3, determine the pressure rise in the tire when the air temperature in the tire rises to 50°C. Also, determine the amount of air that must be bled off to restore pressure to its original value at this temperature. Assume the atmospheric pressure to be 100 kPa.

FIGURE P2–7

Properties The gas constant of air is R = 0.287 kPa·m³/kg·K.

Analysis Initially, the absolute pressure in the tire is

$$P_1 = P_g + P_{atm} = 210 + 100 = 310 \text{ kPa}$$

Treating air as an ideal gas and assuming the volume of the tire remain constant, the final pressure in the tire can be determined from

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \longrightarrow P_2 = \frac{T_2}{T_1} P_1 = \frac{323\text{K}}{298\text{K}}(310\text{kPa}) = 336\text{kPa}$$

Thus the pressure rise is

$$\Delta P = P_2 - P_1 = 336 - 310 = \mathbf{26\ kPa}$$

The amount of air that needs to be bled off to restore pressure to its or

$$m_1 = \frac{P_1 V}{RT_1} = \frac{(310\text{kPa})(0.025\text{m}^3)}{(0.287\text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(298\text{K})} = 0.0906\text{kg}$$

$$m_2 = \frac{P_2 V}{RT_2} = \frac{(310\text{kPa})(0.025\text{m}^3)}{(0.287\text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(323\text{K})} = 0.0836\text{kg}$$

$$\Delta m = m_1 - m_2 = 0.0906 - 0.0836 = \mathbf{0.0070\ kg}$$

2–47 The clutch system shown in Fig. P2–47 is used to transmit torque through a 3-mm-thick oil film with μ = 0.38 N · s/m^2 between two identical 30-cm-diameter disks. When the driving shaft rotates at a speed of 1450 rpm, the driven shaft is observed to rotate at 1398 rpm. Assuming a linear velocity profile for the oil film, determine the transmitted torque.

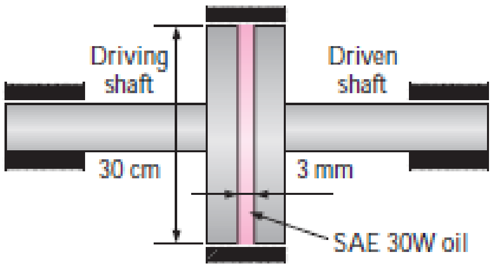
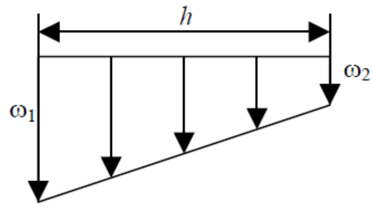


FIGURE P2–47

$$\tau_w = \mu\frac{du}{dr} = \mu\frac{V}{h} = \mu\frac{(\omega_1-\omega_2)r}{h}$$



Then the shear force acting on a differential area dA on the surface and the torque generation associated with it can be expressed as

$$dF = \tau_w dA = \mu\frac{(\omega_1-\omega_2)r}{h}(2\pi r)dr$$

$$d\mathrm{T} = rdF = \mu\frac{(\omega_1-\omega_2)r^2}{h}(2\pi r)dr = \frac{2\pi\mu(\omega_1-\omega_2)}{h}r^3dr$$

Integrating,

$$\mathrm{T} = \frac{2\pi\mu(\omega_1-\omega_2)}{h}\int_{r=0}^{D/2} r^3dr = \frac{2\pi\mu(\omega_1-\omega_2)}{h}\left.\frac{r^4}{4}\right|_{r=0}^{D/2} = \frac{\pi\mu(\omega_1-\omega_2)D^4}{32h}$$

Noting that $\omega = 2\pi\dot{n}$, the relative angular speed is

$$\omega_1-\omega_2 = 2\pi(\dot{n}_1-\dot{n}_2) = (2\pi\ \text{rad/rev})[(1450-1398)\ \text{rev/min}]\left(\frac{1\ \text{min}}{60\ \text{s}}\right) = 5.445\ \text{rad/s},$$

Substituting, the torque transmitted is determined to be

$$\mathrm{T} = \frac{\pi(0.38\ \text{N}\cdot\text{s/m}^2)(5.445\ \text{/s})(0.30\ \text{m})^4}{32(0.003\ \text{m})} = \mathbf{0.55\ N\cdot m}$$

2–67 A 20-m^3 tank contains nitrogen at 25°C and 800 kPa. Some nitrogen is allowed to escape until the pressure in the tank drops to 600 kPa. If the temperature at this point is 20°C, determine the amount of nitrogen that has escaped. *Answer:* 42.9 kg

Analysis Treating N_2 as an ideal gas, the initial and the final masses

$$m_1 = \frac{P_1 V}{RT_1} = \frac{(800\text{kPa})(20\text{m}^3)}{(0.2968\text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(298\text{K})} = 180.9\text{kg}$$

$$m_2 = \frac{P_2 V}{RT_2} = \frac{(600\text{kPa})(20\text{m}^3)}{(0.2968\text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(293\text{K})} = 138.0\text{kg}$$

Thus the amount of N_2 that escaped is

$$\Delta m = m_1 - m_2 = 180.9 - 138.0 = \mathbf{42.9\ kg}$$

Problem #1 (16 points)

A thin plate moves at a velocity of 5 m/s as the result of a force F. A 2-m-long, 1-m-wide area of the plate is always immersed in oil ($\mu = 0.8$ Pa s) between two stationary surfaces that are 4 cm apart.

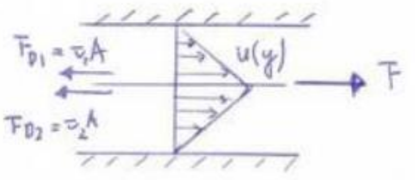
Assume that the plate is centered between the surfaces with $h_1 = h_2 = 2$cm.

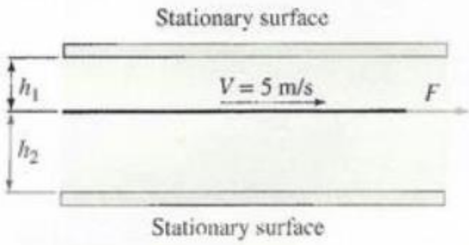
a) Sketch the forces on the plate and the velocity distribution in the oil. **(4 points)**

b) Determine the required force F **(6 points)**

c) Determine the required force F if $h_1 = 1$cm and $h_2 = 3$cm to achieve the same velocity of 5 m/s. **(4 points)**

a)





b) $\tau_1 = \mu \frac{du}{dy} = 0.8 \frac{5}{0.02} = 200\,Pa = \tau_2 \rightarrow F_{D_1} = \tau_1 A = 200 * 2 * 1 = 400\,N = F_{D_2}$

$F = F_{D_1} + F_{D_2} = 800\,N \ (\rightarrow)$

c) $\tau_1 = 0.8 \frac{5}{0.01} = 400\,Pa$

$\rightarrow F_D = (\tau_1 + \tau_2) A = 533.\bar{3} * 2 * 1 = 1067\,N$

$\tau_2 = 0.8 \frac{5}{0.03} = 133.\bar{3}\,Pa \ (\rightarrow)$