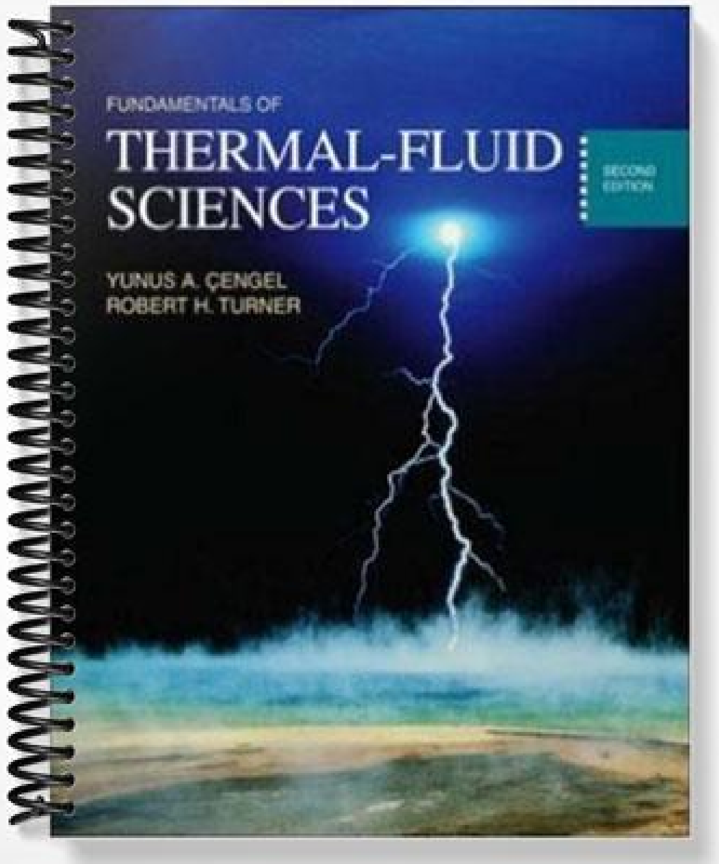
SOLUTIONS MANUAL



Review Problems

2-80E The efficiency of a refrigerator increases by 3% per °C rise in the minimum temperature. This increase is to be expressed per °F, K, and R rise in the minimum temperature.

Analysis The magnitudes of 1 K and 1°C are identical, so are the magnitudes of 1 R and 1°F. Also, a change of 1 K or 1°C in temperature corresponds to a change of 1.8 R or 1.8°F. Therefore, the increase in efficiency is

(a) **3%** for each K rise in temperature, and
(b), (c) 3/1.8 = **1.67%** for each R or °F rise in temperature.

2-81E The boiling temperature of water decreases by 3°C for each 1000 m rise in altitude. This decrease in temperature is to be expressed in °F, K, and R.

Analysis The magnitudes of 1 K and 1°C are identical, so are the magnitudes of 1 R and 1°F. Also, a change of 1 K or 1°C in temperature corresponds to a change of 1.8 R or 1.8°F. Therefore, the decrease in the boiling temperature is

(a) **3 K** for each 1000 m rise in altitude, and
(b), (c) 3×1.8 = **5.4°F = 5.4 R** for each 1000 m rise in altitude.

2-82E The average body temperature of a person rises by about 2°C during strenuous exercise. This increase in temperature is to be expressed in °F, K, and R.

Analysis The magnitudes of 1 K and 1°C are identical, so are the magnitudes of 1 R and 1°F. Also, a change of 1 K or 1°C in temperature corresponds to a change of 1.8 R or 1.8°F. Therefore, the rise in the body temperature during strenuous exercise is

(a) **2 K**
(b) 2×1.8 = **3.6°F**
(c) 2×1.8 = **3.6 R**

2-83E Hypothermia of 5°C is considered fatal. This fatal level temperature change of body temperature is to be expressed in °F, K, and R.

Analysis The magnitudes of 1 K and 1°C are identical, so are the magnitudes of 1 R and 1°F. Also, a change of 1 K or 1°C in temperature corresponds to a change of 1.8 R or 1.8°F. Therefore, the fatal level of hypothermia is

(a) **5 K**
(b) 5×1.8 = **9°F**
(c) 5×1.8 = **9 R**

2-84E A house is losing heat at a rate of 3000 kJ/h per °C temperature difference between the indoor and the outdoor temperatures. The rate of heat loss is to be expressed per °F, K, and R of temperature difference between the indoor and the outdoor temperatures.

Analysis The magnitudes of 1 K and 1°C are identical, so are the magnitudes of 1 R and 1°F. Also, a change of 1 K or 1°C in temperature corresponds to a change of 1.8 R or 1.8°F. Therefore, the rate of heat loss from the house is

(a) **3000 kJ/h** per K difference in temperature, and
(b), (c) 3000/1.8 = **1667 kJ/h** per R or °F rise in temperature.

2-85 The average temperature of the atmosphere is expressed as $T_{atm} = 288.15 - 6.5z$ where z is altitude in km. The temperature outside an airplane cruising at 12,000 m is to be determined.

Analysis Using the relation given, the average temperature of the atmosphere at an altitude of 12,000 m is determined to be

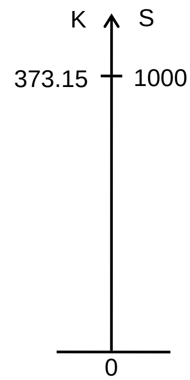
$$\begin{aligned} T_{atm} &= 288.15 - 6.5z \\ &= 288.15 - 6.5\times12 \\ &= \mathbf{210.15\ K = -63°C} \end{aligned}$$

Discussion This is the "average" temperature. The actual temperature at different times can be different.

