SOLUTIONS MANUAL TO ACCOMPANY

INTRODUCTION TO FLIGHT
8th Edition

By

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Chapter 2

2.1 $\rho = p/RT = (1.2)(1.01\times10^5)/(287)(300)$

$\rho = 1.41\ \text{kg/m}^2$

$v = 1/\rho = 1/1.41 = 0.71\ \text{m}^3/\text{kg}$

2.2 Mean kinetic energy of each atom $= \frac{3}{2}k\,T = \frac{3}{2}(1.38\times10^{-23})(500) = 1.035\times10^{-20}\,\text{J}$

One kg-mole, which has a mass of 4 kg, has 6.02 × 10^{26} atoms. Hence 1 kg has

$\frac{1}{4}(6.02\times10^{26}) = 1.505\times10^{26}$ atoms.

$$\text{Total internal energy} = (\text{energy per atom})(\text{number of atoms})$$
$$= (1.035\times10^{-20})(1.505\times10^{26}) = 1.558\times10^{6}\,\text{J}$$

2.3 $\rho = \frac{p}{RT} = \frac{2116}{(1716)(460+59)} = 0.00237\frac{\text{slug}}{\text{ft}^3}$

$$\text{Volume of the room} = (20)(15)(8) = 2400\,\text{ft}^3$$
$$\text{Total mass in the room} = (2400)(0.00237) = 5.688\,\text{slug}$$
$$\text{Weight} = (5.688)(32.2) = 183\,\text{lb}$$

2.4 $\rho = \frac{p}{RT} = \frac{2116}{(1716)(460-10)} = 0.00274\frac{\text{slug}}{\text{ft}^3}$

Since the volume of the room is the same, we can simply compare densities between the two problems.

$$\Delta\rho = 0.00274 - 0.00237 = 0.00037\frac{\text{slug}}{\text{ft}^3}$$

$$\%\,\text{change} = \frac{\Delta\rho}{\rho} = \frac{0.00037}{0.00237}\times(100) = 15.6\%\ \text{increase}$$

2.5 First, calculate the density from the known mass and volume, $\rho = 1500/900 = 1.67\,\text{lb}_\text{m}/\text{ft}^3$

In consistent units, $\rho = 1.67/32.2 = 0.052\,\text{slug/ft}^3$. Also, T = 70 F = 70 + 460 = 530 R.

Hence,

$$p = \rho RT = (0.52)(1716)(530)$$

$$p = 47{,}290\,\text{lb/ft}^2$$

or $p = 47{,}290/2116 = 22.3\,\text{atm}$

2.6 $p = \rho RT$

$\ell np = \ell np + \ell nR + \ell nT$

Differentiating with respect to time,

$$\frac{1}{p}\frac{dp}{dt} = \frac{1}{\rho}\frac{d\rho}{dt} + \frac{1}{T}\frac{dT}{dt}$$

or, $$\frac{dp}{dt} = \frac{p}{\rho}\frac{d\rho}{dt} + \frac{p}{\mathrm{T}}\frac{dT}{dt}$$

or, $$\frac{dp}{dt} = RT\frac{d\rho}{dt} + \rho R\frac{dT}{dt} \quad (1)$$

At the instant there is 1000 lb_m of air in the tank, the density is

$$\rho = 1000/900 = 1.11 \mathrm{lb_m/ft^3}$$
$$\rho = 1.11/32.2 = 0.0345 \mathrm{slug/ft^3}$$

Also, in consistent units, is given that

T = 50 + 460 = 510 R

and that

$$\frac{dT}{dt} = 1F/\mathrm{min} = 1R/\mathrm{min} = 0.016R/\mathrm{sec}$$

From the given pumping rate, and the fact that the volume of the tank is 900 ft^3, we also have

$$\frac{d\rho}{dt} = \frac{0.5 \mathrm{\ lb_m/sec}}{900 \mathrm{\ ft^3}} = 0.000556 \mathrm{\ lb_m/(ft^3)(sec)}$$
$$\frac{d\rho}{dt} = \frac{0.000556}{32.2} = 1.73\times10^{-5} \mathrm{slug/(ft^3)(sec)}$$

