工程流體力學題解

Solutions Manual

for use with

ENGINEERING FLUID MECHANICS

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AUTHORS' NOTE

We have attempted to eliminate all errors in the solutions; however, there are undoubtedly still some remaining. If the users of this manual find errors, the authors would appreciate being notified of same. Please send correspondence to the first author, Department of Civil Engineering, Washington State University, Pullman, Washington 99163. Your help will be sincerely appreciated. A list of corrections will be subsequently sent to you if the number of errors is significant.

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CHAPTER TWO

2-1 $\rho = \frac{P}{RT} = \frac{140,000}{R(39 + 273)} = \frac{462.0}{R}$ kg/m^3

From Table A-2: $R_{air} = 287$ J/kgK

$R_{He} = 2,077$

$R_{CO_2} = 189$

Then $\rho_{air} = \frac{462.0}{287} = \underline{1.61 \text{ kg/m}^3}$

$\rho_{He} = \frac{462.0}{2,077} = \underline{0.222 \text{ kg/m}^3}$

$\rho_{CO_2} = \frac{462.0}{189} = \underline{2.44 \text{ kg/m}^3}$

2-2 $\rho_{CO_2} = \frac{P}{RT} = \frac{300,000}{189(60 + 273)} = 4.767$ kg/m^3

Then $\gamma_{CO_2} = \rho_{CO_2} \times g = 4.767 \times 9.81 = \underline{46.764 \text{ N/m}^3}$

2-3 $\rho_{He} = \frac{P}{RT} = \frac{300,000}{2,077(60 + 273)} = 0.434$ kg/m^3

Then $\gamma_{He} = \rho_{He} \times g = 0.434 \times 9.81 = \underline{4.255 \text{ N/m}^3}$

2-4 Assume average pressure based on elevation = (5,280/2) ft.

Then $P \cong 14.7 - \frac{5,280}{2} = 0.00242 \times 32.2/144 = 13.3$ psia

Assume T = 50°F

Then $\rho = \frac{P}{RT} = \frac{13.3 \times 144}{1,716(50 + 460)} = 0.00223$ slugs/ft^3

Mass = $\rho V = 0.00223 \times (5.280)^3 = \underline{3.28 \times 10^8 \text{ slugs}}$

$3.28 \times 10^8 \times 32.2 = \underline{1.06 \times 10^{10} \text{ lbm}}$

$1.06 \times 10^{10} \times 0.4536 = \underline{4.80 \times 10^9 \text{ kg}}$

2-5 $\rho_{air} = \frac{P}{RT} = \frac{103,000}{287(10 + 273)} = 1.268 \text{ kg/m}^3$

$\rho_{water} = 1,000 \text{ kg/m}^3$ Then $\frac{\rho_{water}}{\rho_{air}} = \frac{1,000}{1.268} = \underline{788}$

2-6 $\rho_{air} = \frac{P}{RT} = \frac{1,000 \times 144}{1,716(70 + 460)} = 0.158 \text{ slugs/ft}^3$

Then $\gamma_{air} = \rho_{air} \times g = 0.158 \times 32.2 = 5.10 \text{ lbs/ft}^3$

$Wt_{air} = 5.10 \times 3 = 15.3 \text{ lbs}$

$Wt_{total} = Wt_{air} + Wt_{tank} = 15.3 + 80 = \underline{95.3 \text{ lbs}}$

2-7 $\rho_{air} = \frac{P}{RT} = \frac{345,000}{287(38 + 273)} = \underline{3,865 \text{ kg/m}^3}$

$\gamma_{air} = \rho_{air} \times g = 3,865 \times 9.81 = \underline{37.918 \text{ N/m}^3}$

2-8 Mass and Weight are extensive properties; the remaining properties are intensive.

2-9 $du/dy = 10/((1/4)/12)s^{-1}$; $\mu = 1.4 \times 10^{-3} \text{lb-sec/ft}^2$

Then $\tau = \mu du/dy = 1.4 \times 10^{-3} \times 10 \times 48 = \underline{0.672 \text{ lb/ft}^2}$

2-10. Viscosities from Table A-3 in Appendix

T	Air	Water
10°C	1.76×10^{-5}	1.31×10^{-3}
60°C	2.00×10^{-5}	4.66×10^{-4}

Then $\Delta\mu_{air,10\to60} = (2.00 - 1.76) \times 10^{-5} = \underline{+2.4 \times 10^{-6} \text{N·s/m}^2}$

$\Delta\mu_{water,10\to60} = (4.66 - 13.1) \times 10^{-4} = \underline{-8.44 \times 10^{-4} \text{N·s/m}^2}$

2-11 $\Delta\nu_{air,10\to60} = (1.89 - 1.41) \times 10^{-5} = \underline{4.8 \times 10^{-6} \text{m}^2/\text{s}}$

2-12 $u = 100y(0.1 - y) = 10y - 100y^2$

$du/dy = 10 - 200y$

$(du/dy)_{y=0} = 10s^{-1}$ $(du/dy)_{y=0.1} = -10s^{-1}$

$\tau_0 = \mu du/dy = (3 \times 10^{-5}) \times 10 = \underline{3 \times 10^{-4} \text{lb/ft}^2}$