2-86 A new "Smith" absolute temperature scale is proposed, and a value of 1000 S is assigned to the boiling point of water. The ice point on this scale, and its relation to the Kelvin scale are to be determined.

Analysis All linear absolute temperature scales read zero at absolute zero pressure, and are constant multiples of each other. For example, T(R) = 1.8 T(K). That is, multiplying a temperature value in K by 1.8 will give the same temperature in R.

The proposed temperature scale is an acceptable absolute temperature scale since it differs from the other absolute temperature scales by a constant only. The boiling temperature of water in the Kelvin and the Smith scales are 315.15 K and 1000 K, respectively. Therefore, these two temperature scales are related to each other by



$$T(S) = \frac{1000}{373.15} T(K) = \mathbf{2.6799\ T(K)}$$

The ice point of water on the Smith scale is

$$T(S)_{ice} = 2.6799\ T(K)_{ice} = 2.6799 \times 273.15 = \mathbf{732.0\ S}$$

2-87E An expression for the equivalent wind chill temperature is given in English units. It is to be converted to SI units.

Analysis The required conversion relations are 1 mph = 1.609 km/h and T(°F) = 1.8T(°C) + 32. The first thought that comes to mind is to replace T(°F) in the equation by its equivalent 1.8T(°C) + 32, and V in mph by 1.609 km/h, which is the "regular" way of converting units. However, the equation we have is not a regular dimensionally homogeneous equation, and thus the regular rules do not apply. The V in the equation is a constant whose value is equal to the numerical value of the velocity in mph. Therefore, if V is given in km/h, we should divide it by 1.609 to convert it to the desired unit of mph. That is,

$$T_{\text{equiv}}(^\circ\text{F}) = 91.4 - [91.4 - T_{\text{ambient}}(^\circ\text{F})][0.475 - 0.0203(V/1.609) + 0.304\sqrt{V/1.609}]$$

or

$$T_{\text{equiv}}(^\circ\text{F}) = 91.4 - [91.4 - T_{\text{ambient}}(^\circ\text{F})][0.475 - 0.0126V + 0.240\sqrt{V}]$$

where V is in km/h. Now the problem reduces to converting a temperature in °F to a temperature in °C, using the proper convection relation:

$$1.8T_{\text{equiv}}(^\circ\text{C}) + 32 = 91.4 - [91.4 - (1.8T_{\text{ambient}}(^\circ\text{C}) + 32)][0.475 - 0.0126V + 0.240\sqrt{V}]$$

which simplifies to

$$T_{\text{equiv}}(^\circ\text{C}) = 33.0 - (33.0 - T_{\text{ambient}})(0.475 - 0.0126V + 0.240\sqrt{V})$$

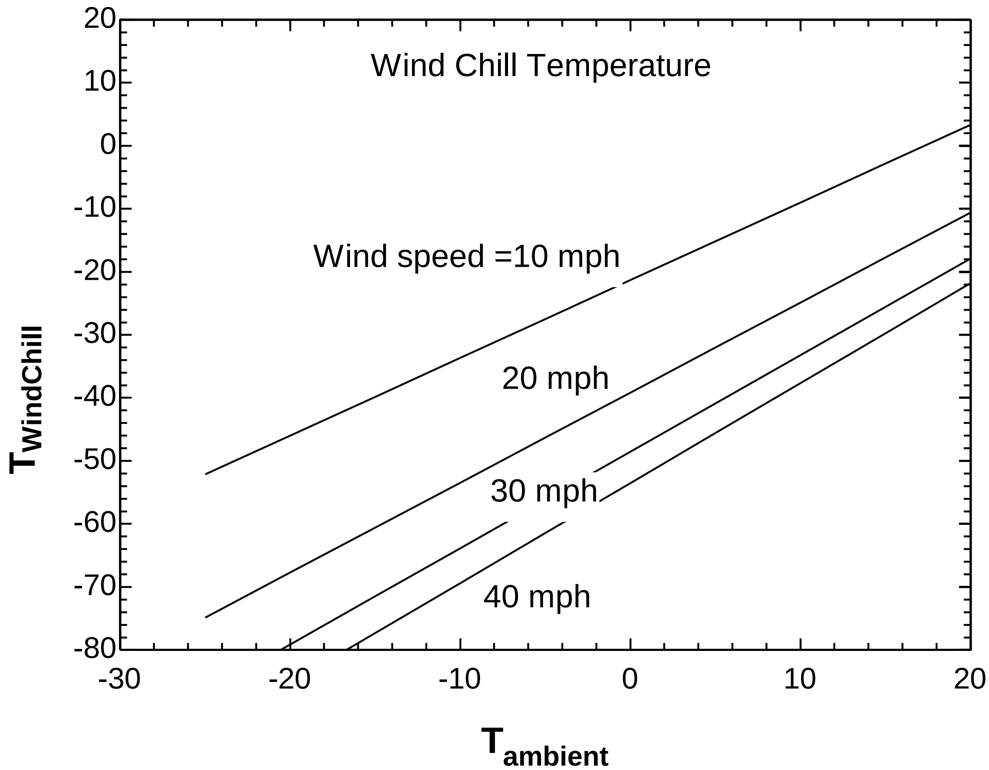
where the ambient air temperature is in °C.

