A schematic diagram showing the gauge pressure, vacuum pressure, and the absolute pressure are given in Fig.1.6.

Gauge pressure: the pressure that is above the atmospheric pressure is known as gauge pressure; the atmospheric pressure is zero gauge pressure.(Fig.1.6)

Vacuum pressure: the pressure which is below the atmospheric pressure is known as vacuum pressure.(Fig.1.6)

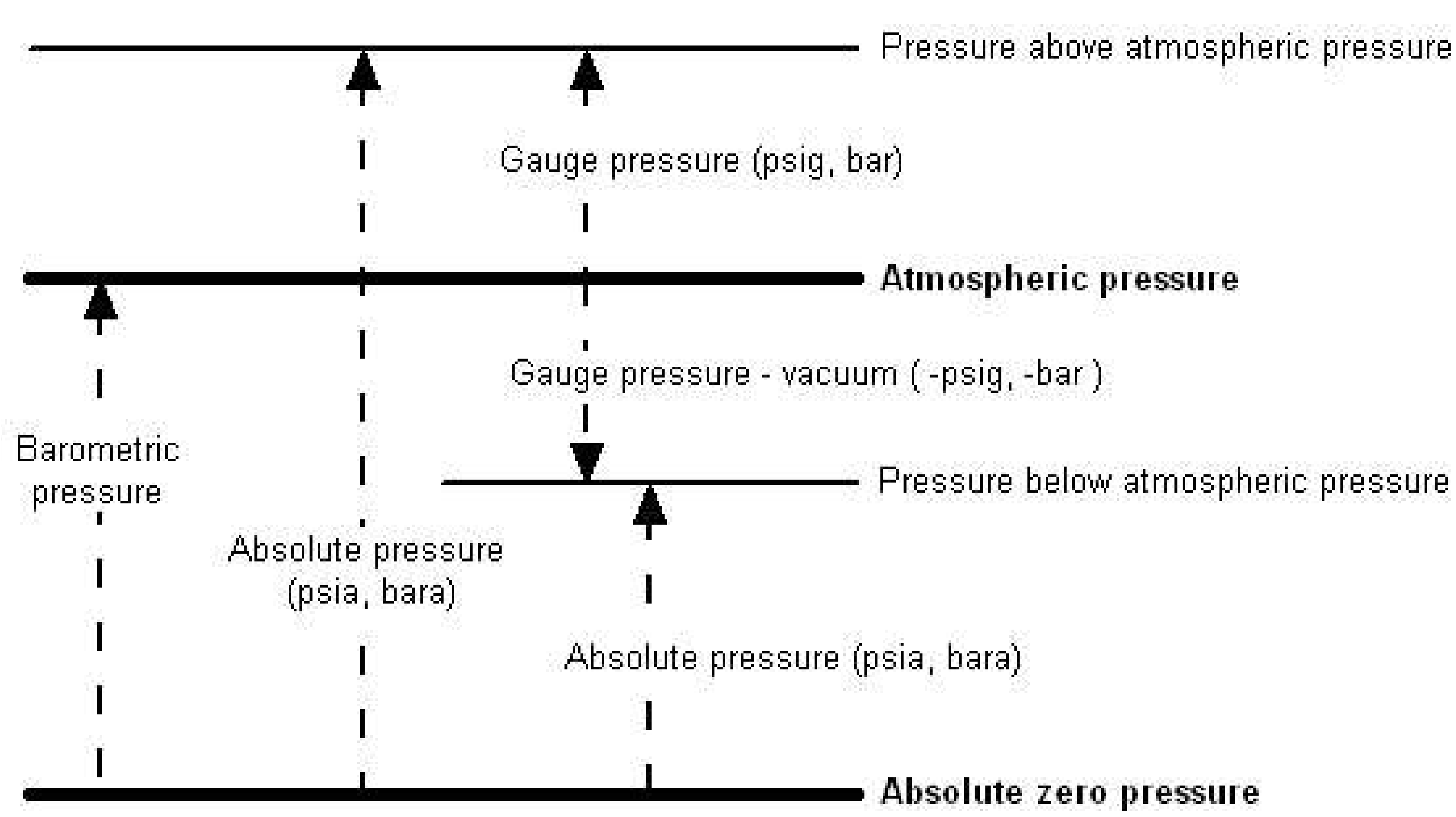


Fig.1.6. Schematic diagram showing gauge, vacuum and absolute pressures.

