P2.4 Pressure gages, such as the Bourdon gage in Fig. P2.4, are calibrated with a deadweight piston. If the Bourdon gage is designed to rotate the pointer 10 degrees for every 2 psig of internal pressure, how many degrees does the pointer rotate if the piston and weight together total 44 newtons?

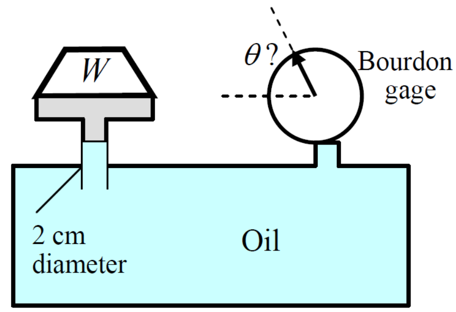


Fig. P2.4

Solution: The deadweight, divided by the piston area, should equal the pressure applied to the Bourdon gage. Stay in SI units for the moment:

$$p_{Bourdon} = \frac{F}{A_{piston}} = \frac{44\,N}{(\pi/4)(0.02m)^2} = 140,060\ Pa \div 6894.8 = 20.3\ \frac{lbf}{in^2}$$

At 10 degrees for every 2 psig, the pointer should move approximately **100 degrees**. *Ans*.

P2.5 Quito, Ecuador has an average altitude of 9,350 ft. On a standard day, pressure gage A in a laboratory experiment reads 63 kPa and gage B reads 105 kPa. Express these readings in gage pressure or vacuum pressure, whichever is appropriate.

Solution: Convert 9,350 ft x 0.3048 = 2,850 m. We can interpolate in the Standard Altitude Table A.6 to a pressure of about 71.5 kPa. Or we could use Eq. (2.20):

$$p = p_a\left(1 - \frac{Bz}{T_o}\right)^{g/RB} = (101350)\left[1 - \frac{(0.0065)(2850)}{288.16}\right]^{5.26} = (101350)(0.70503) = 71,500\ Pa$$

Good interpolating! Then p_A = 71500-63000 = **8500 Pa** (vacuum pressure) *Ans*.(A),
and p_B = 105000 - 71500 = **33500 Pa** (gage pressure) *Ans*.(B)

P2.9 A storage tank, 26 ft in diameter and 36 ft high, is filled with SAE 30W oil at 20°C. (*a*) What is the gage pressure, in lbf/in^2, at the bottom of the tank? (*b*) How does your result in (*a*) change if the tank diameter is reduced to 15 ft? (*c*) Repeat (*a*) if leakage has caused a layer of 5 ft of water to rest at the bottom of the (full) tank.

Solution: This is a straightforward problem in hydrostatic pressure. From Table A.3, the density of SAE 30W oil is 891 kg/m^3 ÷ 515.38 = 1.73 slug/ft^3. (*a*) Thus the bottom pressure is

$$p_{bottom} = \rho_{oil}\, g\, h = (1.73\frac{slug}{ft^3})(32.2\frac{ft}{s^2})(36\, ft) = 2005\frac{lbf}{ft^2} = \mathbf{13.9}\frac{lbf}{in^2}\, gage \quad Ans.(a)$$

(*b*) The tank diameter has nothing to do with it, just the depth: p_{bottom} = **13.9** psig. *Ans.*(*b*)

(*c*) If we have 31 ft of oil and 5 ft of water (ρ = 1.94 slug/ft^3), the bottom pressure is

$$p_b = \rho_{oil} g h_{oil} + \rho_{water} g h_{water} = (1.73)(32.2)(31) + (1.94)(32.2)(5) =$$

$$= 1727 + 312 = 2039\ \frac{lbf}{ft^2} = \mathbf{14.2}\ \frac{lbf}{in^2} \quad Ans.(c)$$

P2.22 The fuel gage for an auto gas tank reads proportional to the bottom gage pressure as in Fig. P2.22. If the tank accidentally contains 2 cm of water plus gasoline, how many centimeters "h" of air remain when the gage reads "full" in error?

