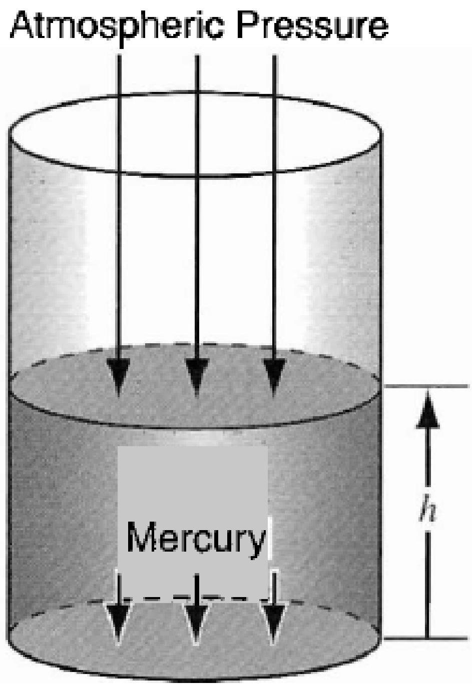
CHAPTER 5: PRESSURE

5.1 Pressure and Its Units

- **Pressure** is defined as the normal (perpendicular) force per unit area.

Fig. 1



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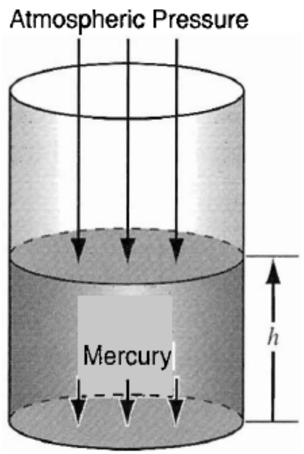
- The pressure at the bottom of the **static** (nonmoving) column of mercury exerted on the sealing plate is:



$$p = \frac{F}{A} = \rho g h + p_o$$

where p = pressure at the bottom of the column of the fluid
F = force
A = area
ρ = density of fluid
g = acceleration of gravity
h = height of the fluid column
$\boldsymbol{p_o}$ = pressure at the top of the column of fluid

- In the SI system the force is expressed in newtons, and area in square meters; then the pressure is N/m^2 or pascal (Pa).

Example: Suppose that the cylinder of fluid in Figure (1) is a column of mercury that has an area of 1 cm^2 and is 50 cm high. The density of the Hg is 13.55 g/cm^3. What is the pressure on the section of the plate covered by the mercury.

Solution:

$$p = \rho g h + p_o$$

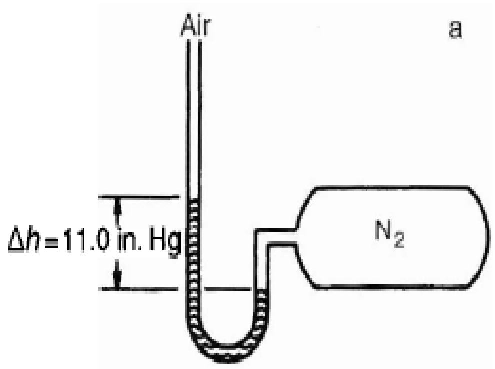
$$p = \underbrace{\frac{13.55\ \text{g}}{\text{cm}^3}}_{\rho}\bigg|\underbrace{\frac{980\ \text{cm}}{\text{s}^2}}_{g}\bigg|\underbrace{\frac{50\ \text{cm}}{}}_{h}\bigg|\frac{1\ \text{kg}}{1000\ \text{g}}\bigg|\frac{100\ \text{cm}}{1\ \text{m}}\bigg|\underbrace{\frac{1(\text{N})(\text{s}^2)}{1(\text{kg})(\text{m})}}_{C}$$