Mathematically:

i. Absolute pressure= Atmospheric pressure + Gauge pressure

$$P_{abs} = P_{atm} + P_{guage}$$

ii. Vacuum pressure = Atmospheric pressure – Absolute pressure

Note:

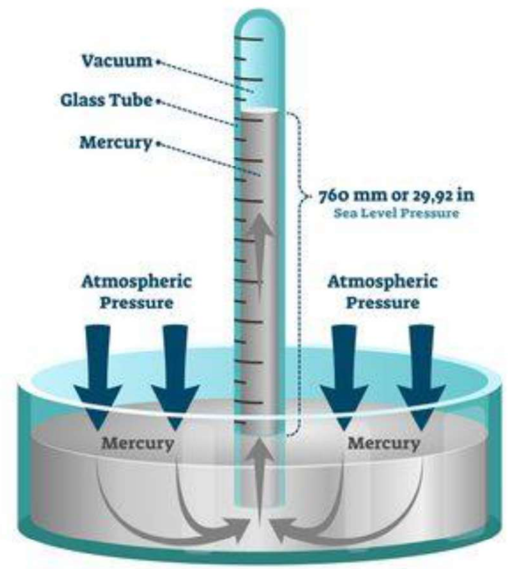
A vacuum is defined as the absence of pressure. A perfect vacuum is obtained when absolute pressure is zero, at this instant molecular momentum is zero.

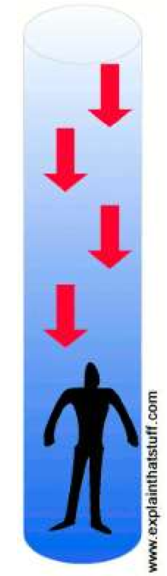
Atmospheric pressure is measured with the help of a barometer.

Barometer: the atmospheric pressure is measured by a device called a barometer.

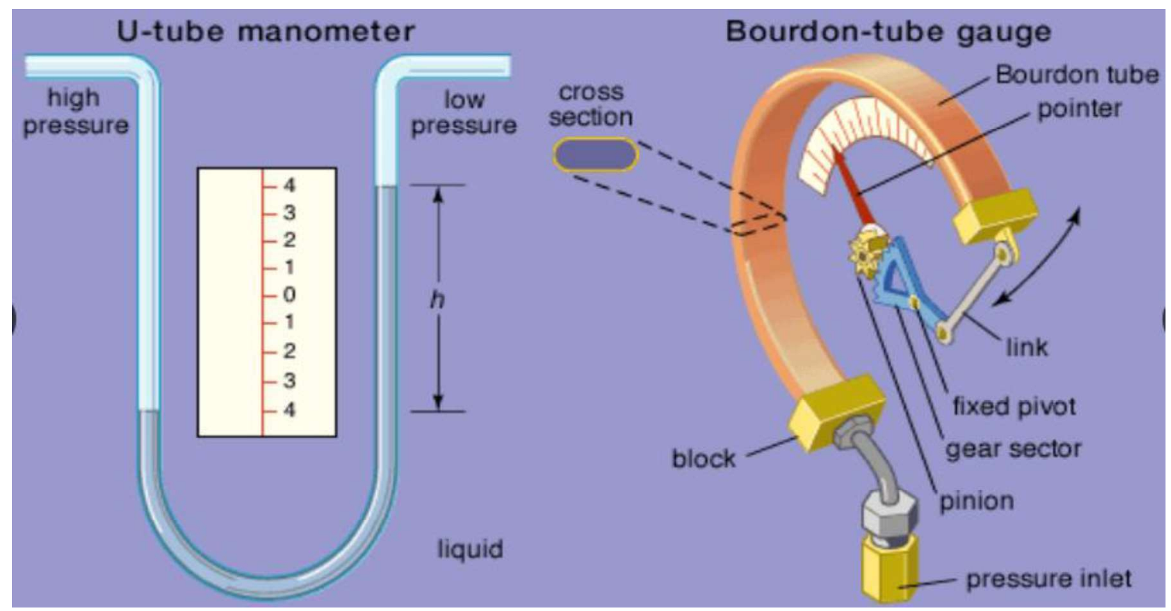
Manometer: it is a device that measures either gauge pressure or vacuum pressure.

Barometer: the atmospheric pressure is measured by a device called a barometer.





Manometer: it is a device which measures either gauge pressure or vacuum pressure.



1.16.2 Unit of pressure:

1. The fundamental SI unit in N/m^2 (sometimes called *Pascal*, Pa)

2. Pressure is also measured in bar, 1bar= 10^5 N/m^2

3. Standard atmospheric pressure = 1.01325 bar =0.76 m Hg(or 760 mmHg).

The pressure unit Pascal is too small for pressure; therefore kilopascal, Mega Pascal and bar commonly used.