$\tau_{0.1} = \underline{-3 \times 10^{-4} \text{lb/ft}^2}$

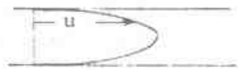
y	u
0	0
0.02	0.16
0.04	0.24
0.06	0.24
0.08	0.16
0.10	0

2-13. $u = 1{,}000y(0.01 - y) = 10y - 1{,}000y^2$

y	u
0	0
0.005	2.5×10^{-2}m/s
0.01	0

$du/dy = 10 - 2{,}000y$

$(du/dy)_{y=0} = 10s^{-1}$; $(du/dy)_{y=0.1} = -10s^{-1}$



$\tau_0 = \mu du/dy = 1.9 \times 10^{-3} \times 10 = \underline{1.9 \times 10^{-2} N/m^2}$

$\tau_{0.01m} = 1.9 \times 10^{-3} \times (-10) = -\underline{1.9 \times 10^{-2} N/m^2}$

2-14. $V = ((dp/dx)/2\mu)(By - y^2)$; $B = 0.05m$

$dp/dx = 1{,}600N/m^2$; $y = 0.012$; $\mu = 6.2 \times 10^{-1} N \cdot s/m^2$

Then $V_{12mm} = (1{,}600/(2 \times 0.62))(0.05 \times 0.012 - (0.012)^2)$

$V_{12mm} = \underline{0.588\ m/s}$

Shear stress: $\tau = \mu dV/dy$ where $dV/dy = (1/2\mu)(dp/dx)(B - 2y)$

$\tau_0 = (1{,}600/2)(0.05) = \underline{40N/m^2}$

$\tau_{12} = (1{,}600/2)(0.05 - 2 \times 0.012) = \underline{20.8N/m^2}$

2-15.	Oil (SAE 10W)	kerosene	water
$\mu(N \cdot s/m^2)$	$\underline{3.6 \times 10^{-2}}$ (Table A-4)	$\underline{1.4 \times 10^{-3}}$ (Fig. A-2)	$\underline{6.8 \times 10^{-4}}$ (Table A-5)
$\rho(kg/m^3)$	870		993
$\nu(m^2/s)$	$\underline{4.1 \times 10^{-5}}$	$\underline{1.7 \times 10^{-6}}$ (Fig. A-2)	$\underline{6.8 \times 10^{-7}}$

2-16. $\mu_{air,20°C} = 1.81 \times 10^{-5} N \cdot s/m^2$; $\nu = 1.51 \times 10^{-5} m^2/s$

$\mu_{water,20°C} = 1.00 \times 10^{-3} N \cdot s/m^2$; $\nu = 1.00 \times 10^{-6} m^2/s$

$\mu_{air}/\mu_{water} = \underline{1.81 \times 10^{-2}}$; $\nu_{air}/\nu_{water} = \underline{15.1}$

2-17. Assume linear velocity distribution: $dV/dy = V/y = \omega r/y$

$\tau = \mu dV/dy = \mu\omega r/y$

$\tau_2/\tau_3 = (\mu \times 1 \times 2/y)/(\mu \times 1 \times 3/y) = 2/3 = \underline{0.667}$

$V = \omega r = 2 \times 0.03 = \underline{0.06\ m/s}$

$\tau = \mu dV/dy = 0.01 \times 0.06/0.002 = \underline{0.30N/m^2}$

2-18. Solution like that for P2-17.

$\tau = \mu\omega r/y$

$\tau_2/\tau_3 = 0.667$

$V = \omega r = 0.25 \times 2 = 0.50$ ft/sec.

$\tau = \mu dV/dy = 0.01 \times 0.50/0.001 = \underline{5\ \text{lb/ft}^2}$

2-19. $\mu_{air} = 1.76 \times 10^{-5} \text{N}\cdot\text{s/m}^2$ (Table A-3)

$\mu_{water} = 1.31 \times 10^{-3} \text{N}\cdot\text{s/m}^2$

$\rho_{air} = p/RT = 103{,}000/(287 \times 283) = 1.268\ \text{kg/m}^3$

$\rho_{water} = 1{,}000\ \text{kg/m}^3$

Then $\nu_{air} = \mu_{air}/\rho_{air} = (1.76 \times 10^{-5})/1.27 = \underline{1.39 \times 10^{-5} \text{m}^2/\text{s}}$

$\nu_{water} = (1.31 \times 10^{-3}/1{,}000) = \underline{1.31 \times 10^{-6} \text{m}^2/\text{s}}$

2-20. $E = -\Delta p/(\Delta V\!\!\!/ / V\!\!\!/)$

$2.2 \times 10^9 = -2 \times 10^6/(\Delta V\!\!\!/ /1{,}000)$

Therefore, $\Delta V\!\!\!/ = (2 \times 10^6 \times 1{,}000)/(2.2 \times 10^9) = 0.91$ cc

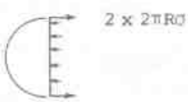
Volume after pressure applied $= V\!\!\!/ - \Delta V\!\!\!/ = \underline{999.09\ \text{cc}}$

2-21. $E = -\Delta p/(\Delta V\!\!\!/ / V\!\!\!/)$

$2.2 \times 10^9 = -\Delta p/(-1/100)$

$\Delta p = 2.2 \times 10^7 \text{N/m}^2 = \underline{22\ \text{MN/m}^2\ \text{(increase)}}$

2-22. $\Sigma F = 0$



$\Delta p \pi R^2 - 2(2\pi R\sigma) = 0$

$\Delta p = \underline{4\sigma/R}$

Note: Effect of thickness, t, is assumed negligible.