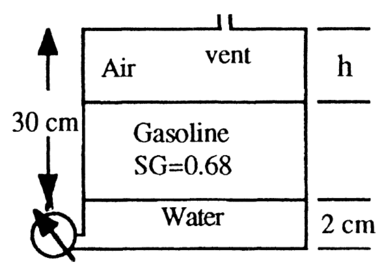


Fig. P2.22

Solution: Given $\gamma_{\text{gasoline}} = 0.68(9790) = 6657\ \text{N/m}^3$, compute the gage pressure when "full":

$$p_{\text{full}} = \gamma_{\text{gasoline}}(\text{full height}) = (6657\ \text{N/m}^3)(0.30\ \text{m}) = 1997\ \text{Pa}$$

Set this pressure equal to 2 cm of water plus "Y" centimeters of gasoline:

$$p_{\text{full}} = 1997 = 9790(0.02\ \text{m}) + 6657Y, \quad \text{or} \quad Y \approx 0.2706\ \text{m} = 27.06\ \text{cm}$$

Therefore the air gap h = 30 cm – 2 cm(water) – 27.06 cm(gasoline) ≈ **0.94 cm** *Ans.*

P2.23 In Fig. P2.23 both fluids are at 20°C. If surface tension effects are negligible, what is the density of the oil, in kg/m^3?

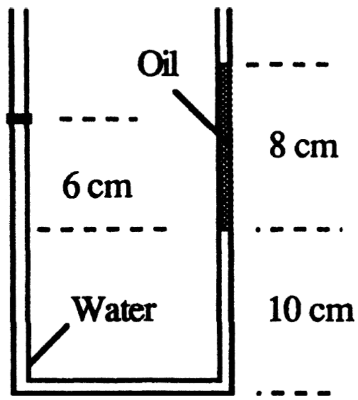


Fig. P2.23

Solution: Move around the U-tube from left atmosphere to right atmosphere:

$$p_a + (9790\ \text{N/m}^3)(0.06\ \text{m}) - \gamma_{oil}(0.08\ \text{m}) = p_a,$$

$$\text{solve for} \quad \gamma_{oil} \approx 7343\ \text{N/m}^3,$$

$$\text{or:} \quad \rho_{oil} = 7343/9.81 \approx \mathbf{748\ kg/m^3} \quad \textit{Ans.}$$

P2.24 In Prob. 1.2 we made a crude integration of atmospheric density from Table A.6 and found that the atmospheric mass is approximately $m \approx$ 6E18 kg. Can this result be used to estimate sea-level pressure? Can sea-level pressure be used to estimate m?

Solution: Yes, atmospheric pressure is essentially a result of the weight of the air above. Therefore the air weight divided by the surface area of the earth equals sea-level pressure:

$$p_{sea\text{-}level} = \frac{W_{air}}{A_{earth}} = \frac{m_{air}g}{4\pi R_{earth}^2} \approx \frac{(6.0E18\ \text{kg})(9.81\ \text{m/s}^2)}{4\pi(6.377E6\ \text{m})^2} \approx \mathbf{115000}\ \textit{Pa} \quad \textit{Ans.}$$

This is a little off, thus our mass estimate must have been a little off. If global average sea-level pressure is actually 101350 Pa, then the mass of atmospheric air must be more nearly

$$m_{air} = \frac{A_{earth}p_{sea\text{-}level}}{g} \approx \frac{4\pi(6.377E6\ \text{m})^2(101350\ \text{Pa})}{9.81\ \text{m/s}^2} \approx \mathbf{5.28E18\ kg} \quad \textit{Ans.}$$

P2.66 Dam ABC in Fig. P2.66 is 30 m wide into the paper and is concrete (SG ≈ P2.40). Find the hydrostatic force on surface AB and its moment about C. Could this force tip the dam over? Would fluid seepage under the dam change your argument?

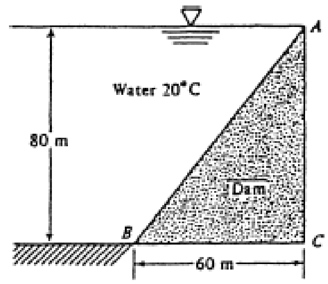
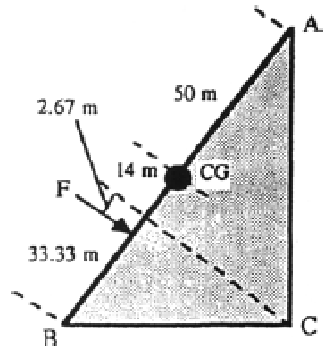