1 kPa = 10^3 Pa

1 MPa = 10^6 Pa =10^3 kPa

1 bar = 10^5 Pa =100 kPa

Atmospheric pressure varies with location on the earth, a standard reference can be defined and used to express other pressures

1 standard atmosphere (atm.) =101.325 Pa

=101.325 kPa

=1.01325 bar

Absolute pressure = atmospheric pressure $\pm$ *Gauge pressure*

Or, $p_{abs} = p_a + p_{gauge}$

$p_{gauge} = \rho g h$

Using the relation

$p = \rho g h$

Let p=1 bar=10^5 N/m^2 ; $\rho =$
$1000\ kg/m^3\ for\ water$; $g = 9 \cdot 81\, m/s^2$

For water

$$1 \times 10^5 = 1000 \times 9 \cdot 81 \times h$$

$$h = \frac{1 \times 10^5}{1000 \times 9.81} = 10 \cdot 2\ m\ of\ water$$

$$or \quad 1\ mm\ of\ water = 9 \cdot 81 \frac{N}{m^2} = 9 \cdot 81\ Pa$$

By using the relation

$$h_{water} \times S_{water} = h_{mercury} \times 13 \cdot 6$$

Therefore, 1 bar= 750 mm of Hg

1.16.3 U-tube manometer

Low pressures are generally determined by manometers which employ liquid columns. A U-tube manometer is in the form of a U-tube and is made of glass (Fig.1.7).

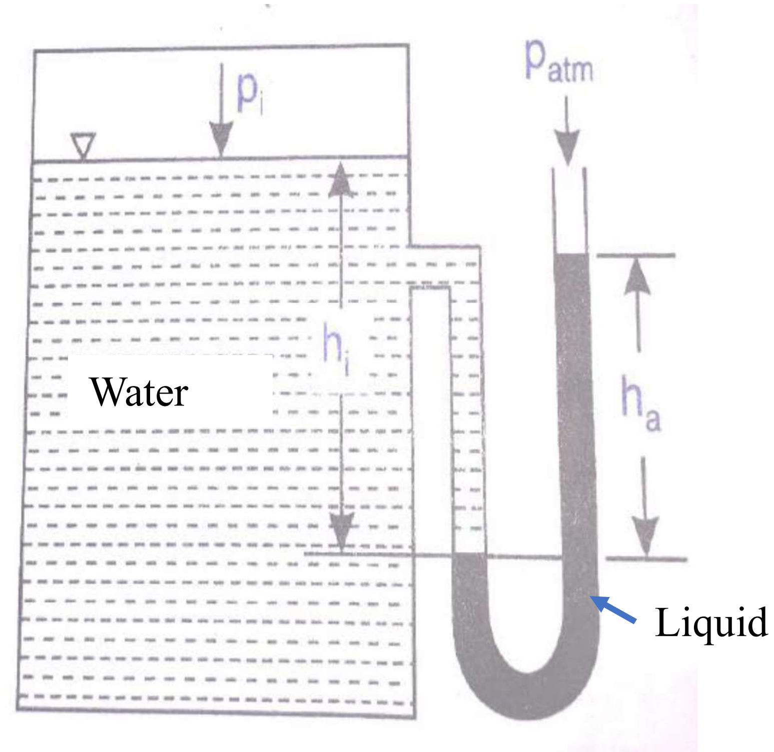


Fig.1.7. Principle of U-tube manometer.

Considering the equilibrium condition, we have

$$P_{atm} + w_a h_a = p_i + w_i h_i$$

Where, P_{atm} =*Atmospheric pressure*, p_i =*Pressure over water surface in the container, ha=Heigh of liquid in U−tube manometer, hi=Difference between water surface and lower surface of the liquid in manometerwa=Specific weight of liquid wi=Specific weight of water* $= \rho . g = \frac{mg}{m^3}$

1.17 Specific volume

The specific volume of a system is the volume occupied by the unit mass *Specific volume=v=Total Volumemass=*$V_m = \left(\frac{m^3}{kg}\right)$

Example 1.1. ***Convert the following readings of pressure to kPa assuming that barometer read 760 mm of Hg.***

ملاحظة: الباروميتر (barometer) جهاز لقياس الضغط الجوي

(i) 80 cm of Hg
(ii) 30 cm Hg vacuum
(iii) 1.35 m H_2O Guage
(iv) 4.2 bar

Solution. Assuming density of Hg

$$\rho_{Hg} = 13600 \ kg/m^3$$

Where $\rho_{hg} = density\ of\ Hg$

Pressure of 760 mm of Hg will be

$$p = \rho_{Hg} gh = 13600 \times 9 \cdot 81 \times \frac{760}{1000} \approx 101 \cdot 325\ kPa$$

i.e **760 mm of Hg =101.325 kPa**

(i) pressure of 80 cm of Hg

Pressure in mm of Hg	pressure in kPa
760	101.325
800	p

$$p = \frac{101 \cdot 325 \times 800}{760} = 106 \cdot 65\ kPa \quad (Ans\ \cdot)$$

Example 1.1. ***Convert the following readings of pressure to kPa assuming that barometer read 760 mm of Hg.***

ملاحظة: الباروميتر (barometer) جهاز لقياس الضغط الجوي

(i) 80 cm of Hg
(ii) 30 cm Hg vacuum
(iii) 1.35 m H_2O Guage
(iv) 4.2 bar

(ii) 30 cm Hg vacuum

$$= 76 - 30 = 46\ cm\ of\ Hg\ absolute$$

$$= \frac{101 \cdot 325 \times 460}{760} = 61 \cdot 328\ kPa \quad (Ans\ \cdot)$$

(iii) pressure due to 1.35 m H_2O gauge

$$p = \rho_{H_2O} \times g \times h = 1000 \times 9 \cdot 81 \times 1 \cdot 35 = 13 \cdot 238\ kPa \ (Ans\ \cdot)$$

(iv) 4.2 bar

$$= 4 \cdot 2 \times 10^5 = 420000\ Pa = \frac{420000}{10^3} = 420\ kPa \quad (Ans\ \cdot)$$

Note.