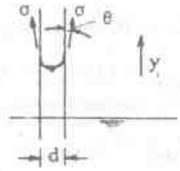
2-23. $\Delta h = 4\sigma/(\gamma d) = 4 \times 0.005/(62.4 \times d) = 3.21 \times 10^{-4}/d$ ft

$d = 1/4$ in. $= 1/48$ ft; $\Delta h = 3.21 \times 10^{-4}/(1/48) = 0.0154$ ft $= \underline{0.185\ \text{in.}}$

$d = 1/8$ in. $= 1/96$ ft; $\Delta h = 3.21 \times 10^{-4}/(1/96) = 0.0308$ ft $= \underline{0.369\ \text{in.}}$

$d = 1/32$ in. $= 1/384$ ft; $\Delta h = 3.21 \times 10^{-4}/(1/384) = 0.123$ ft $= \underline{1.48\ \text{in.}}$

2-24. $\Sigma F_z = 0$



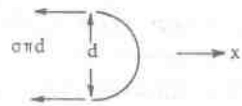
$2\sigma\ell - h\ell t\gamma = 0$

$h = 2\sigma/\gamma t$

$\sigma = 7.3 \times 10^{-2}\,N/m$

$h = 2 \times 7.3 \times 10^{-2}/(0.001 \times 9{,}810) = 0.0149m = \underline{14.9\ mm}$

2-25. Solution is similar to that for P2-22 except that only one surface exists here.



$\Delta p \pi R^2 - 2\pi R\sigma = 0$

$\Delta p = 2\sigma/R$

$\Delta p = 2 \times 7.3 \times 10^{-2}/(0.5 \times 10^{-3}) = \underline{292\ N/m^2}$

2-26. $c_p/c_v = k \qquad c_p - c_v = R$

$c_p/c_v - c_v/c_v = R/c_v$

$k - 1 = R/c_v; \quad c_v = \underline{R/(k-1)}$

$c_p = R + c_v = R + R/(k-1) = \underline{kR/(k-1)}$

2-27. $100 - (101 - 69)/3.1 = \underline{89.7°C}$

CHAPTER THREE

3-1. $p = \gamma\Delta z = 9{,}790 \times 50 = 489{,}500\ N/m^2 = \underline{489.5\ kPa}$

$p_{50}/p_{atm} = (489.5 + 101.3)/101.3 = \underline{5.83}$

3-2. $p_v + \gamma_{Hg}h = p_{atm}$; Assume p_v is nil

$p_{atm} = 133{,}000 \times 0.75 = \underline{99.75\ kPa}$

3-3. $p = 20/(\pi/4) \times (1)^2 = 25.46$ psi $= 175.4$ kPa

% gage error $= (26 - 25.46) \times 100/25.46 = \underline{2.10\%}$

3-4. $F = (14-4)(\pi)(7.5) = \underline{1{,}767\ lbf}$

Note: Forces acting on the surface where the shells are joined are neglected.

3-5. $F = 80\pi \times (15 \times 10^{-2})^2 = 5.65$ kN

3-6. $p = 400$ kPa; $\rho = p/RK$

So $\gamma = gp/RK = 9.81 \times 400 \times 10^3/(287 \times 300) = 45.6\ N/m^3$

By applying conversion factor $\gamma = \underline{0.29\ lbf/ft^3}$

3-7. $F = pA = 80 \times 10^3 \times 1 \times 2.2 = 176{,}000\ N = \underline{176\ kN}$

3-8. F per bolt at A-A $= p(\pi/4)D\ /20$

Assume same force per bolt at B-B

$p(\pi/4)D^2/20 = p(\pi/4)d^2/n$

$n = 20 \times (d/D)^2 = 20 \times (1/2)^2 = \underline{5}$

3-9. $p = 10 \times 8{,}630 = 86{,}300$ Pa $= \underline{86.3\ kPa}$

3-10. $\gamma = p/h = 73.6 \times 10^3/5 = 14.72\ kN/m^3$

Sp. gr. $= 14.72/9.81 = \underline{1.50}$

3-11. $dp/dz = -\gamma$

$dp = -\gamma(dz) = \gamma d(d) = (10{,}000 + 100d)d(d)$

$p = \int_0^4 (10{,}000 + 100d)d(d) = [10{,}000d + (100/2)d^2]_0^4$

$= 40{,}800\ N/m^2 = \underline{40.8\ kPa}$

3-12. $p = \gamma h = 9{,}790 \times 7 = 68{,}530\ N/m^2 = \underline{68.53\ kPa}$

3-13. $p = \gamma h = 62.37 \times 22 = \underline{1{,}372.14\ psf}$

$= \underline{9.53\ psi}$

3-14. $0 + (2/12) \times 847 - 3 \times 62.3 = p_A$

$p_A = \underline{-45.7\ psf} = \underline{-0.317\ psig}$

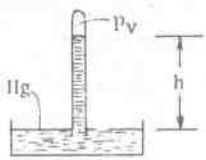
3-15. $h = p/\gamma = 120.000/9{,}810 = \underline{12.23\ m}$