Thus, from equation (1) above,

$$\frac{d\rho}{dt} = (1716)(510)(1.73\times10^{-5}) + (0.0345)(1716)(0.0167)$$
$$= 15.1 + 0.99 = 16.1 \mathrm{\ lb/(ft^2)(sec)} = \frac{16.1}{2116}$$
$$= 0.0076 \mathrm{\ atm/sec}$$

2.7 In consistent units,

$$T = -10 + 273 = 263 \mathrm{\ K}$$

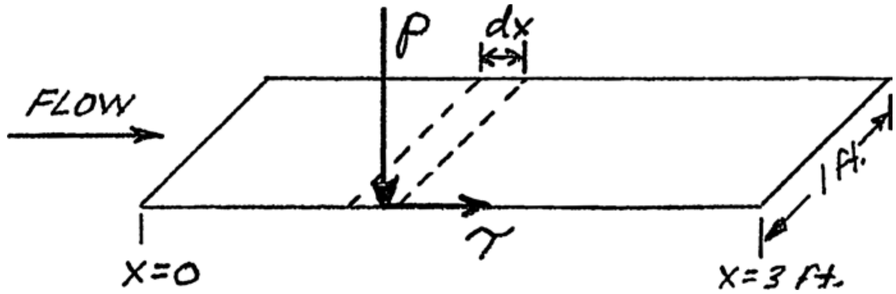
Thus,

$$\rho = p/RT = (1.7\times10^4)/(287)(263)$$
$$\rho = 0.225 \mathrm{\ kg/m^3}$$

2.8 $\rho = p/RT = 0.5\times10^5/(287)(240) = 0.726 \mathrm{\ kg/m^3}$

$v = 1/\rho = 1/0.726 = 1.38 \mathrm{\ m^3/kg}$

2.9

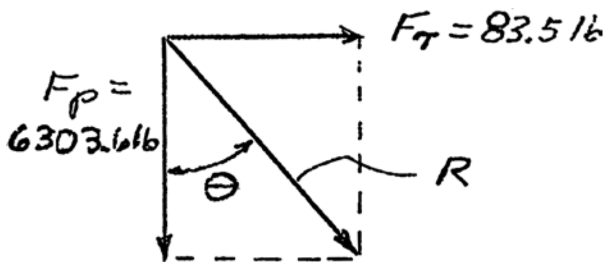


$$F_p = \text{Force due to pressure} = \int_0^3 p\,dx = \int_0^3 (2116 - 10x)\,dx$$

$$= [2116x - 5x^2]_0^3 = 6303 \text{ lb perpendicular to wall.}$$

$$F_\tau = \text{Force due to shear stress} = \int_0^3 \tau\,dx = \int_0^3 \frac{90}{(x+9)^{\frac{1}{2}}}\,dx$$

$$= [180\,(x+9)^{\frac{1}{2}}]_0^3 = 623.5 - 540 = 83.5 \text{ lb tangential to wall.}$$



Magnitude of the resultant aerodynamic force =

$$R = \sqrt{(6303)^2 + (835)^2} = 6303.6 \text{ lb}$$

$$\theta = \text{Arc Tan}\left(\frac{83.5}{6303}\right) = 0.76^\circ$$

2.10 $V = \frac{3}{2} V_\infty \sin\theta$

Minimum velocity occurs when sin θ = 0, i.e., when θ = 0° and 180°.

$V_{\min}$ = 0 at θ = 0° and 180°, i.e., at its most forward and rearward points.

Maximum velocity occurs when sin θ = 1, i.e., when θ = 90°. Hence,

$$V_{\max} = \frac{3}{2}(85)(1) = 127.5 \text{ mph at } \theta = 90^\circ,$$

i.e., the entire rim of the sphere in a plane perpendicular to the freestream direction.