Pressure of 1 atmospheric = 760 mm of Hg = 101325 N/m^2

Example 1.2. *On a piston of 10 cm diameter a force of 1000 N is uniformly applied .Find the pressure on the piston.*

Solution. Diameter of the piston, d=10 cm=0.1 m

$\therefore$ *Pressure on the piston*

$$p = \frac{Force}{Area} = \frac{F}{A} = \frac{F}{\pi d^2/4} = \frac{1000}{\pi (0.1)^2/4} = 127307\ N/m^2 = 127 \cdot 307\ kN/m^2$$

Example 1.3. *A tube contains an oil of specific gravity 0.9 to a depth of 120 cm. Find the gauge pressure at this depth* $(in\ kN/m^2)$.

Solution.

Specific gravity of oil =0.9

Depth of oil in the tube, h=120 cm=1,2 m

We know that

$p = \rho g h \qquad \rho = density\ in\ kg/m^3$

$$Specific\ gravity = S = \frac{density\ of\ matter}{density\ of\ water} = \frac{\rho_{matter}}{\rho_{water}}$$

In this example the matter is the oil, hence

$\rho_{oil} = S \times \rho_w = 0 \cdot 9 \times 1000$

$p = (0 \cdot 9 \times 100) \times g \times h = (0 \cdot 9 \times 1000) \times 9 \cdot 81 \times 1 \cdot 2 = 10 \cdot 595\, kN/m^2$

Example 1.4. ***A U-tube manometer is connected to a gas pipe. The level of the liquid in the manometer arm open to the atmosphere is 170 mm lower than the level of the liquid in the arm connected to the gas pipe. The liquid in the manometer has specific gravity of 0.8. find the absolute pressure of the gas if the manometer reads 760 mmHg.***

Solution.

Equating pressure on both arms above the line XX, Fig.1.8

$p_{gauge} + p_{liquid} = p_{atm}$ (i)

Now $p_{liquid} = \rho g h = (0 \cdot 8 \times 1000) \times 9 \cdot .81 \times \frac{170}{1000} =$
$1334.16\ N/m^2 = \frac{1334.16}{10^5} = 0 \cdot 0133416\ bar$

Substituting these value in eqn.(i) above, we have

$p_{gas} + 0 \cdot 0133416 = 1 \cdot 01325$

$\therefore \quad p_{gas} = 1 \cdot 01325 - 0 \cdot 0133416 = 0 \cdot 9999\ bar$ ***(Ans·)***