3-16. $p = (\gamma h)_{water} + (\gamma h)_{kerosene}$

$= 9{,}790 \times 60 \times 10^{-2} + 8{,}010 \times 1 = 13/884\ N/m^2$

$= \underline{13.88\ kPa}$

3-17. $p_v + \gamma_{Hg} h = p_{atm}$



$h = (p_{atm} - p_v)/\gamma_{Hg}$

Assume $p_{v_{Hg}} = 0$

$h = (98{,}000 - 0)/133{,}000 = 0.737\ m = \underline{737\ mm}$

3-18. $0 + 4\gamma_{H_2O} + 3 \times 3\ \gamma_{H_2O} = p_{max}$

$p_{max} = 13 \times 9{,}810 = 127{,}530\ N/m^2 = \underline{127.53\ kPa}$

Maximum pressure will be at the bottom of the liquid with a sp. gr. of 3.0.

$F_{CD} = pA = (127{,}530 - 1 \times 3 \times 9{,}810) \times 1\ m^2 = \underline{98.1\ kN}$

3-19. $\Delta p = \gamma h = 10{,}070 \times 6 \times 10^3$

$E_v = \Delta p/(d\rho/\rho)$

$(d\rho/\rho) = \Delta p/E_v = (10{,}070 \times 6 \times 10^3)/(2.2 \times 10^9) = 27.46 \times 10^{-3} = \underline{2.75\%}$

3-20. $p_A = 9{,}810\ (1 \times 13.55 - 1.5 + 1.3 \times 0.9) = 129{,}700\ N/m^2 = \underline{129.7\ kPa}$

3-21. $\Delta h_{surface\ tension} = 4\sigma/(\gamma d) = (4 \times 7.3 \times 10^{-2})/(9{,}810 \times 1 \times 10^{-3})$

$= 0.0298\ m = 2.98\ cm$

$p_A = \gamma h = 9{,}810(10 - 2.98) \times 10^{-2} = \underline{689\ Pa}$

3-22. $\Delta p = \gamma h$; $h = \Delta p/\gamma = 100 \times 10^3/9{,}810 = \underline{10.19\ m}$

3-23 $p_B = 50 \times (3/5) \times 10^{-2} \times 20 \times 10^3 - 10 \times 10^{-2} \times 20 \times 10^3 - 50 \times 10^{-2} \times 10 \times 10^3$

$p_B = -1{,}000\ Pa = \underline{-1.00\ kPa}$

3-24. $(\pi/4)\ D^2_{tube} \times \ell = (\pi/4)\ D^2_{cistern} \times (\Delta h)_{cistern}$

$(\Delta h)_{cistern} = (1/10)^2 \times 50 = 0.5\ cm$

$p_{cistern} = (\ell \sin 10° + \Delta h)\rho g$

$= (50 \sin 10° + 0.5) \times 10^{-2} \times 800 \times 9.81 = \underline{721\ Pa}$

3-25. $\Delta h = (1/10)^2 \times 2 = 0.02\ ft$

$p_{cistern} = (2 \sin 10° + 0.02)50 = \underline{18.36\ psf}$

3-26. $\Delta h_{cistern} = (0.5/10)^2 \times 20 = \underline{0.05\ cm}$

$p_{cistern} = (20 \sin \alpha + \Delta h)\gamma_{oil}$

$600 = (20 \times 10^{-2} \sin \alpha + 0.5 \times 10^{-2}) \times 0.85 \times 9{,}810$

$\sin \alpha = 0.357$; $\underline{\alpha = 20.9°}$

3-27. p_A $62.4(3 \times 1 - 1 + 2) = 249.6\ psf = \underline{1.733\ psi}$

$p_A = 9{,}810 \times (3 \times 0.305 - 0.305 + 2 \times 0.305)$

$= 11{,}968\ Pa = \underline{11.968\ kPa}$

3-28. $p_A = 1.64 \times 846 - 4.92 \times 62.4 = \underline{1{,}080\ psf} = \underline{7.50\ psi}$

$p_A = 0.50 \times 1.33 \times 10^5 - 1.50 \times 9{,}810 = \underline{51.8\ kPa}$

3-29. (1): $y_L + y_R = 1/2\ ft$

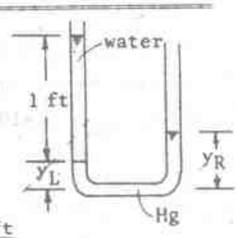
$0 + (1 \times 62.4) + (y_L \times 846) - (y_R \times 846) = 0$

(2): $y_L + y_R = -0.0738\ ft$

(1) + (2): $2y_L = 0.5 - 0.0738$ $\quad y_L = \underline{0.213\ ft}$

$y_R = 1/2 - y_L = 0.5 - 0.213 = \underline{0.287\ ft}$

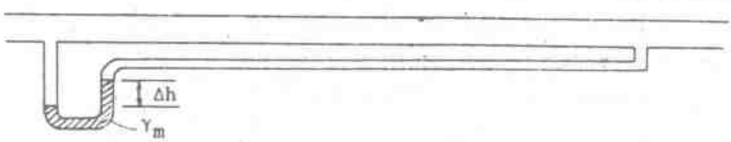
$p_{max} = 0.287 \times 846 = \underline{243\ psf}$



3-30. $(34 - 10) \times 10^{-2} \times 9{,}810 = 36 \times 10^{-2} \times 9{,}810 \times$ (Sp. gr.)