C= Conversion factor

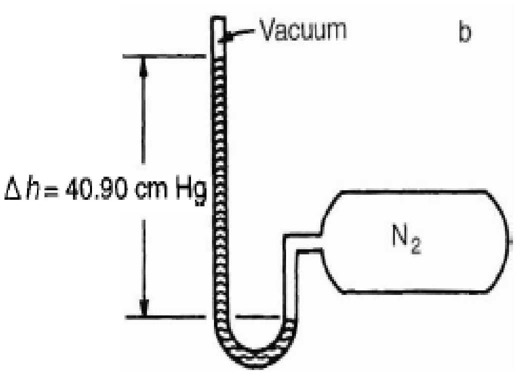
$$\frac{(1\ \text{m}^2)(1\ \text{Pa})}{(1\ \text{N})}\bigg|\frac{1\ \text{kPa}}{1000\ \text{Pa}} + p_0 = 66.4\ \text{kPa} + p_0$$

5.2 Measurement of Pressure

- Pressure can be expressed using either an absolute or a relative scale. Whether relative or absolute pressure is measured in a pressure measuring device depends on the nature of the instrument used to make the measurements



(a) Open- end manometer



(a) Closed- end manometer

- Water and mercury are commonly used indicating fluids for manometers; the readings thus can be expressed in "inches or cm of water," "inches or cm of mercury,“ and so on.

gauge pressure + barometric pressure = absolute pressure

- The **standard atmosphere** is defined as the pressure (in a standard gravitational field) equivalent to 1 atm or 760 mm Hg at 0°C or other equivalent value.

- **Atmospheric pressure** is variable and must be obtained from a barometric measurement each time you need it.

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- The **standard atmosphere** is equal to:

1.000 atmospheres (atm)

33.91 feet of water (ft H_20)

14.7 (14.696, more exactly) pounds (force) per square inch absolute (psia)

29.92 (29.921, more exactly) inches of mercury (in. Hg)

760.0 millimeters of mercury (mm Hg)

1.013 x lo^5 pascal (Pa) or newtons per square meter (N/m^2); or 101.3 kPa

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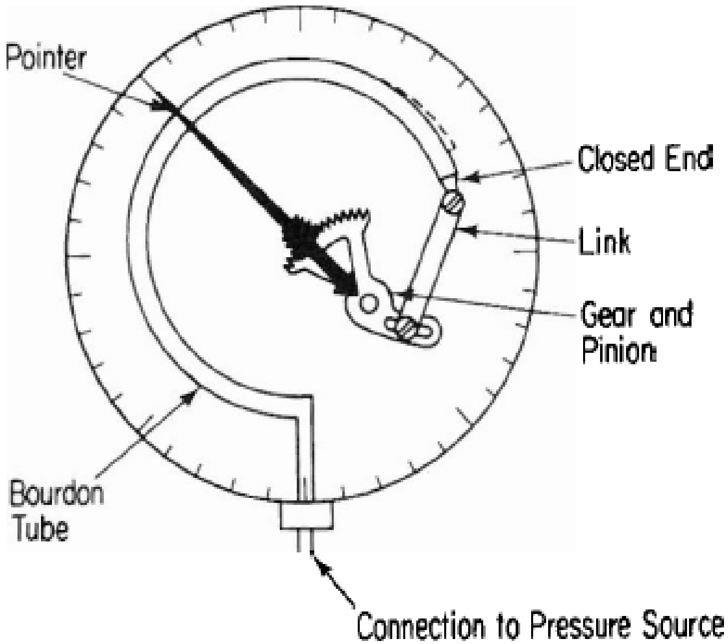