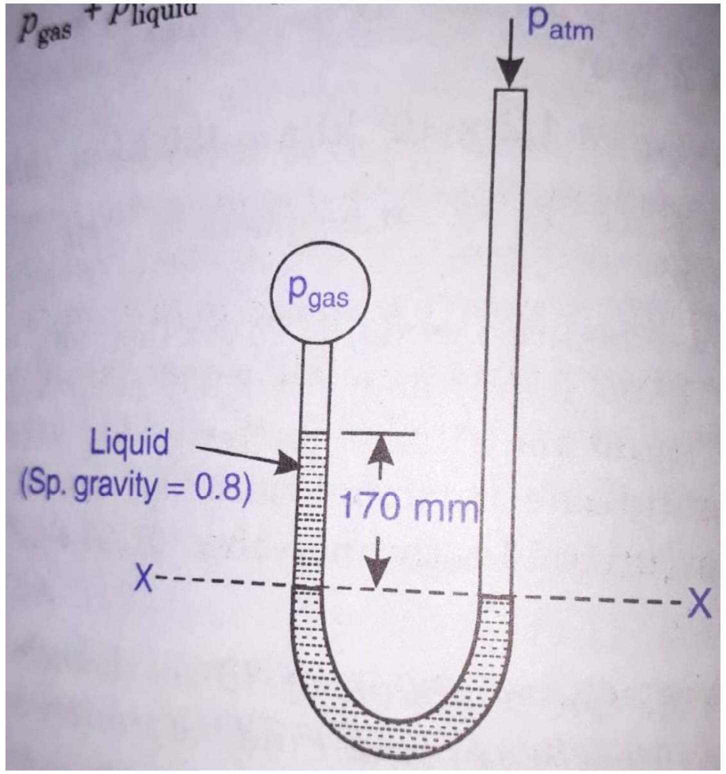


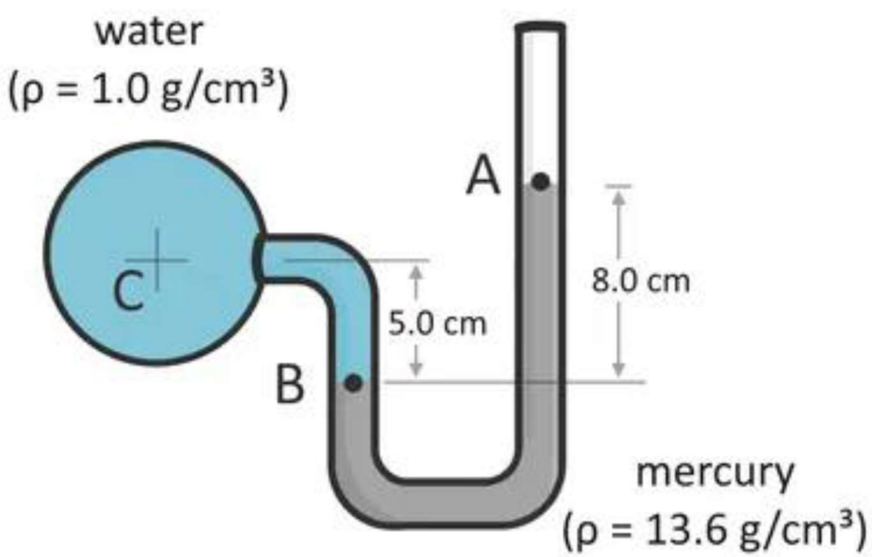
Fig.1.8

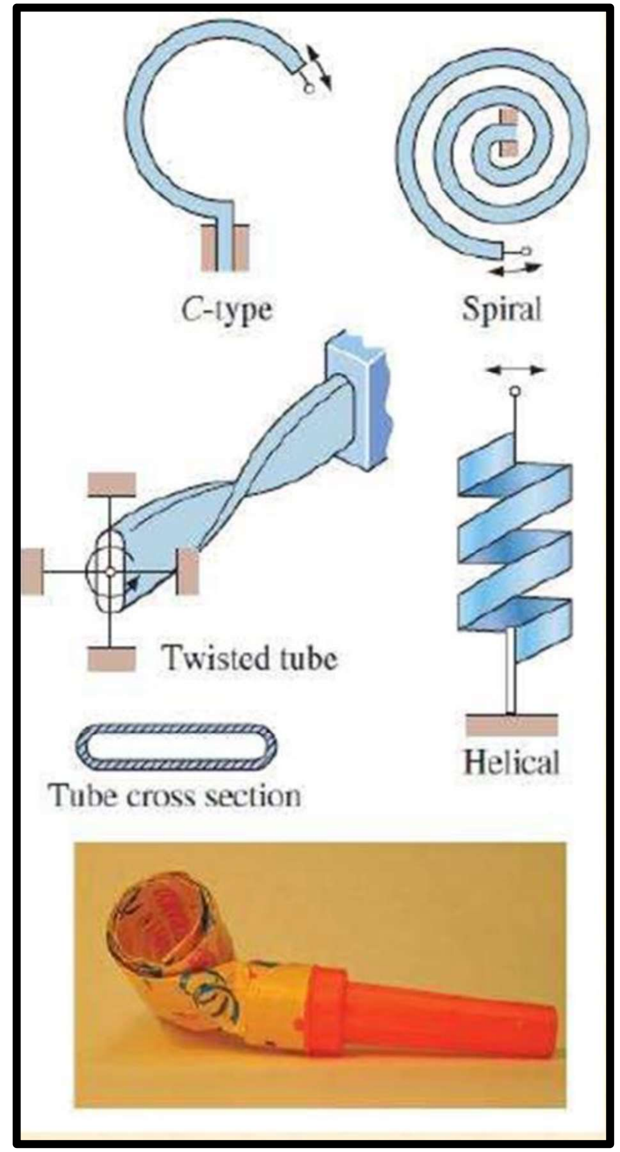
Example: Determine the pressure at point C? from the following figure.

