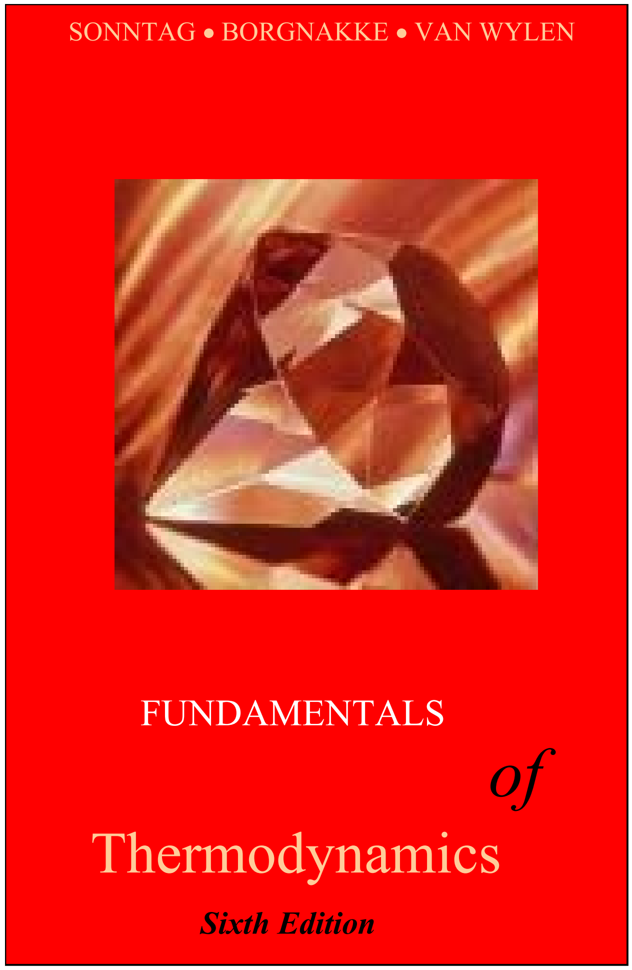
SOLUTION MANUAL
ENGLISH UNIT PROBLEMS
CHAPTER 2



CHAPTER 2

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Correspondence table

The correspondence between the problem set in this sixth edition versus the problem set in the 5'th edition text. Problems that are new are marked new and the SI number refers to the corresponding 6th edition SI unit problem.

New	5th Ed.	SI	New	5th Ed.	SI
87	new	-	97	43E	43
88	new	11	98	new	50
89	new	12	99	new	53
90	new	19	100	45E	70
91	new	20	101	46E	45
92	new	24	102	new	82
93	39E	33	103	48E	55
94	40E	-	104	new	80
95	new	47	105	47E	77
96	42E	42			

Concept Problems

2.87E

A mass of 2 lbm has acceleration of 5 ft/s^2, what is the needed force in lbf?

Solution:

Newtons 2nd law: $F = ma$

$$F = ma = 2 \text{ lbm} \times 5 \text{ ft/s}^2 = 10 \text{ lbm ft/s}^2$$
$$= \frac{10}{32.174} \text{ lbf} = \mathbf{0.31 \text{ lbf}}$$

2.88E

How much mass is in 0.25 gallon of liquid mercury (Hg)? Atmospheric air?

Solution:

A volume of 1 gal equals 231 in^3, see Table A.1. From Figure 2.7 the density is in the range of 10 000 kg/m^3 = 624.28 lbm/ft^3, so we get

$$m = \rho V = 624.3 \text{ lbm/ft}^3 \times 0.25 \times (231/12^3\ ) \text{ ft}^3 = \mathbf{20.86 \text{ lbm}}$$

A more accurate value from Table F.3 is ρ = 848 lbm/ft^3.

For the air we see in Figure 2.7 that density is about 1 kg/m^3 = 0.06243 lbm/ft^3 so we get

$$m = \rho V = 0.06243 \text{ lbm/ft}^3 \times 0.25 \times (231/12^3\ ) \text{ ft}^3 = \mathbf{0.00209 \text{ lbm}}$$

A more accurate value from Table F.4 is ρ = 0.073 lbm/ft^3 at 77 F, 1 atm.

2.89E

Can you easily carry a one gallon bar of solid gold?

Solution:

The density of solid gold is about 1205 lbm/ft^3 from Table F.2, we could also have read Figure 2.7 and converted the units.

$$V = 1 \text{ gal} = 231 \text{ in}^3 = 231 \times 12^{-3} \text{ ft}^3 = 0.13368 \text{ ft}^3$$

Therefore the mass in one gallon is

$$m = \rho V = 1205 \text{ lbm/ft}^3 \times 0.13368 \text{ ft}^3$$
$$= 161 \text{ lbm}$$

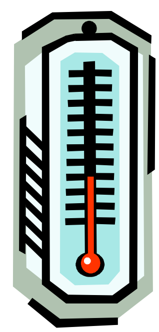
and some people can just about carry that in the standard gravitational field.