(Sp. gr.) = <u>0.667</u>

3-31.



Use a manometer fluid heavier than water. The specific weight of the manometer fluid is identified as γ_m.

Then $\Delta h_{max} = \Delta p_{max}/(\gamma_m - \gamma_{H_2O})$.

If the manometer fluid is carbon-tetrachloride (γ_m = 15,600),

$\Delta h_{max} = 60 \times 10^3/(15{,}600 - 9{,}810) = 10.36$ m ---(too large).

If the manometer fluid is mercury (γ_m = 133,000),

$\Delta h_{max} = 60 \times 10^3/(133{,}000 - 9{,}810) = 0.487$ m ---(O.K.).

Assume the manometer can be read to ± 2 mm.

Then % error = ± 2/487 = ± 0.004 = ± 0.4%

The probable accuracy near 1 kPa is about <u>99.6%</u>

3-32. $p_A + (4 + 2)\ 62.4 \times 0.8 + 3 \times 62.4 - (3 + 2)62.4 \times 0.8 = p_B$

$p_A - p_B = -237$ psf = <u>-1.65 psi</u>

3-33. $p_A + (3 + 1)9{,}810 \times 0.8 + 2 \times 9{,}810 - (2 + 1)\ 9{,}810 \times 0.8 = p_B$

$p_A - p_B = -27{,}470$ Pa = <u>-27.47 kPa</u>

3-34. $(1 + 3)51 + z \times 180 - (z + 3)62.37 = 2 \times 144$

z = <u>2.31 ft</u>

3-35. $(0 + 3)51 + z \times 847 - (z + 3)62.3 = 3 \times 144$

z = <u>0.594 ft</u>

3-36. $(0 + 1)8{,}010 + z \times 133{,}000 - (z + 1)9{,}810 = 10{,}000$

z = 0.0958 m = <u>95.8 mm</u>

3-37. $p = 3 \times 144 + 5 \times 0.75 \times 62.4$ = <u>666 psf</u> = <u>4.62 psi</u>

3-38. $p_A = (0.15 + 0.3 \times 13.55 - 0.6)9{,}810 = 35{,}610$ Pa = $\underline{\underline{35.46 \text{ kPa}}}$

3-39. $p_A = (0.9 + 0.6 \times 13.6 - 1.8 \times 0.8 + 1.5)9{,}810 = 89{,}470$ Pa = $\underline{\underline{89.47 \text{ kPa}}}$

3-40. $p_A = (90 + 60 \times 13.6 - 180 \times 0.8 + 150) \times (1/12) \times 62.4 = 4{,}742$ psf = $\underline{\underline{32.93 \text{ psi}}}$

3-41. $p_A - 1 \times 0.85 \times 9{,}810 + 0.5 \times 0.85 \times 9{,}810 = p_B$

$p_A - p_B = 4{,}169$ Pa = $\underline{\underline{4.169 \text{ kPa}}}$

$(p_A/\gamma + z_A) - (p_B/\gamma + z_B) = (4{,}169/0.85 \times 9{,}810) - 1 = \underline{\underline{-0.50 \text{ m}}}$

3-42. $p_A - (40/12) \times 0.85 \times 62.4 + (65 - 3 \times 12) \times 0.85 \times 62.4/12 = p_B$

$p_A - p_B = 48.62$ psf

$(p_A/\gamma + z_A) - (p_B/\gamma + z_B) = (48.62/0.85 \times 62.4) + 10 - 13 = \underline{\underline{-2.08 \text{ ft}}}$

3-43. $p_0 = 101.3$ kPa

$$p_B = p_0\left(\frac{T_0 - \alpha(z-z_0)}{T_0}\right)^{g/\alpha R}$$

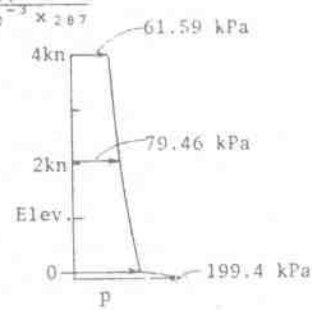
$$= 101.3\left(\frac{(273+15) - 6.5 \times 10^{-3}(4{,}000-0)}{(273+15)}\right)^{\frac{9.81}{6.5 \times 10^{-3} \times 287}}$$

$= 61.59$ kPa

$$p_C = 101.3\ [(288 - 6.5 \times 10^{-3}(2{,}000-0))/288]^{5.259}$$

$= \underline{\underline{79.46 \text{ kPa}}}$

$p_A = 101.3 + 9.810 \times 100 = \underline{\underline{1{,}082.3 \text{ kPa}}}$



3-44. For standard atmosphere $T_{\text{sea level}} = 288$ K = 15°C

$p = p_0[(T_0 - \alpha(z-z_0))/T_0]^{g/\alpha R} = 101.3[(288 - 6.5\ (z-z_0))/288]^{g/\alpha R}$

where $g/\alpha R = 9.81/(6.5 \times 287) = 5.26$

Then $p_{1,500} = 101.3[(288 - 6.5(1.5))/288]^{5.26} = 84.5$ kPa

And $p_{3,000} = 101.3[(288 - 6.5(3.0))/288]^{5.26} = 70.1$ kPa

From Table A-5, $T_{\text{boiling, 1,500 m}} \approx \underline{\underline{95°C}}$ (interpolated);