$$P_C + \rho_W . g . \frac{5}{100} = \rho_{Hg} . g . \frac{8}{100}$$

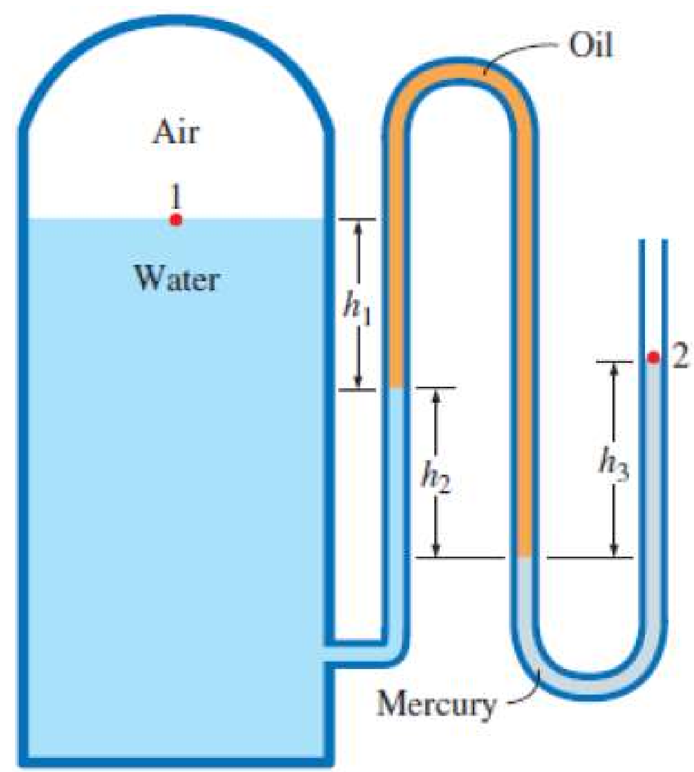
$$P_C + 1 \times 1000 \times 9.81 \times \frac{5}{100} = 13600 \times 9.82 . \frac{8}{100}$$

$$P_C = 13600.9.82 . \frac{8}{100} - 1000 \times 9.81 \times \frac{5}{100} = 10{,}178.6 \text{ pa}$$





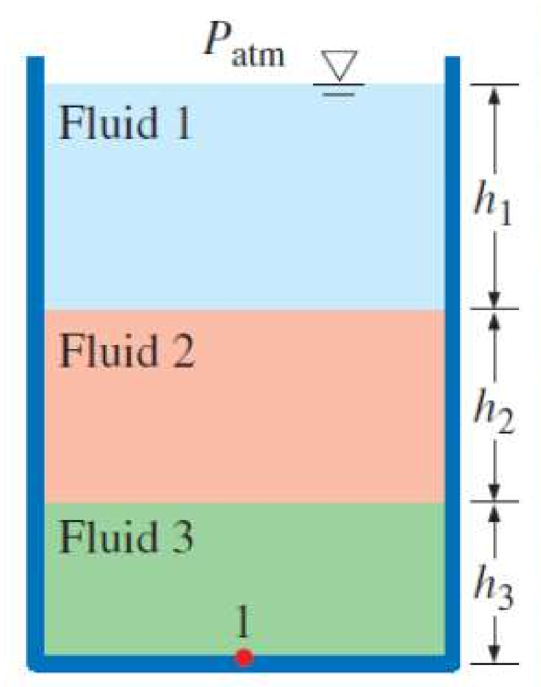
The water in a tank is pressurized by air, and the pressure is measured by a multifluid manometer as shown in Fig. 3–23. The tank is located on a mountain at an altitude of 1400 m where the atmospheric pressure is 85.6 kPa. Determine the air pressure in the tank if $h_1 = 0.1$ m, $h_2 = 0.2$ m, and $h_3 = 0.35$ m. Take the densities of water, oil, and mercury to be 1000 kg/m^3, 850 kg/m^3, and 13,600 kg/m^3, respectively.



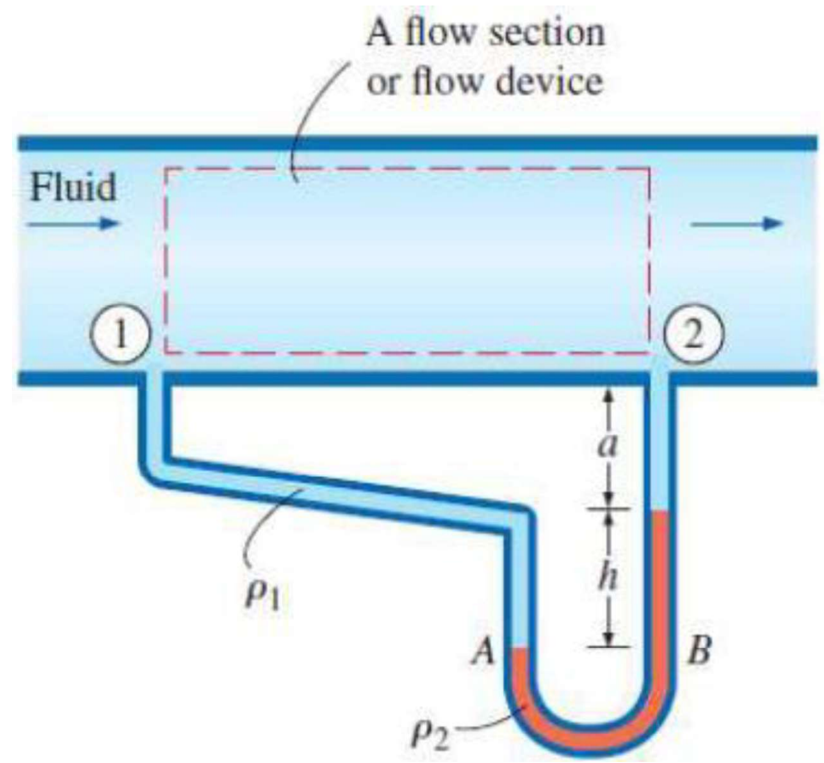
$$P_1 + \rho_{\text{water}} g h_1 + \rho_{\text{oil}} g h_2 - \rho_{\text{mercury}} g h_3 = P_2 = P_{\text{atm}}$$