2-88E Problem 2-87E is reconsidered. The equivalent wind-chill temperatures in °F as a function of wind velocity in the range of 4 mph to 100 mph for the ambient temperatures of 20, 40, and 40°F is to be plotted, and the results are to be discussed.

```
"Obtain V and T_ambient from the Diagram Window"
{T_ambient=10
V=20}
V_use=max(V,4)
T_equiv=91.4-(91.4-T_ambient)*(0.475 - 0.0203*V_use + 0.304*sqrt(V_use))

"The parametric table was used to generate the plot,  Fill in values for T_ambient
and V (use Alter Values under Tables menu) then use F3 to solve table.  Plot
the first 10 rows and then overlay the second ten, and so on.  Place the text on
the plot using Add Text under the Plot menu."
```

T_{equiv} [F]	$T_{ambient}$ [F]	V [mph]
-52	-25	10
-46	-20	10
-40	-15	10
-34	-10	10
-27	-5	10
-21	0	10
-15	5	10
-9	10	10
-3	15	10
3	20	10
-75	-25	20
-68	-20	20
-61	-15	20
-53	-10	20
-46	-5	20
-39	0	20
-32	5	20
-25	10	20
-18	15	20
-11	20	20
-87	-25	30
-79	-20	30
-72	-15	30
-64	-10	30
-56	-5	30
-49	0	30
-41	5	30
-33	10	30
-26	15	30
-18	20	30
-93	-25	40
-85	-20	40
-77	-15	40
-69	-10	40
-61	-5	40
-54	0	40
-46	5	40
-38	10	40
-30	15	40
-22	20	40


Wind Chill Temperature
Wind speed =10 mph
20 mph
30 mph
40 mph
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-30
-20
-10
0
10
20
T WindChill
T ambient

2-89 One section of the duct of an air-conditioning system is laid underwater. The upward force the water will exert on the duct is to be determined.

Assumptions **1** The diameter given is the outer diameter of the duct (or, the thickness of the duct material is negligible). **2** The weight of the duct and the air in is negligible.

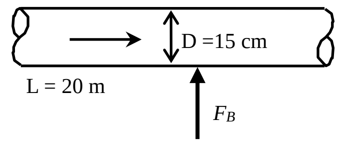
Properties The density of air is given to be ρ = 1.30 kg/m³. We take the density of water to be 1000 kg/m³.

Analysis Noting that the weight of the duct and the air in it is negligible, the net upward force acting on the duct is the buoyancy force exerted by water. The volume of the underground section of the duct is

$$V = AL = (\pi D^2 / 4)L = [\pi(0.15\,\text{m})^2/4](20\text{m}) = 0.353\ \text{m}^3$$

Then the buoyancy force becomes

$$F_B = \rho g V = (1000\ \text{kg/m}^3)(9.81\,\text{m/s}^2)(0.353\text{m}^3)\left(\frac{1\,\text{kN}}{1000\,\text{kg}\cdot\text{m/s}^2}\right) = \mathbf{3.46\,kN}$$



Discussion The upward force exerted by water on the duct is 3.46 kN, which is equivalent to the weight of a mass of 353 kg. Therefore, this force must be treated seriously.

2-90 A helium balloon tied to the ground carries 2 people. The acceleration of the balloon when it is first released is to be determined.

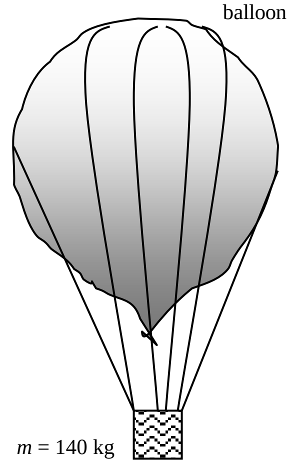
Assumptions The weight of the cage and the ropes of the balloon is negligible.

Properties The density of air is given to be ρ = 1.16 kg/m³. The density of helium gas is 1/7th of this.

Analysis The buoyancy force acting on the balloon is

$$V_{balloon} = 4\pi r^3/3 = 4\pi(5m)^3/3 = 523.6m^3$$

$$F_B = \rho_{air}\, g V_{balloon}$$
$$= (1.16\text{kg/m}^3)(9.807\text{m/s}^2)(523.6\text{m}^3)\left(\frac{1\text{N}}{1\text{kg}\cdot\text{m/s}^2}\right) = 5956.5\text{N}$$



The total mass is

$$m_{He} = \rho_{He} V = \left(\frac{1.16}{7}\text{kg/m}^3\right)(523.6\text{m}^3) = 86.8\text{kg}$$

$$m_{total} = m_{He} + m_{people} = 86.8 + 2\times 70 = 226.8\text{kg}$$

The total weight is

$$W = m_{total}\, g = (226.8\text{kg})(9.807\text{m/s}^2)\left(\frac{1\text{N}}{1\text{kg}\cdot\text{m/s}^2}\right) = 2224.2\text{N}$$

Thus the net force acting on the balloon is

$$F_{net} = F_B - W = 5956.5 - 2224.2 = 3732.3\ \text{N}$$

Then the acceleration becomes

$$a = \frac{F_{net}}{m_{total}} = \frac{3732.2\text{N}}{226.8\text{kg}}\left(\frac{1\text{kg}\cdot\text{m/s}^2}{1\text{N}}\right) = \mathbf{16.5m/s^2}$$