2.90E

What is the temperature of –5F in degrees Rankine?

Solution:

The offset from Fahrenheit to Rankine is 459.67 R, so we get



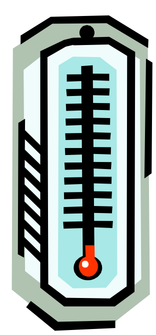
$$T_R = T_F + 459.67 = -5 + 459.67$$
$$= \mathbf{454.7\ R}$$

2.91E

What is the smallest temperature in degrees Fahrenheit you can have? Rankine?

Solution:

The lowest temperature is absolute zero which is at zero degrees Rankine at which point the temperature in Fahrenheit is negative



$$T_R = 0 \text{ R} = -459.67 \text{ F}$$

Properties and Units

2.92E

An apple weighs 0.2 lbm and has a volume of 6 in^3 in a refrigerator at 38 F. What is the apple density? List three intensive and two extensive properties for the apple.

Solution:

$$\rho = \frac{m}{V} = \frac{0.2}{6} \frac{\text{lbm}}{\text{in}^3} = 0.0333 \frac{\text{lbm}}{\text{in}^3} = 57.6 \frac{\text{lbm}}{\text{ft}^3}$$

Intensive

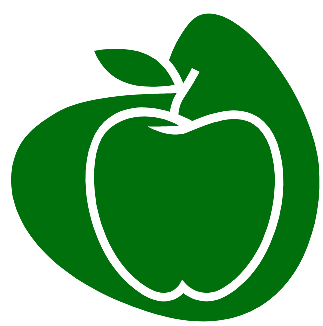
$$\rho = 57.6 \frac{\text{lbm}}{\text{ft}^3}; \qquad v = \frac{1}{\rho} = 0.0174 \frac{\text{ft}^3}{\text{lbm}}$$

$$T = 38 \text{ F}; \qquad P = 14.696 \text{ lbf/in}^2$$

Extensive

$$m = 0.2 \text{ lbm}$$

$$V = 6 \text{ in}^3 = 0.026 \text{ gal} = 0.00347 \text{ ft}^3$$



Force, Energy, Density

2.93E

A 2500-lbm car moving at 15 mi/h is accelerated at a constant rate of 15 ft/s^2 up to a speed of 50 mi/h. What are the force and total time required?

Solution:

$$a = \frac{d\mathbf{V}}{dt} = \frac{\Delta\mathbf{V}}{\Delta t} \;\Rightarrow\; \Delta t = \frac{\Delta\mathbf{V}}{a}$$

$$\Delta t = \frac{(50 - 15) \text{ mi/h} \times 1609.34 \text{ m/mi} \times 3.28084 \text{ ft/m}}{3600 \text{ s/h} \times 15 \text{ ft/s}^2} = \mathbf{3.42\ sec}$$

$$F = ma = (2500 \times 15 / 32.174) \text{ lbf} = \mathbf{1165\ lbf}$$

2.94E

Two pound moles of diatomic oxygen gas are enclosed in a 20-lbm steel container. A force of 2000 lbf now accelerates this system. What is the acceleration?

Solution:

The molecular weight for oxygen is M = 31.999 from Table F.1. The force must accelerate both the container and the oxygen mass.

$$m_{O_2} = n_{O_2} M_{O_2} = 2 \times 31.999 = 64 \text{ lbm}$$

$$m_{tot} = m_{O_2} + m_{steel} = 64 + 20 = 84 \text{ lbm}$$

$$a = \frac{F}{m_{tot}} = \frac{2000 \text{ lbf}}{84 \text{ lbm}} \times 32.174 \frac{\text{lbm ft s}^{-2}}{\text{lbf}} = \mathbf{766 \ ft/s^2}$$

2.95E

A valve in a cylinder has a cross sectional area of 2 in^2 with a pressure of 100 psia inside the cylinder and 14.7 psia outside. How large a force is needed to open the valve?

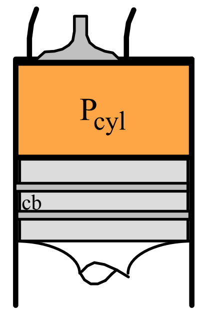
Solution:

$$F_{net} = P_{in}A - P_{out}A$$

$$= (100 - 14.7) \text{ psia} \times 2 \text{ in}^2$$

$$= 170.6 \text{ (lbf/in}^2) \times \text{in}^2$$

$$= \mathbf{170.6\ lbf}$$



2.96E

One pound-mass of diatomic oxygen (O_2 molecular weight 32) is contained in a 100-gal tank. Find the specific volume on both a mass and mole basis (v and $\bar{v}$).