Solving for P_1 and substituting,

$$\begin{aligned} P_1 &= P_{\text{atm}} - \rho_{\text{water}} g h_1 - \rho_{\text{oil}} g h_2 + \rho_{\text{mercury}} g h_3 \\ &= P_{\text{atm}} + g(\rho_{\text{mercury}} h_3 - \rho_{\text{water}} h_1 - \rho_{\text{oil}} h_2) \\ &= 85.6 \text{ kPa} + (9.81 \text{ m/s}^2)[(13{,}600 \text{ kg/m}^3)(0.35 \text{ m}) - (1000 \text{ kg/m}^3)(0.1 \text{ m}) \\ &\quad - (850 \text{ kg/m}^3)(0.2 \text{ m})]\left(\frac{1 \text{ N}}{1 \text{ kg}\cdot\text{m/s}^2}\right)\left(\frac{1 \text{ kPa}}{1000 \text{ N/m}^2}\right) \\ &= \mathbf{130 \text{ kPa}} \end{aligned}$$



$$P_{atm} + \rho_1 g h_1 + \rho_2 g h_2 + \rho_3 g h_3 = P_1$$



$$P_1 + \rho_1 g(a + h) - \rho_2 g h - \rho_1 g a = P_2$$

$$P_1 - P_2 = (\rho_2 - \rho_1) g h$$

Properties The densities of seawater and mercury are given to be ρ_{sea} = 1035 kg/m^3 and ρ_{Hg} = 13,600 kg/m^3. We take the density of water to be ρ_w =1000 kg/m^3. The specific gravity of oil is given to be 0.72, and thus its density is 720 kg/m^3.

$h_{sea} = 40\ cm, h_{oil} = 70\ cm, \quad h_{Hg} = 10\ cm, and\ h_w = 60\ cm.$

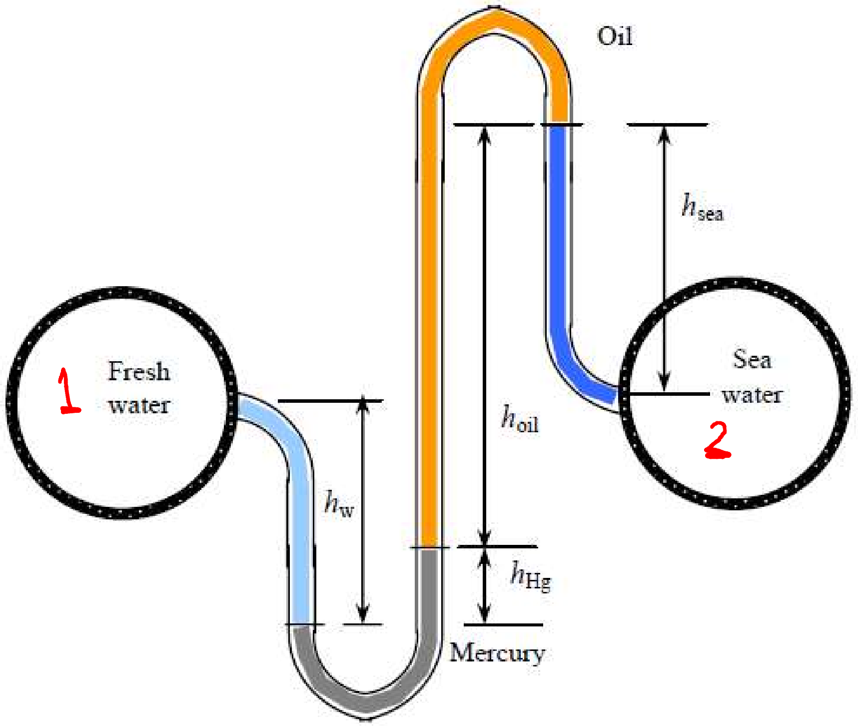
$$P_1 + \rho_w g h_w - \rho_{Hg} g h_{Hg} - \rho_{oil} g h_{oil} + \rho_{sea} g h_{sea} = P_2$$

Rearranging,

$$P_1 - P_2 = -\rho_w g h_w + \rho_{Hg} g h_{Hg} + \rho_{oil} g h_{oil} - \rho_{sea} g h_{sea}$$
$$= g(\rho_{Hg} h_{Hg} + \rho_{oil} h_{oil} - \rho_w h_w - \rho_{sea} h_{sea})$$