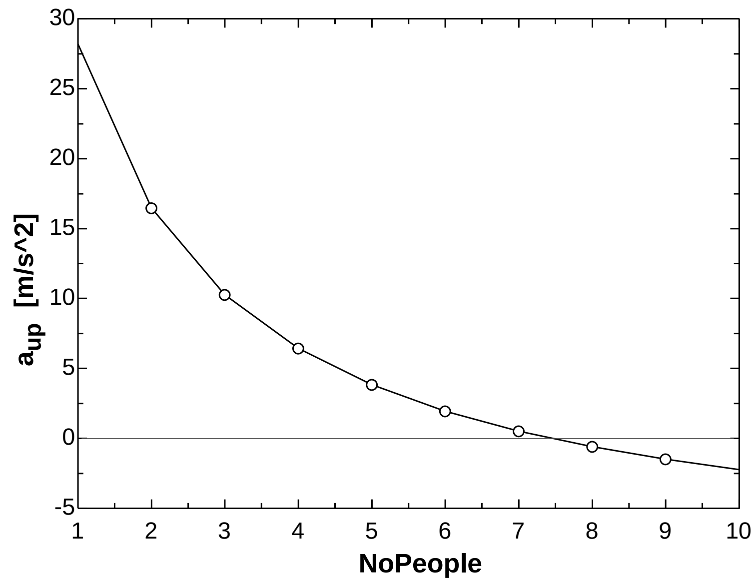
2-91 Problem 2-90 is reconsidered. The effect of the number of people carried in the balloon on acceleration is to be investigated. Acceleration is to be plotted against the number of people, and the results are to be discussed.

```
"Given Data:"
rho_air=1.16"[kg/m^3]" "density of air"
```

```
g=9.807"[m/s^2]"
d_balloon=10"[m]"
m_1person=70"[kg]"
{NoPeople = 2}  "Data suppied in Parametric Table"

"Calculated values:"
rho_He=rho_air/7"[kg/m^3]" "density of helium"
r_balloon=d_balloon/2"[m]"
V_balloon=4*pi*r_balloon^3/3"[m^3]"
m_people=NoPeople*m_1person"[kg]"
m_He=rho_He*V_balloon"[kg]"
m_total=m_He+m_people"[kg]"
"The total weight of balloon and people is:"
W_total=m_total*g"[N]"
"The buoyancy force acting on the balloon, F_b, is equal to the weight of the air displaced by
the balloon."
F_b=rho_air*V_balloon*g"[N]"
"From the free body diagram of the balloon, the balancing vertical forces must equal the
product of the total mass and the vertical acceleration:"
F_b- W_total=m_total*a_up
```

A_{up} [m/s^2]	NoPeople
28.19	1
16.46	2
10.26	3
6.434	4
3.831	5
1.947	6
0.5204	7
-0.5973	8
-1.497	9
-2.236	10



2-92 A balloon is filled with helium gas. The maximum amount of load the balloon can carry is to be determined.

Assumptions The weight of the cage and the ropes of the balloon is negligible.

Properties The density of air is given to be ρ = 1.16 kg/m³. The density of helium gas is 1/7th of this.

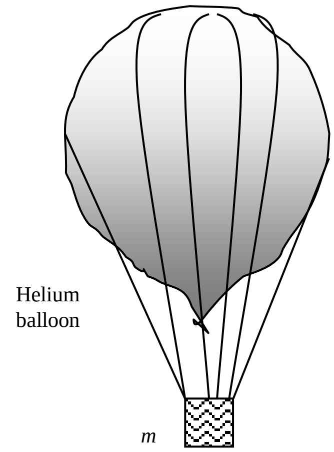
Analysis In the limiting case, the net force acting on the balloon will be zero. That is, the buoyancy force and the weight will balance each other:

$$W = mg = F_B$$

$$m_{total} = \frac{F_B}{g} = \frac{5956.5\ \text{N}}{9.807\ \text{m/s}^2} = 607.4\ \text{kg}$$

Thus,

$$m_{\text{people}} = m_{\text{total}} - m_{\text{He}} = 607.4 - 86.8 = \mathbf{520.6\ kg}$$



2-93 The pressure in a steam boiler is given in kgf/cm². It is to be expressed in psi, kPa, atm, and bars.

Analysis We note that 1 atm = 1.03323 kgf/cm², 1 atm = 14.696 psi, 1 atm = 101.325 kPa, and 1 atm = 1.01325 bar (inner cover page of text). Then the desired conversions become:

In atm: $$P = (75\ \text{kgf/cm}^2)\left(\frac{1\ \text{atm}}{1.03323\ \text{kgf/cm}^2}\right) = 72.6\ \text{atm}$$

In psi: $$P = (75\ \text{kgf/cm}^2)\left(\frac{1\ \text{atm}}{1.03323\ \text{kgf/cm}^2}\right)\left(\frac{14.696\ \text{psi}}{1\ \text{atm}}\right) = \mathbf{1067\ psi}$$

In kPa: $$P = (75\ \text{kgf/cm}^2)\left(\frac{1\ \text{atm}}{1.03323\ \text{kgf/cm}^2}\right)\left(\frac{101.325\ \text{kPa}}{1\ \text{atm}}\right) = \mathbf{7355\ kPa}$$

In bars: $$P = (75\ \text{kgf/cm}^2)\left(\frac{1\ \text{atm}}{1.03323\ \text{kgf/cm}^2}\right)\left(\frac{1.01325\ \text{bar}}{1\ \text{atm}}\right) = \mathbf{73.55\ bar}$$

Discussion Note that the units atm, kgf/cm², and bar are almost identical to each other.