$T_{\text{boiling, 3,000 m}} \approx \underline{\underline{90°C}}$

3-45. $p = p_0[(T_0 - \alpha(z-z_0))/T_0]^{g/\alpha R}$

$= 101[((273+25) - 6.5(6-0))/(273+25)]^{9.81/(6.5\times 10^{-3}\times 287)}$

$= \underline{48.3 \text{ kPa}}$

3-46. $p = p_0[(T_0-\alpha(z-z_0))/T_0]^{g/\alpha R}$

$= 14.7[(520 - 3.566\times 10^{-3}(20{,}000-0))/520]^{32.2/3.566\times 10^{-3}\times 1{,}715}$

$= 6.76$ psia

$p_a = 101[(288-6.5\times 10^{-3}(6{,}096-0))/288]^{9.81/6.5\times 10^{-3}\times 287}$

$p_a = \underline{46.4 \text{ kPa}}$ abs.

3-47 Assume $b\forall\rho$ = constant where b = breath rate, $\forall$ = volume per breath, and ρ = mass density of air. Assume point 1 is sea level and point 2 is 15,000 ft elevation.

Then $b_1\forall_1\rho_1 = b_2\forall_2\rho_2$

$b_2 = b_1(\forall_1/\forall_2)(\rho_1/\rho_2)$

Assuming $\forall_1 = \forall_2$, then $b_2 = b_1(\rho_1/\rho_2)$ but $\rho = (p/RT)$

Thus, $b_2 = b_1(p_1/p_2)(T_2/T_1)$

$p_2 = p_1(T_2/T_1)^{g/\alpha R}$; $p_1/p_2 = (T_2/T_1)^{-g/\alpha R}$

Then $b_2 = b_1(T_2/T_1)^{1-g/\alpha R}$

when b_1 = 16 breaths per minute and $T_1 = 59°F = 519°R$

$T_2 = T_1 - \alpha(z_2-z_1) = 519 - 3.566\times 10^{-3}(15{,}000-0) = 465.5°R$

$b_2 = 16(465.5/519)^{1-32.2/3.566\times 10^{-3}\times 1{,}715}$ = 25 breaths per minute

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3-48. $p = p_0[(T_0-\alpha(z-z_0))/T_0]^{g/\alpha R}$

$75 = 95[(283-6.5(z-1))/283]^{9.81/(6.5\times 10^{-3}\times 287)}$

$z = 2.91$ km

$T = T_0 - \alpha(z-z_0) = 10 - 6.5(2.91-1) = \underline{-2.41°C}$

3-49. $p = p_0[(T_0 - \alpha(z-z_0))/T_0]^{g/\alpha R}$

$10 = 13.6[((70+460) - 3.566\times 10^{-3}(z-2{,}000))/(70+460)]^{32.2/3.566\times 10^{-3}\times 1{,}715}$

$z = \underline{10{,}430 \text{ ft}}$

3-50. $T = T_0 - \alpha(z - z_0) = 519 - 3.566 \times 10^{-3}(5{,}280 - 0) = \underline{500°R}$

$= 288 - 6.5 \times 10^{-3}(1{,}609 - 0) = \underline{278°K}$

$p = p_0(T/T_0)^{g/\alpha R} = 14.7(500/519(^{5.261} = \underline{12.1 \text{ psia}}$

$p_a = 101.3(278/288)^{9.81/(6.5\times 10^{-3}\times 287)} = \underline{83.4 \text{ kPa}}$

$\rho = p/RT = (12.1 \times 144)/(1{,}715 \times 500) = \underline{0.00203 \text{ slugs/ft}^3}$

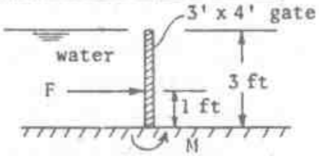
$\rho = 83{,}400/(287 \times 278) = \underline{1.05 \text{ kg/m}^3}$

3-51. $F = \bar{p}A = 1.5 \times 62.4 \times 3 \times 4 = 1{,}123$ lbf

$x = 3 - y_{cp} = 3 - \bar{y} - \bar{I}/\bar{y}A$

$= 3 - 1.5 - (4 \times 3^3)/(12 \times 1.5 \times 12) = 1$ ft

$M = Fx = 1{,}123 \times 1 = \underline{1{,}123 \text{ ft-lbf}}$



3-52. $F = \bar{p}A = (1.5)9{,}810 \times (3 \times 4) = 1.77 \times 10^5$ N

$x = 1/3(3) = 1$ m

$M = \underline{1.77 \times 10^5 \text{ N·m}}$

3-53. $F = \bar{p}A = 10 \times 9{,}810 \times 4 \times 4 = 1{,}569.600$ N $= 32.8 \times 62.4 \times 13.1 \times 13.1 = 351{,}238$ lbf

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = (4 \times 4^3/12)/(10 \times 4 \times 4) = 0.133$ m