Solution:

$V = 231 \text{ in}^3 = (231 / 12^3) \text{ ft}^3 = 0.1337 \text{ ft}^3$ conversion seen in Table A.1

This is based on the definition of the specific volume

$$v = V/m = 0.1337 \text{ ft}^3/1 \text{ lbm} = \mathbf{0.1337 \ ft^3/lbm}$$

$$\bar{v} = V/n = \frac{V}{m/M} = Mv = 32 \times 0.1337 = \mathbf{4.278 \ ft^3/lbmol}$$

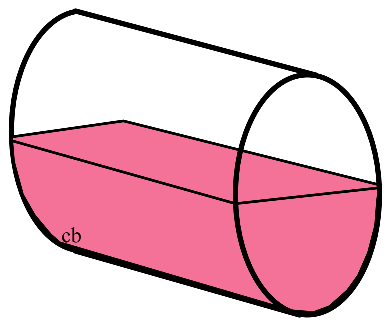
Pressure

2.97E

A 30-lbm steel gas tank holds 10 ft^3 of liquid gasoline, having a density of 50 lbm/ft^3. What force is needed to accelerate this combined system at a rate of 15 ft/s^2?

Solution:

$$m = m_{tank} + m_{gasoline}$$
$$= 30 \text{ lbm} + 10 \text{ ft}^3 \times 50 \text{ lbm/ft}^3$$
$$= 530 \text{ lbm}$$



$$F = ma = (530 \text{ lbm} \times 15 \text{ ft/s}^2) / (32.174 \text{ lbm ft/s}^2 \text{ lbf}) = \mathbf{247.1 \text{ lbf}}$$

2.98E

A laboratory room keeps a vacuum of 4 in. of water due to the exhaust fan. What is the net force on a door of size 6 ft by 3 ft?

Solution:

The net force on the door is the difference between the forces on the two sides as the pressure times the area

$$
\begin{aligned}
F &= P_{outside}\, A - P_{inside}\, A = \Delta P \times A \\
&= 4 \text{ in } H_2O \times 6 \text{ ft} \times 3 \text{ ft} \\
&= 4 \times 0.036126 \text{ lbf/in}^2 \times 18 \text{ ft}^2 \times 144 \text{ in}^2/\text{ft}^2 \\
&= \mathbf{374.6\ lbf}
\end{aligned}
$$

Table A.1: 1 in H_2O is 0.036 126 lbf/in^2, unit also often listed as psi.

2.99E

A 7 ft m tall steel cylinder has a cross sectional area of 15 ft^2. At the bottom with a height of 2 ft m is liquid water on top of which is a 4 ft high layer of gasoline. The gasoline surface is exposed to atmospheric air at 14.7 psia. What is the highest pressure in the water?

Solution:

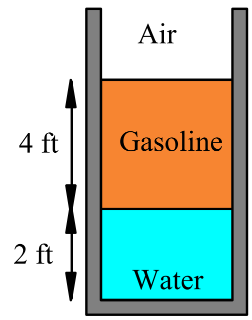
The pressure in the fluid goes up with the depth as

$$P = P_{top} + \Delta P = P_{top} + \rho g h$$

and since we have two fluid layers we get

$$P = P_{top} + [(\rho h)_{gasoline} + (\rho h)_{water}]g$$

The densities from Table F.4 are:



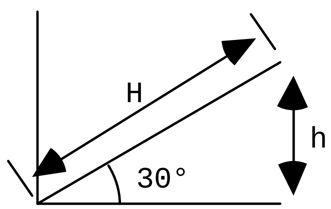
$$\rho_{gasoline} = 46.8 \text{ lbm/ft}^3; \quad \rho_{water} = 62.2 \text{ lbm/ft}^3$$

$$P = 14.7 + [46.8 \times 4 + 62.2 \times 2] \frac{32.174}{144 \times 32.174} = \mathbf{16.86\ lbf/in^2}$$

2.100E

A U-tube manometer filled with water, density 62.3 lbm/ft^3, shows a height difference of 10 in. What is the gauge pressure? If the right branch is tilted to make an angle of 30° with the horizontal, as shown in Fig. P2.72, what should the length of the column in the tilted tube be relative to the U-tube?

Solution:



$$\Delta P = F/A = mg/A = h\rho g$$

$$= \frac{(10/12)\times 62.3 \times 32.174}{32.174 \times 144}$$

$$= P_{gauge} = \mathbf{0.36\ lbf/in^2}$$

$$h = H \times \sin 30°$$

$$\Rightarrow\ H = h/\sin 30° = 2h = 20 \text{ in} = \mathbf{0.833\ ft}$$

2.101E

A piston/cylinder with cross-sectional area of 0.1 ft^2 has a piston mass of 200 lbm resting on the stops, as shown in Fig. P2.45. With an outside atmospheric pressure of 1 atm, what should the water pressure be to lift the piston?