2.11 The mass of air displaced is

$$M = (2.2)(0.002377) = 5.23 \times 10^{-3}\ \text{slug}$$

The weight of this air is

$$W_{\text{air}} = (5.23 \times 10^{-3})(32.2) = 0.168\ \text{lb}$$

This is the lifting force on the balloon due to the outside air. However, the helium inside the balloon has weight, acting in the downward direction. The weight of the helium is less than that of air by the ratio of the molecular weights

$$W_{H_c} = (0.168)\frac{4}{28.8} = 0.0233\ \text{lb.}$$

Hence, the maximum weight that can be lifted by the balloon is

0.168 – 0.0233 = 0.145 lb.

2.12 Let p_3, ρ_3, and T_3 denote the conditions at the beginning of combustion, and p_4, ρ_4, and T_4 denote conditions at the end of combustion. Since the volume is constant, and the mass of the gas is constant, then $p_4 = \rho_3$ = 11.3 kg/m^3. Thus, from the equation of state,

$$p_4 = \rho_4\, RT_4 = (11.3)(287)(4000) = 1.3 \times 10^7\ \text{N/m}^2$$

or,

$$p_4 = \frac{1.3 \times 10^7}{1.01 \times 10^5} = \boxed{129\ \text{atm}}$$

2.13 The area of the piston face, where the diameter is 9 cm = 0.09 m, is

$$A = \frac{\pi(0.09)^2}{4} = 6.36 \times 10^{-3}\text{m}^2$$

(a) The pressure of the gas mixture at the beginning of combustion is

$$p_3 = \rho_3 RT_3 = 11.3(287)(625) = 2.02 \times 10^6\ \text{N/m}^2$$

The force on the piston is

$$F_3 = p_3 A = (2.02 \times 10^6)(6.36 \times 10^{-3}) = 1.28 \times 10^4\text{N}$$

Since 4.45 N = l lb*f*,

$$F_3 = \frac{1.28 \times 10^4}{4.45} = \boxed{2876\ \text{lb}}$$

(b) $p_4 = \rho_4 RT_4 = (11.3)(287)(4000) = 1.3 \times 10^7\,\text{N/m}^2$

The force on the piston is

$$F_4 = p_4 A = (1/3 \times 10^7)(6.36 \times 10^{-3}) = \boxed{8.27 \times 10^4\text{N}}$$

$$F_4 = \frac{8.27 \times 10^4}{4.45} = \boxed{18{,}579\ \text{lb}}$$

2.14 Let p_3 and T_3 denote conditions at the inlet to the combustor, and T_4 denote the temperature at the exit. Note: $p_3 = p_4 = 4 \times 10^6 \text{ N/m}^2$

(a) $$\rho_3 = \frac{p_3}{RT_3} = \frac{4 \times 10^6}{(287)(900)} = \boxed{15.49 \text{ kg/m}^3}$$

(b) $$\rho_4 = \frac{p_4}{RT_4} = \frac{4 \times 10^6}{(287)(1500)} = \boxed{9.29 \text{ kg/m}^3}$$

2.15 1 mile = 5280 ft, and 1 hour = 3600 sec.

So:

$$\left(60\frac{\text{miles}}{\text{hour}}\right)\left(\frac{5280 \text{ ft}}{\text{mile}}\right)\left(\frac{1 \text{ hour}}{3600 \text{ sec}}\right) = 88 \text{ ft/sec.}$$

A very useful conversion to remember is that

$$\boxed{60 \text{ mph} = 88 \text{ ft/sec}}$$

also, 1 ft = 0.3048 m

$$\left(88\frac{\text{ft}}{\text{sec}}\right)\left(\frac{0.3048 \text{ m}}{1 \text{ ft}}\right) = 26.82\frac{\text{m}}{\text{sec}}$$

Thus $$\boxed{88\frac{\text{ft}}{\text{sec}} = 26.82\frac{\text{m}}{\text{sec}}}$$

2.16 $$692\frac{\text{miles}}{\text{hour}}\left(\frac{88 \text{ ft/sec}}{60 \text{ mph}}\right) = \boxed{1015 \text{ ft/sec}}$$

$$692\frac{\text{miles}}{\text{hour}}\left(\frac{26.82 \text{ m/sec}}{60 \text{ mph}}\right) = \boxed{309.3 \text{ m/sec}}$$

2.17 On the front face

$$F_f = p_f A = (1.0715 \times 10^5)(2) = 2.143 \times 10^5 \text{ N}$$

On the back face

$$F_b = p_b A = (1.01 \times 10^5)(2) = 2.02 \times 10^5 \text{ N}$$

The net force on the plate is

$$F = F_f - F_b = (2.143 - 2.02) \times 10^5 = 0.123 \times 10^5 \text{ N}$$

From Appendix C,

$$1\, lb_f = 4.448 \text{ N.}$$

So,

$$F = \frac{0.123 \times 10^5}{4.448} = \boxed{2765 \text{ lb}}$$

This force acts in the same direction as the flow (i.e., it is aerodynamic drag.)