$= (13.1 \times 13.1^3/12)/(32.8 \times 13.1 \times 13.1) = 0.436$ ft

$F_{block} = 1{,}569{,}600 \times 0.133/2 = \underline{104{,}378 \text{ N}}$

$= 351{,}238 \times 0.436/6.55 = \underline{23{,}380 \text{ lbf}}$

3-54. $F = \bar{p}A = 4 \times 150 \times (8 \times 1) = 4{,}800$ lbf

$y_{cp} = \bar{y} + \bar{I}/\bar{y}A = 4 + (1 \times 8^3)/(12 \times 4 \times 8) = 5.33$ ft

$F_{TIE} = 2 \times F \times y_{cp}/h = 2 \times 4{,}800 \times 5.33/8 = \underline{6{,}400 \text{ lbf}}$

3-55. $F = \bar{p}A = (3 + 5)9{,}810 \times 10 \times 10 = 7{,}848{,}000$ N

$= (9.84 + 16.4)62.4(32.8 \times 32.8) = 1{,}761{,}554$ lbf

$y_{cp} = \bar{y} + \bar{I}/\bar{y}A = 8 + 10 \times 10^3/(12 \times 8 \times 10 \times 10) = 9.04$ m

$= 26.24 + (32.8 \times 32.8^3)/(12 \times 26.24 \times 32.8 \times 32.8) = 29.65$ ft

$F_{hinge} = F(d - y_{cp}/h = 7{,}848{,}000(13 - 9.04)/10 = 3{,}108{,}000 \text{ N} = \underline{3{,}108 \text{ kN}}$

$= 1{,}761{,}554(42.65 - 29.65)/32.8 = \underline{698{,}000 \text{ lbf}}$

3-56. $F = (6 + 5\sin 30°)9{,}810 \times 10 \times 4 = 3{,}335{,}400$ N

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = 4 \times 10^3/12 \times (6/\sin 30° + 5) \times 10 \times 4 = 0.49$ m

$F_A = 3{,}335{,}400 \times (5 + 0.49)/(10\cos 30°) = \underline{2.114 \text{ MN}}$

3-57. $F = (7 + 2.5)62.4 \times 10 \times 6 = 35{,}568$ lbf

$y_{cp} - \bar{y} = (6 \times 10^3)/(12 \times 19 \times 10 \times 6) = 0.438$ ft

$F_A = (35{,}568 \times 5.438)/(10\cos 30°) = \underline{22{,}334 \text{ lbf}}$

3-58. $F = \bar{p}A = (0.4 + 0.4)9{,}810 \times 0.9 \times 0.8 \times 1.2 = 6{,}781$ N

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = 1.2 \times 0.8^3/(12 \times 0.8 \times 0.8 \times 1.2) = 0.067$ m

$M = 6{,}781 \times (0.4 - 0.067) = \underline{2{,}260 \text{ N·m}}$

3-59. $F = \bar{p}A = (5 + 2.5)9{,}810 \times 4 \times 5/\sin 60° = 1{,}700$ kN

$y_{cp} - \bar{y} = 4 \times (5/\sin 60°)^3/(12 \times (7.5/\sin 60°)(4 \times 5/\sin 60°)) = 0.321$

$T = 0.321 \text{ m} \times 1{,}700 \text{ kN} = \underline{545 \text{ kN·m}}$

3-60. $F = \bar{p}A = (12 + 6)62.4 \times 5 \times 12/\sin 60° = 77{,}820$ lbf

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = 5 \times (12/\sin 60°)^3/(12 \times (18/\sin 60°)(5 \times 12/\sin 60°))$

$= 0.770$ ft

$T = 0.770 \times 77{,}820 = \underline{59{,}906 \text{ ft-lbf}}$

3-61. $F = \bar{p}A = (2 + 2.5)9{,}810 \times 5\sqrt{2} \times 2 = 624{,}304$ N

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = (2 \times 7.071^3)/(12 \times 6.36 \times 2 \times 7.071) = 0.655$ m

$F = 624{,}304 \times (5\sqrt{2}/2 + 0.655)/5\sqrt{2} = \underline{369{,}982 \text{ N}}$

3-62. $F = (10 + 5)62.4 \times 10\sqrt{2} \times 5 = 66{,}185$ lbf

$y_{cp} - \bar{y} = (5 \times 14.14^3)/(12 \times 15\sqrt{2} \times 5 \times 14.14) = 0.785$ ft

$F = 66{,}185 \times (10\sqrt{2}/2 + 0.785)/10\sqrt{2} = \underline{36{,}766 \text{ lbf}}$

3-63. $y_{cp} - \bar{y} = 0.55\ell - 0.5\ell = 0.05\ell$

$0.05 = \bar{I}/\bar{y}A = \ell \times \ell^3/(12 \times (h + \ell/2)\ell^2)$

$h = \underline{1.167\,\ell}$

3-64. $F = \bar{p}A = 1 \times 9{,}810 \times 2 \times 1 = 19{,}620$ N

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = (1 \times 2^3)/(12 \times 1 \times 2 \times 1) = 0.33$ m