Solution:

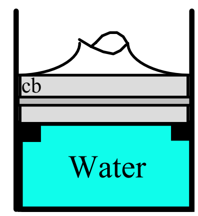
The force acting down on the piston comes from gravitation and the outside atmospheric pressure acting over the top surface.

Force balance: $F\uparrow = F\downarrow = PA = m_p g + P_0 A$

Now solve for P (multiply by 144 to convert from ft^2 to in^2)

$$P = P_0 + \frac{m_p g}{A} = 14.696 + \frac{200 \times 32.174}{0.1 \times 144 \times 32.174}$$

$$= 14.696 \text{ psia} + 13.88 \text{ psia} = \mathbf{28.58\ lbf/in^2}$$



2.102E

The main waterline into a tall building has a pressure of 90 psia at 16 ft elevation below ground level. How much extra pressure does a pump need to add to ensure a waterline pressure of 30 psia at the top floor 450 ft above ground?

Solution:

The pump exit pressure must balance the top pressure plus the column ΔP. The pump inlet pressure provides part of the absolute pressure.

$P_{\text{after pump}} = P_{\text{top}} + \Delta P$

$$\Delta P = \rho g h = 62.2 \text{ lbm/ft}^3 \times 32.174 \text{ ft/s}^2 \times (450 + 16) \text{ ft} \times \frac{1 \text{ lbf s}^2}{32.174 \text{ lbm ft}}$$

$$= 28\ 985 \text{ lbf/ft}^2 = 201.3 \text{ lbf/in}^2$$

$P_{\text{after pump}} = 30 + 201.3 = 231.3$ psia

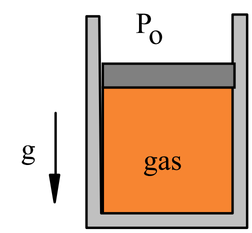
$\Delta P_{\text{pump}} = 231.3 - 90 =$ **141.3 psi**

2.103E

A piston, m_p = 10 lbm, is fitted in a cylinder, A = 2.5 in.^{2}, that contains a gas. The setup is in a centrifuge that creates an acceleration of 75 ft/s^2. Assuming standard atmospheric pressure outside the cylinder, find the gas pressure.

Solution:

Force balance: $F\uparrow = F\downarrow = P_0A + m_pg = PA$



$$P = P_0 + \frac{m_pg}{A}$$

$$= 14.696 + \frac{10 \times 75}{2.5 \times 32.174} \ \frac{\text{lbm ft/s}^2}{\text{in}^2} \ \frac{\text{lbf-s}^2}{\text{lbm-ft}}$$

$$= 14.696 + 9.324 = \mathbf{24.02\ lbf/in^2}$$

Temperature

2.104E

The atmosphere becomes colder at higher elevation. As an average the standard atmospheric absolute temperature can be expressed as $T_{atm} = 518 - 3.84 \times 10^{-3}\, z$, where z is the elevation in feet. How cold is it outside an airplane cruising at 32 000 ft expressed in Rankine and in Fahrenheit?

Solution:

For an elevation of z = 32 000 ft we get

$$T_{atm} = 518 - 3.84 \times 10^{-3}\, z = \mathbf{395.1\ R}$$

To express that in degrees Fahrenheit we get

$$T_F = T - 459.67 = \mathbf{-64.55\ F}$$

2.105E

The density of mercury changes approximately linearly with temperature as

$\rho_{Hg} = 851.5 - 0.086\ T$ lbm/ft^3 $\quad T$ in degrees Fahrenheit

so the same pressure difference will result in a manometer reading that is influenced by temperature. If a pressure difference of 14.7 lbf/in.^{2} is measured in the summer at 95 F and in the winter at 5 F, what is the difference in column height between the two measurements?

Solution:

$$\Delta P = \rho g h \quad \Rightarrow \quad h = \Delta P/\rho g$$

$$\rho_{su} = 843.33 \text{ lbm/ft}^3; \qquad \rho_w = 851.07 \text{ lbm/ft}^3$$

$$h_{su} = \frac{14.7 \times 144 \times 32.174}{843.33 \times 32.174} = 2.51 \text{ ft} = 30.12 \text{ in}$$

$$h_w = \frac{14.7 \times 144 \times 32.174}{851.07 \times 32.174} = 2.487 \text{ ft} = 29.84 \text{ in}$$

$$\Delta h = h_{su} - h_w = 0.023 \text{ ft} = \mathbf{0.28\ in}$$