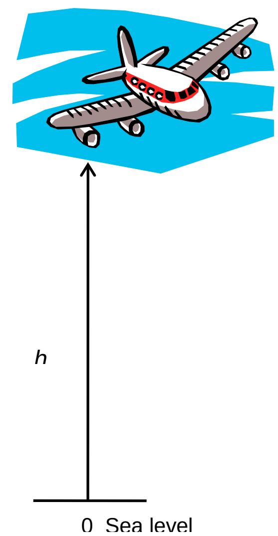
2-94 A barometer is used to measure the altitude of a plane relative to the ground. The barometric readings at the ground and in the plane are given. The altitude of the plane is to be determined.

Assumptions The variation of air density with altitude is negligible.

Properties The densities of air and mercury are given to be ρ = 1.20 kg/m³ and ρ = 13,600 kg/m³.

Analysis Atmospheric pressures at the location of the plane and the ground level are

$$\begin{aligned}P_{\text{plane}} &= (\rho g h)_{\text{plane}} \\ &= (13{,}600\ \text{kg/m}^3)(9.8\ \text{m/s}^2)(0.690\ \text{m})\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right) \\ &= 91.96\ \text{kPa}\end{aligned}$$



$$\begin{aligned}P_{\text{ground}} &= (\rho g h)_{\text{ground}} \\ &= (13{,}600\ \text{kg/m}^3)(9.8\ \text{m/s}^2)(0.753\ \text{m})\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right) \\ &= 100.36\ \text{kPa}\end{aligned}$$

Taking an air column between the airplane and the ground and writing a force balance per unit base area, we obtain

$$W_{\text{air}} / A = P_{\text{ground}} - P_{\text{plane}}$$

$$(\rho g h)_{\text{air}} = P_{\text{ground}} - P_{\text{plane}}$$

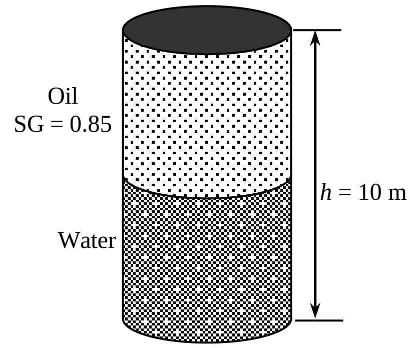
$$(1.20\ \text{kg/m}^3)(9.8\ \text{m/s}^2)(h)\left(\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right) = (100.36 - 91.96)\ \text{kPa}$$

It yields h = **714 m**

which is also the altitude of the airplane.

2-95 A 10-m high cylindrical container is filled with equal volumes of water and oil. The pressure difference between the top and the bottom of the container is to be determined.

Properties The density of water is given to be ρ = 1000 kg/m³. The specific gravity of oil is given to be 0.85.



Analysis The density of the oil is obtained by multiplying its specific gravity by the density of water,

$$\rho = SG \times \rho_{H_2O} = (0.85)(1000\text{kg/m}^3) = 850\text{kg/m}^3$$

The pressure difference between the top and the bottom of the cylinder is the sum of the pressure differences across the two fluids,

$$\begin{aligned}\Delta P_{total} &= \Delta P_{oil} + \Delta P_{water} = (\rho g h)_{oil} + (\rho g h)_{water} \\ &= \left[(850\text{kg/m}^3)(9.807\text{m/s}^2)(5\text{m}) + (1000\text{kg/m}^3)(9.807\text{m/s}^2)(5\text{m})\right]\left(\frac{1\text{kPa}}{1000\text{N/m}^2}\right) \\ &= \mathbf{90.7kPa}\end{aligned}$$

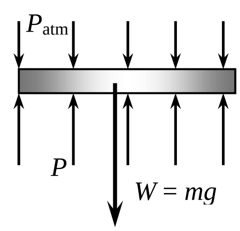
2-96 The pressure of a gas contained in a vertical piston-cylinder device is measured to be 500 kPa. The mass of the piston is to be determined.

Assumptions There is no friction between the piston and the cylinder.

Analysis Drawing the free body diagram of the piston and balancing the vertical forces yield

$$W = PA - P_{atm}A$$
$$mg = (P - P_{atm})A$$
$$(m)(9.807\text{m/s}^2) = (500 - 100\text{kPa})(30\times10^{-4}\text{m}^2)\left(\frac{1000\text{kg/m}\cdot\text{s}^2}{1\text{kPa}}\right)$$

It yields m = **122.4 kg**

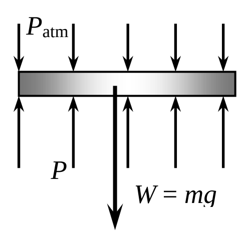


2-97 The gage pressure in a pressure cooker is maintained constant at 100 kPa by a petcock. The mass of the petcock is to be determined.

Assumptions There is no blockage of the pressure release valve.

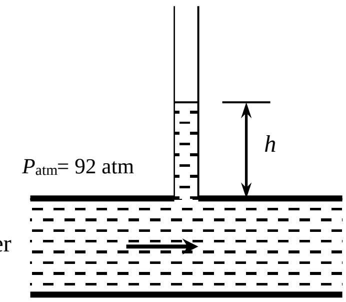
Analysis Atmospheric pressure is acting on all surfaces of the petcock, which balances itself out. Therefore, it can be disregarded in calculations if we use the gage pressure as the cooker pressure. A force balance on the petcock ($\Sigma F_y = 0$) yields

$$W = P_{gage}A$$
$$m = \frac{P_{gage}A}{g} = \frac{(100kPa)(4\times10^{-6}m^2)}{9.807m/s^2}\left(\frac{1000kg/m\cdot s^2}{1kPa}\right)$$
$$= \mathbf{0.0408kg}$$



2-98 A glass tube open to the atmosphere is attached to a water pipe, and the pressure at the bottom of the tube is measured. It is to be determined how high the water will rise in the tube.