2.18 Wing loading $= \frac{W}{s} = \frac{10{,}100}{233} = \boxed{43.35 \text{ lb/ft}^2}$

In SI units:

$$\frac{W}{s} = \left(43.35\frac{\text{lb}}{\text{ft}^2}\right)\left(\frac{4.448 \text{ N}}{1 \text{ lb}}\right)\left(\frac{1 \text{ ft}}{0.3048 \text{ m}}\right)^2$$

$$\frac{W}{s} = \boxed{2075.5\frac{\text{N}}{\text{m}^2}}$$

In terms of kilogram force,

$$\frac{W}{s} = \left(2075.5\frac{\text{N}}{\text{m}^2}\right)\left(\frac{1 \text{ k}_f}{9.8 \text{ N}}\right) = \boxed{211.8\frac{\text{kg}_f}{\text{m}^2}}$$

2.19 $V = \left(437\frac{\text{miles}}{\text{hr}}\right)\left(\frac{5280 \text{ ft}}{\text{mile}}\right)\left(\frac{0.3048 \text{ m}}{1 \text{ ft}}\right) = 7.033\times10^5\,\frac{\text{m}}{\text{hr}} = \boxed{703.3\,\frac{\text{km}}{\text{hr}}}$

$$\text{Altitude} = (25{,}000 \text{ ft})\left(\frac{0.3048 \text{ m}}{1 \text{ ft}}\right) = 7620 \text{ m} = \boxed{7.62 \text{ km}}$$

2.20 $V = \left(26{,}000\,\frac{\text{ft}}{\text{sec}}\right)\left(\frac{0.3048 \text{ m}}{1 \text{ ft}}\right) = 7.925\times10^3\,\frac{\text{m}}{\text{sec}} = \boxed{7.925\,\frac{\text{km}}{\text{sec}}}$

2.21 From Fig. 2.16,

length of fuselage = 33 ft, 4.125 inches = 33.34 ft

$$= 33.34 \text{ ft}\left(\frac{0.3048 \text{ m}}{\text{ft}}\right) = \boxed{10.16 \text{ m}}$$

wing span = 40 ft, 11.726 inches = 40.98 ft

$$= 40.98 \text{ ft}\left(\frac{0.3048 \text{ m}}{\text{ft}}\right) = \boxed{12.49 \text{ m}}$$

2.22 **(a)** From App. C 1 ft. = 0.3048 m.

Thus,

354,200 ft = (354,000)(0.3048) = 107,960 m = 107.96 km

(b) From Example 2.6: 60 mph = 26.82 m/sec

Thus,

$$4520\,\frac{\text{miles}}{\text{hr}} = 4520\,\frac{\text{miles}}{\text{hr}} = \frac{\left(26.82\,\frac{\text{m}}{\text{sec}}\right)}{60\left(\frac{\text{mi}}{\text{hr}}\right)}\ 2020.4 \text{ m/sec}$$

2.23

$$m = \frac{34,000 \text{ lb}}{32.2 \text{ lb/slug}} = 1055.9 \text{ slug}$$

From Newton's 2nd Law

$$F = ma$$

$$a = \frac{F}{M} = \frac{57,000}{1055.9} = 53.98 \text{ ft/sec}^2$$

2.24

$$\text{\# of g's} = \frac{53.98}{32.2} = 1.68$$

2.25 From Appendix C, one pound of force equals 4.448 N. Thus, the thrust of the Rolls-Royce Trent engine in pounds is

$$T = \frac{373.7 \times 10^3 \text{ N}}{4.448 \text{ N/lb}} = 84,015 \text{ lb}$$