Fig. P2.66

Solution: The centroid of surface AB is 40 m deep, and the total force on AB is

$$F = \gamma h_{CG} A = (9790)(40)(100 \times 30) = 1.175E9\ \text{N}$$

The line of action of this force is two-thirds of the way down along AB, or 66.67 m from A. This is seen either by inspection (A is at the surface) or by the usual formula:



$$y_{CP} = -\frac{I_{xx}\sin\theta}{h_{CG}A} = -\frac{(1/12)(30)(100)^3\sin(53.13°)}{(40)(30 \times 100)} = -16.67\ \text{m}$$

to be added to the 50-m distance from A to the centroid, or 50 + 16.67 = 66.67 m. As shown in the figure, the line of action of F is P2.67 m to the left of a line up from C normal to AB. The moment of F about C is thus

$$M_C = FL = (1.175E9)(66.67 - 64.0) \approx \mathbf{3.13E9\ N \cdot m} \quad \textit{Ans.}$$

This moment is counterclockwise, hence it cannot tip over the dam. If there were *seepage* under the dam, the main support force at the bottom of the dam would shift to the left of point C and might indeed cause the dam to tip over.

P2.85 Compute the horizontal and vertical components of the hydrostatic force on the quarter-circle panel at the bottom of the water tank in Fig. P2.85.

Solution: The horizontal component is

$$F_H = \gamma h_{CG} A_{vert} = (9790)(6)(2\times 6)$$
$$= \mathbf{705000\ N} \quad \textit{Ans.}\ \text{(a)}$$

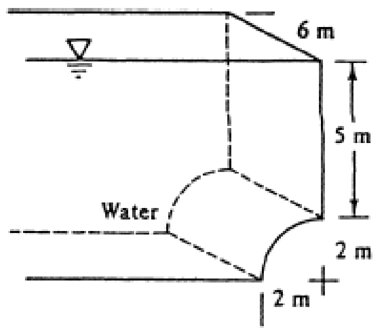


Fig. P2.85

The vertical component is the weight of the fluid above the quarter-circle panel:

$$F_V = W(\text{2 by 7 rectangle}) - W(\text{quarter-circle})$$
$$= (9790)(2\times 7\times 6) - (9790)(\pi/4)(2)^2(6)$$
$$= 822360 - 184537 = \mathbf{638000\ N} \quad \textit{Ans.}\ \text{(b)}$$

P2.141 The same tank from Prob. P2.139 is now accelerating while rolling *up* a 30° inclined plane, as shown. Assuming rigid-body motion, compute (a) the acceleration **a**, (b) whether the acceleration is up or down, and (c) the pressure at point A if the fluid is mercury at 20°C.

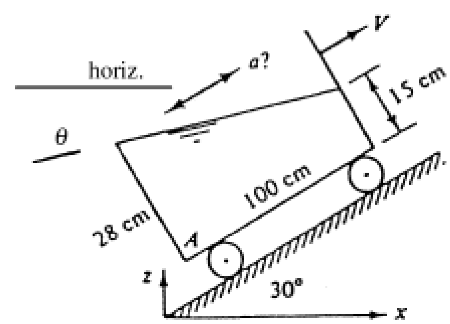


Fig. P2.141

Solution: The free surface is tilted at the angle $\theta = -30° + 7.41° = -22.59°$. This angle must satisfy Eq. (2.55):

$$\tan\theta = \tan(-22.59°) = -0.416 = a_x/(g + a_z)$$

But the 30° incline constrains the acceleration such that $a_x = 0.866a$, $a_z = 0.5a$. Thus

$$\tan\theta = -0.416 = \frac{0.866a}{9.81 + 0.5a}, \quad \text{solve for} \quad \mathbf{a \approx -3.80\ \frac{m}{s^2}\ (down)} \quad \textit{Ans.}\ \text{(a, b)}$$

The cartesian components are $a_x = -3.29\ m/s^2$ and $a_z = -1.90\ m/s^2$.

(c) The distance ΔS normal from the surface down to point A is (28 cosθ) cm. Thus

$$p_A = \rho[a_x^2 + (g + a_z)^2]^{1/2} = (13550)[(-3.29)^2 + (9.81 - 1.90)^2]^{1/2}(0.28\cos 7.41°)$$

$$\approx \mathbf{32200\ Pa\ (gage)} \quad \textit{Ans.}\ \text{(c)}$$