Properties The density of water is given to be ρ = 1000 kg/m³.



Analysis The pressure at the bottom of the tube can be expressed as

$$P = P_{atm} + (\rho g h)_{tube}$$

Solving for *h*,

$$h = \frac{P - P_{\text{atm}}}{\rho g}$$

$$= \frac{(115-92)\text{ kPa}}{(1000\text{ kg/m}^3)(9.8\text{ m/s}^2)}\left(\frac{1\text{ kg}\cdot\text{m/s}^2}{1\text{ N}}\right)\left(\frac{1000\text{ N/m}^2}{1\text{ kPa}}\right)$$

$$= \mathbf{2.35\ m}$$

2-99 The average atmospheric pressure is given as $P_{atm} = 101.325(1-0.02256z)^{5.256}$ where *z* is the altitude in km. The atmospheric pressures at various locations are to be determined.

Analysis The atmospheric pressures at various locations are obtained by substituting the altitude z values in km into the relation

$$P_{atm} = 101.325(1-0.02256z)^{5.256}$$

Atlanta:	(z = 0.306 km): $P_{atm} = 101.325(1 - 0.02256\times0.306)^{5.256}$ = **97.7 kPa**
Denver:	(z = 1.610 km): $P_{atm} = 101.325(1 - 0.02256\times1.610)^{5.256}$ = **83.4 kPa**
M. City:	(z = 2.309 km): $P_{atm} = 101.325(1 - 0.02256\times2.309)^{5.256}$ = **76.5 kPa**
Mt. Ev.:	(z = 8.848 km): $P_{atm} = 101.325(1 - 0.02256\times8.848)^{5.256}$ = **31.4 kPa**

2-100 The air pressure in a duct is measured by an inclined manometer. For a given vertical level difference, the gage pressure in the duct and the length of the differential fluid column are to be determined.

Assumptions The manometer fluid is an incompressible substance.

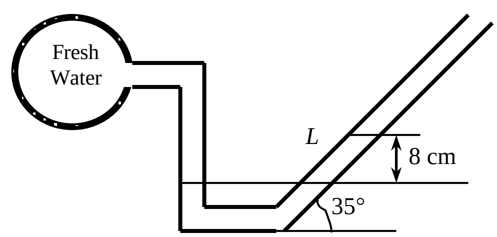
Properties The density of the liquid is given to be ρ = 0.81 kg/L = 810 kg/m³.

Analysis The gage pressure in the duct is determined from

$$P_{\text{gage}} = P_{\text{abs}} - P_{\text{atm}} = \rho g h$$

$$= (810\text{kg/m}^3)(9.81\text{m/s}^2)(0.08\text{m})\left(\frac{1\text{N}}{1\text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\text{Pa}}{1\text{N/m}^2}\right)$$

$$= \mathbf{636\ \ Pa}$$



The length of the differential fluid column is

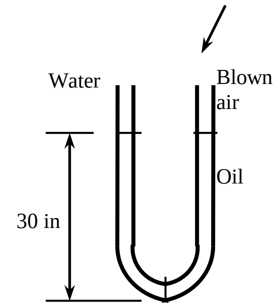
$$L = h/\sin\theta = (8\text{cm})/\sin 35° = \mathbf{13.9\ cm}$$

Discussion Note that the length of the differential fluid column is extended considerably by inclining the manometer arm for better readability.

2-101E Equal volumes of water and oil are poured into a U-tube from different arms, and the oil side is pressurized until the contact surface of the two fluids moves to the bottom and the liquid levels in both arms become the same. The excess pressure applied on the oil side is to be determined.

Assumptions **1** Both water and oil are incompressible substances. **2** Oil does not mix with water. **3** The cross-sectional area of the U-tube is constant.

Properties The density of oil is given to be ρ_{oil} = 49.3 lbm/ft^3. We take the density of water to be ρ_w = 62.4 lbm/ft^3.



Analysis Noting that the pressure of both the water and the oil is the same at the contact surface, the pressure at this surface can be expressed as

$$P_{\text{contact}} = P_{\text{blow}} + \rho_{\text{a}} g h_{\text{a}} = P_{\text{atm}} + \rho_{\text{w}} g h_{\text{w}}$$

Noting that $h_a = h_w$ and rearranging,

$$\begin{aligned} P_{\text{gage, blow}} &= P_{\text{blow}} - P_{\text{atm}} = (\rho_w - \rho_{oil})gh \\ &= (62.4 - 49.3\ \text{lbm/ft}^3)(32.2\ \text{ft/s}^2)(30/12\ \text{ft})\left(\frac{1\,\text{lbf}}{32.2\,\text{lbm}\cdot\text{ft/s}^2}\right)\left(\frac{1\,\text{ft}^2}{144\,\text{in}^2}\right) \\ &= 0.227\,\textbf{psi} \end{aligned}$$

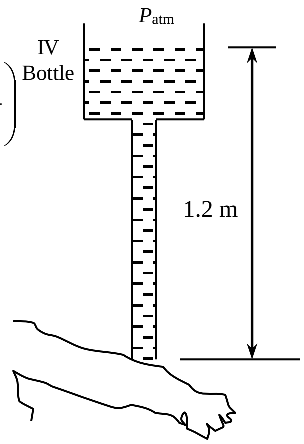
Discussion When the person stops blowing, the oil will rise and some water will flow into the right arm. It can be shown that when the curvature effects of the tube are disregarded, the differential height of water will be 23.7 in to balance 30-in of oil.