2.26

(a) $F = (690,000)(9.8) = \boxed{6.762 \times 10^6 \text{ N}}$

(b) $F = 6.762 \times 10^6 / 4.448 = \boxed{1.5 \times 10^6 \text{ lb}}$

Chapter 3

3.1 An examination of the standard temperature distribution through the atmosphere given in Figure 3.3 of the text shows that both 12 km and 18 km are in the same constant temperature region. Hence, the equations that apply are Eqs. (3.9) and (3.10) in the text. Since we are in the same isothermal region with therefore the same base values of p and ρ, these equations can be written as

$$\frac{\rho_2}{\rho_1} = \frac{p_2}{p_1} = e^{-(g_0/RT)(h_2-h_1)}$$

where points 1 and 2 are any two arbitrary points in the region. Hence, with g_0 = 9.8 m/sec^2 and R = 287 joule/kgK, and letting points 1 and 2 correspond to 12 km and 18 km altitudes, respectively,

$$\frac{\rho_2}{\rho_1} = \frac{p_2}{p_1} = e^{\frac{9.8}{(287)(216.66)}(6000)} = 0.3884$$

Hence:

$$p_2 = (0.3884)(1.9399 \times 10^4) = 7.53 \times 10^3 \text{ N/m}^2$$
$$\rho_2 = (0.3884)(3.1194 \times 10^{-1}) = 0.121 \text{ kg/m}^3$$

and, of course,

$$T_2 = 216.66 \text{ K}$$

These answers check the results listed in Appendix A of the text within round-off error.

3.2 From Appendix A of the text, we see immediately that p = 2.65 × 10^4 N/m^2 corresponds to 10,000 m, or 10 km, in the standard atmosphere. Hence,

pressure altitude = 10 km

The outside air density is

$$\rho = \frac{p}{RT} = \frac{2.65 \times 10^4}{(287)(220)} = 0.419 \text{ kg/m}^3$$

From Appendix A, this value of ρ corresponds to 9.88 km in the standard atmosphere. Hence,

density altitude = 9.88 km

3.3 At 35,000 ft, from Appendix B, we find that p = 4.99 × 10^2 = 499 lb/ft^2.

3.4 From Appendix B in the text,

33,500 ft corresponds to p = 535.89 lb/ft^2

32,000 ft corresponds to ρ = 8.2704 × 10^{-4} slug/ft^3

Hence,

$$T = \frac{p}{\rho R} = \frac{535.89}{(8.2704 \times 10^{-4})(1716)} = 378\ R$$

3.5 $\frac{|h - h_G|}{h} = 0.02 = \left|1 - \frac{h_G}{h}\right|$

From Eq. (3.6), the above equation becomes

$$\left|1 - \left(\frac{r + h_G}{r}\right)\right| = \left|1 - 1 - \frac{h_G}{r}\right| = 0.02$$

$$h_G = 0.02\, r = 0.02(6.357 \times 10^6)$$

$$h_G = 1.27 \times 10^5 \text{m} = 127 \text{ km}$$

3.6 $T = 15 - 0.0065h = 15 - 0.0065(5000) = -17.5°\text{C} = 255.5°\text{K}$

$$a = \frac{dT}{dh} = -0.0065$$

From Eq. (3.12)

$$\frac{p}{p_1} = \left(\frac{T}{T_1}\right)^{-g_0/aR} = \left(\frac{255.5}{288}\right)^{-(2.8)/(-0.0065)(287)} = 0.533$$

$$p = 0.533\, p_1 = 0.533\,(1.01 \times 10^5) = 5.38 \times 10^4 \text{N/m}^2$$

3.7 $\ell n \frac{p}{p_1} = -\frac{g}{RT}(h - h_1)$

$$h - h_1 = -\frac{1}{g} RT\, \ell n \frac{p}{p_1} = -\frac{1}{24.9}(4157)(150)\, \ell n\, 0.5$$