Weight $W = 19{,}620 \times (1 - 0.33)/2.5 = 5{,}258$ N

Volume $\forall = 5{,}258/(23{,}600 - 9{,}810) = \underline{0.381 \text{ m}^3}$

3-65. $F = 2.5 \times 62.4 \times 2 \times 5 = 1{,}560$ lbf

$y_{cp} - \bar{y} = (2 \times 5^3)/(12 \times 2.5 \times 2 \times 5) = 0.833$ ft

$W = 1{,}560(2.5 - 0.833)/6.25 = 416$ lbf

$\forall = 416/(150 - 62.4) = \underline{4.74 \text{ ft}^3}$

3-66. $F = \bar{p}A = (1 + 1.5)9{,}810 \times 1 \times 3\sqrt{2} = 104{,}050$

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = 1 \times (3\sqrt{2})^3/(12 \times (2.5 \times \sqrt{2})(1 \times 3\sqrt{2})) = 0.424$ m

Overturning moment $M_1 = 90{,}000 \times 1.5 = 135{,}000$ N·m

Restoring moment $M_2 = 104{,}050 \times (3\sqrt{2}/2 - 0.424) = 176{,}606 \text{ N·m} > M_1$

So the <u>gate will stay</u>.

3-67. $F = (4 + 3.535)62.4 \times (3 \times 7.07\sqrt{2}) = 14{,}103$ lbf

$y_{cp} - \bar{y} = 3 \times (7.07\sqrt{2})^3/(12 \times 7.535\sqrt{2} \times 3 \times 7.07\sqrt{2}) = 0.782$ ft

Overturning moment $M_1 = 18{,}000 \times 7.07/2 = 63{,}630$ N·m

Restoring moment $M_2 = 14{,}103(7.07\sqrt{2}/2 - 0.782) = 59{,}476 \text{ N·m} < M_1$

So the <u>gate will fall</u>.

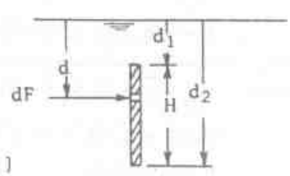
3-68. $F = \bar{p}A = (1 + 6)9{,}810 \times 0.5 \times 4 \times 9 = 1.236$ MN

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = (4 \times 9^3)/(36 \times 7 \times 0.5 \times 4 \times 9) = 0.643$ m

$P = 1{,}236{,}060 \times (3 - 0.643)/9 = \underline{323.7 \text{ kN}}$

3-69. $dF = p\,dA = \gamma_0(1 + kd/d_0)d\,d(d)W$

$$F = \gamma_0 W \int_{d_1}^{d_2} d(1 + kd/d_0)\,d(d)$$



$F = \gamma_0 W[1/2(H^2 + 2d_1H) + (k/3d_0)(H^3 + 3d_1d_2H)]$

3-69 (continued)

or $F = \underline{\gamma_0 W[1/2(d_2^2 - d_1^2) + (k/3d_0)(d_2^3 - d_1^3]}$

When $d_1 = 0$ $\quad F = \gamma_0 W(H^2/2 + kH^3/3d_0)$

Since the specific weight increases with the increase in depth, the location of the center of pressure will be <u>located below</u> that for constant density liquid.

3-70. Equivalent depth of liquid for 2 psi = (2 x 144)/(0.8 x 62.4) = 5.77 ft

$F = \bar{p}A = (5.77 + 2 + 5)(62.4 \times 0.08)(5 \times 10) = 31{,}874$ psf

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = (5 \times 10^3)/(12 \times 12.77 \times 5 \times 10) = 0.652$ ft

$P = 31{,}874 \times (5 + 0.652)/10 = \underline{18{,}015 \text{ lbf}}$

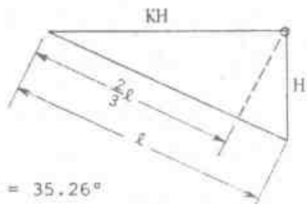
3-71. Equivalent depth of liquid for 30 kPa = 30,000/(0.8 x 9,810) = 3.82 m

$F = (3.82 + 1 + 1.5)(0.8 \times 9{,}810)(3 \times 1) = 148{,}798$ N

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = (1 \times 3\ )/(12 \times 6.32 \times 3 \times 1) = 0.1187$ m

$P = 148{,}798(1.5 + 0.1187)/3 = \underline{80{,}285 \text{ N}}$

3-72. The gate will be on the verge of opening when the line of action of the resultant hydrostatic force, $F_{Hyd.}$, passes through the hinge point. Also, this $F_{Hyd.}$ will be located 2/3 down the gate surface. Therefore, this problem can be solved largely by trigonometry:



$(2/3)\ell = KH \cos\theta$ (1)

and $\ell \cos\theta = KH$ (2)

Solving Eqs. (1) and (2) for θ yields $\theta = 35.26°$

Also, $\tan\theta = H/(KH) = 1/K$

or $K = \cot\theta = \cot(35.26°) = \underline{\sqrt{2}}$

3-73. $F = \bar{p}A = (h + 2h/3)\gamma(Wh/\sin 60°)/2 = 5\gamma Wh/3\sqrt{3}$

$y_{cp} - \bar{y} = \bar{I}/\bar{y}A = W(h/\sin 60°)^3/(36 \times (5h/(3 \sin 60°)) \times (Wh/2 \sin 60°))$

$= h(15\sqrt{3})$; $\quad \Sigma M = 0$

$R_T h/\sin 60° = F[(h/(3 \sin 60°)) - (h/15\sqrt{3})]$

$R_T/F = \underline{3/10}$