2-102 It is given that an IV fluid and the blood pressures balance each other when the bottle is at a certain height, and a certain gage pressure at the arm level is needed for sufficient flow rate. The gage pressure of the blood and elevation of the bottle required to maintain flow at the desired rate are to be determined.

Assumptions **1** The IV fluid is incompressible. **2** The IV bottle is open to the atmosphere.

Properties The density of the IV fluid is given to be ρ = 1020 kg/m^3.

Analysis (*a*) Noting that the IV fluid and the blood pressures balance each other when the bottle is 1.2 m above the arm level, the gage pressure of the blood in the arm is simply equal to the gage pressure of the IV fluid at a depth of 1.2 m,



$$\begin{aligned} P_{\text{gage, arm}} &= P_{\text{abs}} - P_{\text{atm}} = \rho g h_{\text{arm-bottle}} \\ &= (1020\ \text{kg/m}^3)(9.81\ \text{m/s}^2)(1.20\ \text{m})\left(\frac{1\text{kN}}{1000\ \text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\ \text{kPa}}{1\ \text{kN/m}^2}\right) \\ &= \mathbf{12.0\ kPa} \end{aligned}$$

(*b*) To provide a gage pressure of 20 kPa at the arm level, the height of the bottle from the arm level is again determined from $P_{\text{gage, arm}} = \rho g h_{\text{arm-bottle}}$ to be

$$\begin{aligned} h_{\text{arm-bottle}} &= \frac{P_{\text{gage, arm}}}{\rho g} \\ &= \frac{20\ \text{kPa}}{(1020\ \text{kg/m}^3)(9.81\ \text{m/s}^2)}\left(\frac{1000\ \text{kg}\cdot\text{m/s}^2}{1\ \text{kN}}\right)\left(\frac{1\ \text{kN/m}^2}{1\ \text{kPa}}\right) = \mathbf{2.0\ \ m} \end{aligned}$$

Discussion Note that the height of the reservoir can be used to control flow rates in gravity driven flows. When there is flow, the pressure drop in the tube due to friction should also be considered. This will result in raising the bottle a little higher to overcome pressure drop.

2-103 A gasoline line is connected to a pressure gage through a double-U manometer. For a given reading of the pressure gage, the gage pressure of the gasoline line is to be determined.

Assumptions **1** All the liquids are incompressible. **2** The effect of air column on pressure is negligible.

Properties The specific gravities of oil, mercury, and gasoline are given to be 0.79, 13.6, and 0.70, respectively. We take the density of water to be ρ_w = 1000 kg/m^3.

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 gasoline pipe, and setting the result equal to P_{gasoline} gives

$$P_{\text{gage}} - \rho_{\text{w}} g h_w + \rho_{\text{alcohol}} g h_{\text{alcohol}} - \rho_{\text{Hg}} g h_{\text{Hg}} - \rho_{\text{gasoline}} g h_{\text{gasoline}} = P_{\text{gasoline}}$$

Rearranging,

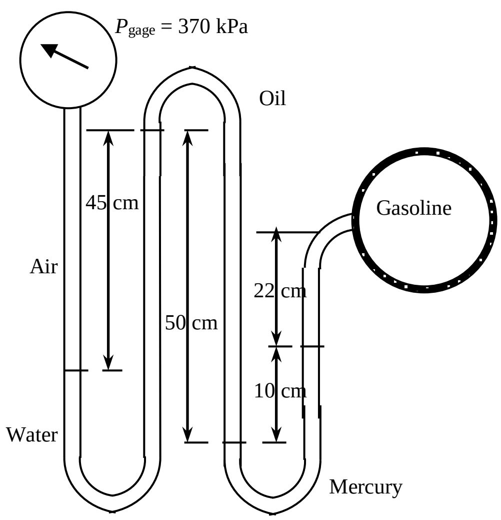
$$P_{\text{gasoline}} = P_{\text{gage}} - \rho_{\text{w}} g (h_w - SG_{\text{alcohol}} h_{\text{alcohol}} + SG_{\text{Hg}} h_{\text{Hg}} + SG_{\text{gasoline}} h_{\text{gasoline}})$$

Substituting,

$$\begin{aligned} P_{\text{gasoline}} &= 370\,\text{kPa} - (1000\,\text{kg/m}^3)(9.81\,\text{m/s}^2)[(0.45\text{m}) - 0.79(0.5\,\text{m}) + 13.6(0.1\,\text{m}) + 0.70(0.22\,\text{m})] \\ &\times \left(\frac{1\,\text{kN}}{1000\,\text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\,\text{kPa}}{1\,\text{kN/m}^2}\right) \\ &= \mathbf{354.6\ kPa} \end{aligned}$$

Therefore, the pressure in the gasoline pipe is 15.4 kPa lower than the pressure reading of the pressure gage.

Discussion Note that sometimes the use of specific gravity offers great convenience in the solution of problems that involve several fluids.



2-104 A gasoline line is connected to a pressure gage through a double-U manometer. For a given reading of the pressure gage, the gage pressure of the gasoline line is to be determined.

Assumptions **1** All the liquids are incompressible. **2** The effect of air column on pressure is negligible.