Letting $h_1 = 0$ (the surface)

h = 17,358 m = 17.358 km

3.8 A standard altitude of 25,000 ft falls within the first gradient region in the standard atmosphere. Hence, the variation of pressure and temperature are given by:

$$\frac{p}{p_1} = \left(\frac{T}{T_1}\right)^{-\frac{g}{aR}} \tag{1}$$

and

$$T = T_1 + a\,(h - h_1) \tag{2}$$

Differentiating Eq. (1) with respect to time:

$$\frac{1}{p_1}\frac{dp}{dt} = \left(\frac{1}{T_1}\right)^{-\frac{g}{aR}}\left(-\frac{g}{AR}\right)T^{\left(-\frac{g}{aR}-1\right)}\frac{dT}{dt} \tag{3}$$

Differentiating Eq. (2) with respect to time:

$$\frac{dT}{dt} = a\frac{dh}{dt} \tag{4}$$

Substitute Eq. (4) into (3)

$$\frac{dp}{dt} = -p_1(T_1)^{\frac{g}{aR}}\left(\frac{g}{R}\right)T^{-\left(\frac{g}{aR}+1\right)}\frac{dh}{dt} \tag{5}$$

In Eq. (5), dh/dt is the rate-of-climb, given by dh/dt = 500 ft/sec. Also, in the first gradient region, the lapse rate can be calculated from the tabulations in Appendix B. For example, take 0 ft and 10,000 ft, we find

$$a = \frac{T_2 - T_1}{h_2 - h_1} = \frac{483.04 - 518.69}{10{,}000 - 0} = -0.00357\frac{°R}{\text{ft}}$$

Also from Appendix B, p_1= 2116.2 lb/ft^2 at sea level, and T = 429.64 °R at 25,000 ft.

Thus,

$$\frac{g}{aR} = \frac{32.2}{(-0.00357)(1716)} = -5.256$$

Hence, from Eq. (5)

$$\frac{dp}{dt} = -(2116.2)(518.69)^{-5.256}\left(\frac{32.2}{1716}\right)(429.64)^{4.256}(500)$$

$$\frac{dp}{dt} = -17.17\frac{\text{lb}}{\text{ft}^2\text{sec}}$$

3.9 From the hydrostatic equation, Eq. (3.2) or (3.3),

$$dp = -\rho g_0 dh$$

or

$$\frac{dp}{dt} = -\rho\, g_0 \frac{dh}{dt}$$

The upward speed of the elevator is *dh*/*dt*, which is

$$\frac{dp}{dt} = \frac{dp/dt}{-\rho\, g_0}$$

At sea level, ρ = 1.225 kg/m^3. Also, a one-percent change in pressure per minute starting from sea level is

$$\frac{dp}{dt} = -(1.01 \times 10^5)(0.01) = -1.01 \times 10^3 \text{ N/m}^2 \text{ per minute}$$

Hence,

$$\frac{dh}{dt} = \frac{-1.01 \times 10^3}{(1.225)(9.8)} = 84.1 \text{meter per minute}$$

3.10 From Appendix B:

At 35,500 ft: *p* = 535.89 lb/ft^2

At 34,000 ft: *p* = 523.47 lb/ft^2

For a pressure of 530 lb/ft^2, the pressure altitude is

$$33{,}500 + 500\left(\frac{535.89 - 530}{535.89 - 523.47}\right) = 33737 \text{ ft}$$

The density at the altitude at which the airplane is flying is

$$\rho = \frac{\rho}{RT} = \frac{530}{(1716)(390)} = 7.919 \times 10^{-4} \text{ slug/ft}^3$$

From Appendix B:

At 33,000 ft: $\rho = 7.9656 \times 10^{-4}$ slug/ft^3

At 33,500 ft: $\rho = 7.8165 \times 10^{-4}$ slug/ft^3

Hence, the density altitude is

$$33{,}000 + 500\left(\frac{7.9656 - 7.919}{7.9656 - 7.8165}\right) = 33{,}156 \text{ ft}$$