Substituting,

$$P_1 - P_2 = (9.81\ \text{m/s}^2)[(13600\ \text{kg/m}^3)(0.1\ \text{m}) + (720\ \text{kg/m}^3)(0.7\ \text{m}) - (1000\ \text{kg/m}^3)(0.6\ \text{m})$$
$$-(1035\ \text{kg/m}^3)(0.4\ \text{m})]\left(\frac{1\ \text{kN}}{1000\ \text{kg}\cdot\text{m/s}^2}\right)$$
$$= 8.34\ \text{kN/m}^2 = \mathbf{8.34\ kPa}$$



3–12 The water in a tank is pressurized by air, and the pressure is measured by a multifluid manometer as shown in Fig. P3–12. Determine the gage pressure of air in the tank if $h_1 = 0.4$ m, $h_2 = 0.6$ m, and $h_3 = 0.8$ m. Take the densities of water, oil, and mercury to be 1000 kg/m^3, 850 kg/m^3, and 13,600 kg/m^3, respectively.

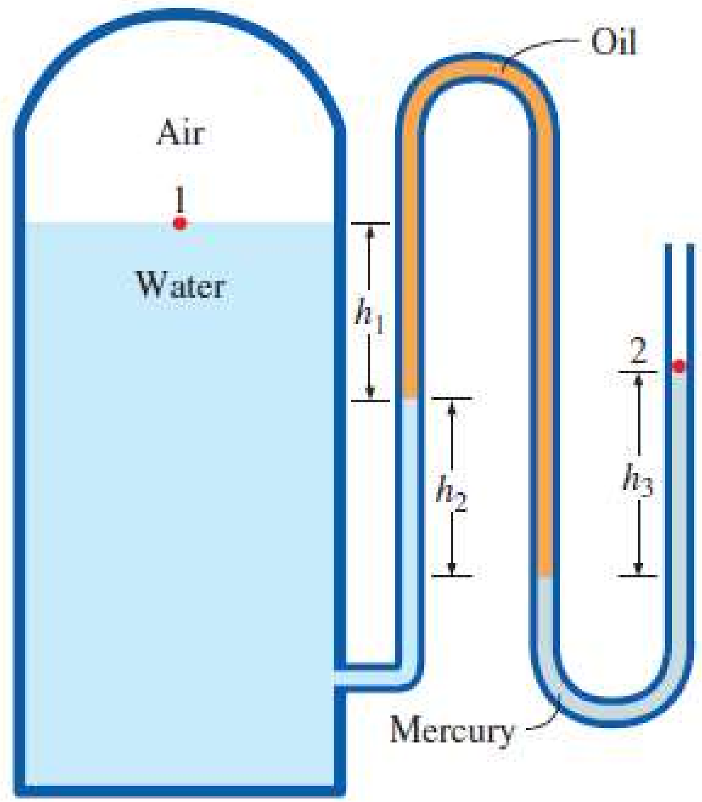
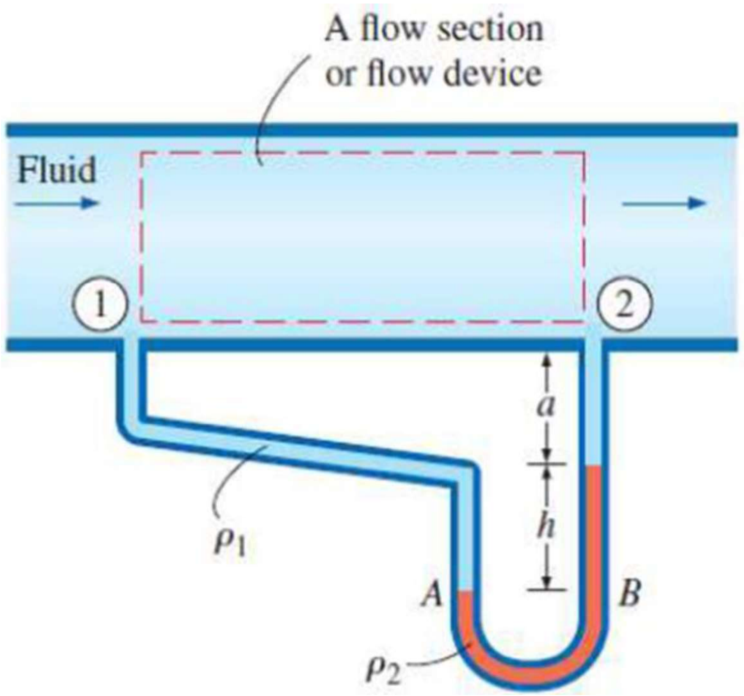


FIGURE P3–12

H.W: If you were an engineer in a company that has a problem reading the gauge pressure precisely by a manometer in the following Figure. How would you help to solve this issue? If you know that the pressure difference is really low. Analyze the problem mathematically and try to repair it in the simplest, and easiest, way. Provide some suggestions and solve them mathematically to improve your point of view.



Given:

The fluid flow in the channel is Air.

The working fluid of the manometer is Mercury.

The Pressure difference between points 1 and 2 is 130 pa.