Properties The specific gravities of oil, mercury, and gasoline are given to be 0.79, 13.6, and 0.70, respectively. We take the density of water to be ρ_w = 1000 kg/m^3.

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 gasoline pipe, and setting the result equal to P_{gasoline} gives

$$P_{gage} - \rho_{\text{w}} g h_w + \rho_{\text{alcohol}} g h_{\text{alcohol}} - \rho_{\text{Hg}} g h_{\text{Hg}} - \rho_{\text{gasoline}} g h_{\text{gasoline}} = P_{\text{gasoline}}$$

Rearranging,

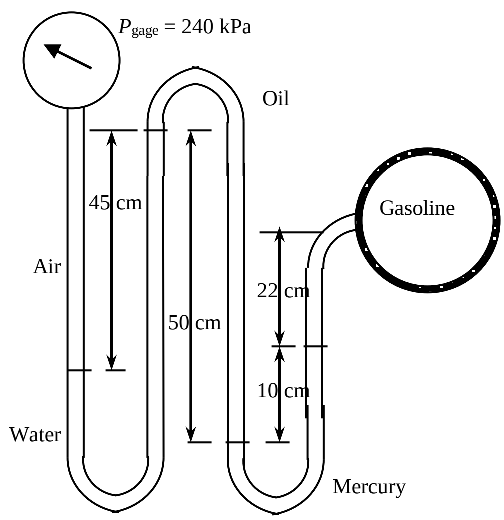
$$P_{\text{gasoline}} = P_{\text{gage}} - \rho_{\text{w}} g (h_w - SG_{\text{alcohol}}\, h_{\text{s,alcohol}} + SG_{\text{Hg}} h_{\text{Hg}} + SG_{\text{gasoline}}\, h_{\text{s,gasoline}})$$

Substituting,

$$P_{\text{gasoline}} = 240\,\text{kPa} - (1000\,\text{kg/m}^3)(9.81\,\text{m/s}^2)[(0.45\text{m}) - 0.79(0.5\,\text{m}) + 13.6(0.1\,\text{m}) + 0.70(0.22\,\text{m})]$$
$$\times \left(\frac{1\,\text{kN}}{1000\,\text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\,\text{kPa}}{1\,\text{kN/m}^2}\right)$$
$$= \mathbf{224.6\ kPa}$$

Therefore, the pressure in the gasoline pipe is 15.4 kPa lower than the pressure reading of the pressure gage.

Discussion Note that sometimes the use of specific gravity offers great convenience in the solution of problems that involve several fluids.



2-105E A water pipe is connected to a double-U manometer whose free arm is open to the atmosphere. The absolute pressure at the center of the pipe is to be determined.

Assumptions **1** All the liquids are incompressible. **2** The solubility of the liquids in each other is negligible.

Properties The specific gravities of mercury and oil are given to be 13.6 and 0.80, respectively. We take the density of water to be ρ_w = 62.4 lbm/ft^3.

Analysis Starting with the pressure at the center of the water pipe, and moving along the tube by adding (as we go down) or subtracting (as we go up) the $\rho g h$ terms until we reach the free surface of oil where the oil tube is exposed to the atmosphere, and setting the result equal to P_{atm} gives

$$P_{\text{water pipe}} - \rho_{\text{water}} g h_{\text{water}} + \rho_{\text{alcohol}} g h_{\text{alcohol}} - \rho_{\text{Hg}} g h_{\text{Hg}} - \rho_{\text{oil}} g h_{\text{oil}} = P_{atm}$$

Solving for $P_{\text{water pipe}}$,

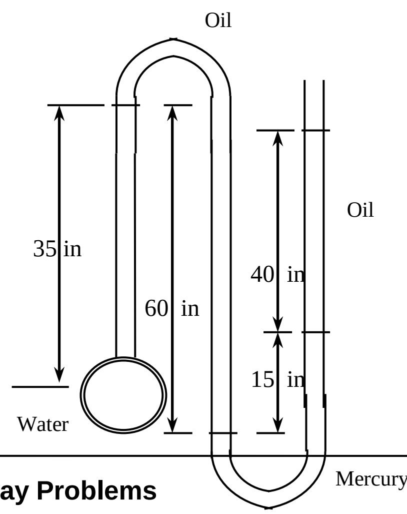
$$P_{\text{water pipe}} = P_{atm} + \rho_{\text{water}} g (h_{\text{water}} - SG_{\text{oil}} h_{\text{alcohol}} + SG_{\text{Hg}} h_{\text{Hg}} + SG_{\text{oil}} h_{\text{oil}})$$

Substituting,

$$\begin{aligned} P_{\text{water pipe}} &= 14.2\,\text{psia} + (62.4\,\text{lbm/ft}^3)(32.2\,\text{ft/s}^2)[(35/12\,\text{ft}) - 0.80(60/12\,\text{ft}) + 13.6(15/12\,\text{ft}) \\ &\quad + 0.8(40/12\,\text{ft})] \times \left(\frac{1\,\text{lbf}}{32.2\,\text{lbm}\cdot\text{ft/s}^2}\right)\left(\frac{1\,\text{ft}^2}{144\,\text{in}^2}\right) \\ &= 22.3\,\textbf{psia} \end{aligned}$$

Therefore, the absolute pressure in the water pipe is 22.3 psia.

Discussion Note that jumping horizontally from one tube to the next and realizing that pressure remains the same in the same fluid simplifies the analysis greatly.



2-106 … 2-107 Design and Essay Problems