3.11 Let ℓ be the length of one wall of the tank, ℓ = 30 ft. Let d be the depth of the pool, d = 10 ft. At the water surface, the pressure is atmospheric pressure, p_a. The water pressure increases with increasing depth; the pressure as a function of distance below the surface, h, is given by the hydrostatic equation

$$dp = \rho g \, dh \qquad (1)$$

Note: The hydrostatic equation given by Eq. (3.2) in the text has a minus sign because h_G is measured positive in the upward direction. In Eq. (1), h is measured positive in the downward direction, with h = 0 at the surface of the water. Hence, no minus sign appears in Eq. (1); as h increases (as we go deeper into the water), p increases. Eq. (1) is consistent with this fact. Integrating Eq. (1) from h = 0 where $p = p_a$ to some local depth h where the pressure is p, and noting that ρ is constant for water, we have

$$\int_{p_a}^{\rho} dp = \rho g \int_0^h dh$$

or, $p - p_a = \rho g h$

or, $$p = \rho g h + p_a \qquad (2)$$

Eq. (2) gives the water pressure exerted on the wall at an arbitrary depth h.

Consider an elementary small sliver of wall surface of length ℓ and height dh.

The water force on this sliver of area is

$$dF = p \, \ell \, dh$$

Total force, F, on the wall is

$$F = \int_0^F dF = \int_0^d p \, \ell \, dh \qquad (3)$$

where p is given by Eq. (2). Inserting Eq. (2) into (3),

$$F = \int_0^d (\rho g h + p_a) \, \ell \, dh$$

or, $$F = \rho g \ell \left(\frac{d^2}{2} \right) + p_a \ell d \qquad (4)$$

In Eq. (4), the product ρg is the specific weight (weight per unit volume) of water; ρg = 62.4 lb/ft^3. From Eq. (4),

$$F = (62.4)(30)\frac{(10)^2}{2} + (2116)(30)(10)$$

$$F = 93{,}600 + 634{,}800 = \boxed{728{,}400 \text{ lb}}$$

Note: This force is the combined effect of the force due to the weight of the water, 93,600 lb, and the force due to atmospheric pressure transmitted through the water, 634,800 lb. In this example, the latter is the larger contribution to the force on the wall. If the wall were freestanding with atmospheric pressure exerted on the opposite side, then the net force exerted on the wall would be that due to the weight of the water only, i.e., 93,600 lb. In tons, the force on the side of the wall in contact with the water is

$$F = \frac{728{,}400}{2000} = \boxed{364.2 \text{ tons}}$$

In the case of a freestanding wall, the net force, that due only to the weight of the water, is

$$F = \frac{93,600}{2000} = \boxed{46.8\,\text{tons}}$$

3.12 For the exponential atmosphere model,

$$\frac{\rho}{\rho_0} = e^{-g_0 h/(RT)}$$

$$\frac{\rho}{\rho_0} = e^{-(9.8)(45{,}000)/(287)(240)} = e^{-6.402}$$

Hence,

$$\rho = \rho_0 e^{-6.402} = (1225)(1.6575 \times 10^{-3}) = \boxed{2.03 \times 10^{-3}\ \text{kg/m}^3}$$

From the standard atmosphere, at 45 km, $p = 2.02 \times 10^{-3}$ kg/m^3. The exponential atmosphere model gives a remarkably accurate value for the density at 45 km when a value of 240 K is used for the temperature.

3.13 At 3 km, from App. A, T = 268.67 K, $p = 7.0121 \times 10^4$ N/m^2, and ρ = 0.90926 kg/m^3. At 3.1 km, from App. A, T = 268.02 K, $p = 6.9235 \times 10^4$ N/m^2, and ρ = 0.89994 kg/m^3. At h = 3.035 km, using linear interpolation:

$$T = 268.67 - (268.67 - 268.02)\left(\frac{0.035}{0.1}\right) = \boxed{268.44\ \text{K}}$$

$$p = 7.0121 \times 10^4 - (7.0121 \times 10^4 - 6.9235 \times 10^4)\left(\frac{0.035}{0.1}\right)$$

$$\boxed{= 6.98099 \times 10^4\ \frac{\text{N}}{\text{m}^2}}$$

$$\rho = 0.09026 - (0.90926 - 0.89994)\left(\frac{0.035}{0.1}\right) = \boxed{0.906\ \frac{\text{kg}}{\text{m}^3}}$$