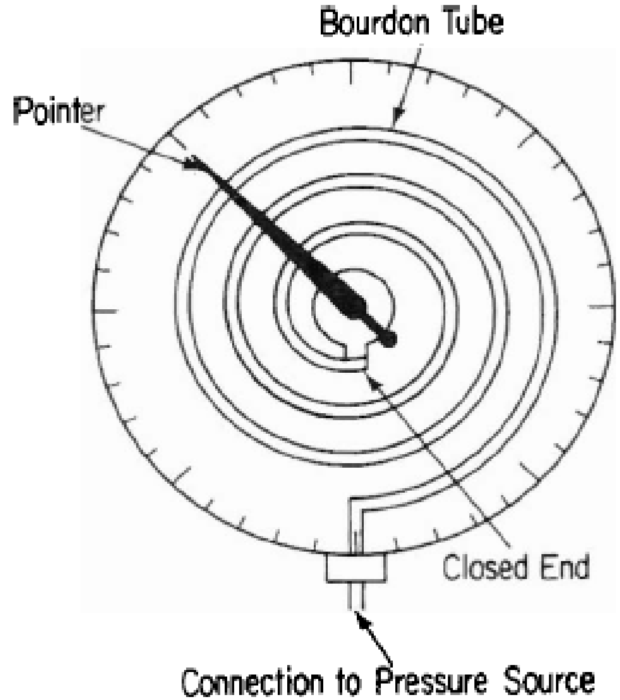

Bourdon gauge pressure-measuring devices

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- when you measure the pressure in "inches of mercury vacuum," you are reversing the usual direction of measurement, and measure from the atmospheric pressure downward to zero absolute pressure.

Inches ***Hg*** *vacuum = barometric pressure - absolute pressure.*

or

Vacuum *pressure = barometric pressure - absolute pressure.*

Example: What is the equivalent pressure to 60 Gpa in:

(a) atmospheres

(b) psia

(c) inches of Hg

(d) mm of Hg

Solution:

Basis: 60 GPa

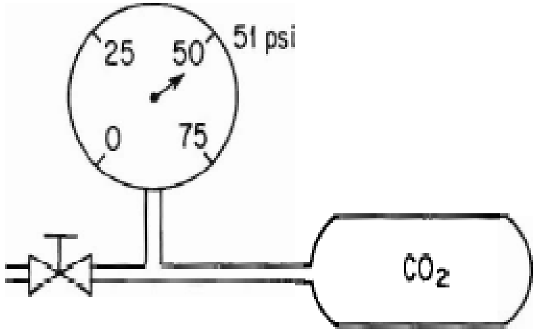
$$\text{(a)}\quad \frac{60\ \text{GPa}}{} \left| \frac{10^6\ \text{kPa}}{1\ \text{GPa}} \right| \frac{1\ \text{atm}}{101.3\ \text{kPa}} = 0.59 \times 10^6\ \text{atm}$$

$$\text{(b)}\quad \frac{60\ \text{GPa}}{} \left| \frac{10^6\ \text{kPa}}{1\ \text{GPa}} \right| \frac{14.696\ \text{psia}}{101.3\ \text{kPa}} = 8.70 \times 10^6\ \text{psia}$$

(c) $$\frac{60\ \text{GPa}}{} \left| \frac{10^6\ \text{kPa}}{1\ \text{GPa}} \right| \frac{29.92\ \text{in. Hg}}{101.3\ \text{kPa}} = 1.77 \times 10^7\ \text{in. Hg}$$

(d) $$\frac{60\ \text{GPa}}{} \left| \frac{10^6\ \text{kPa}}{1\ \text{GPa}} \right| \frac{760\ \text{mm Hg}}{101.3\ \text{kPa}} = 4.50 \times 10^8\ \text{mm Hg}$$

Example: The pressure gauge on a tank of CO_2 used to fill soda-water bottles reads 51.0 psi. At the same time the barometer reads 28.0 in. Hg. What is the absolute pressure in the tank in psia.



Solution:

$$\text{Atmospheric pressure} = \frac{28.0 \text{ in. Hg}}{} \bigg| \frac{14.7 \text{ psia}}{29.92 \text{ in Hg}} = 13.76 \text{ psia}$$

The absolute pressure in the tank is:

$$5\ 1.0 \text{ psia} + 13.76 \text{ psia} = 64.8 \text{ psia}$$

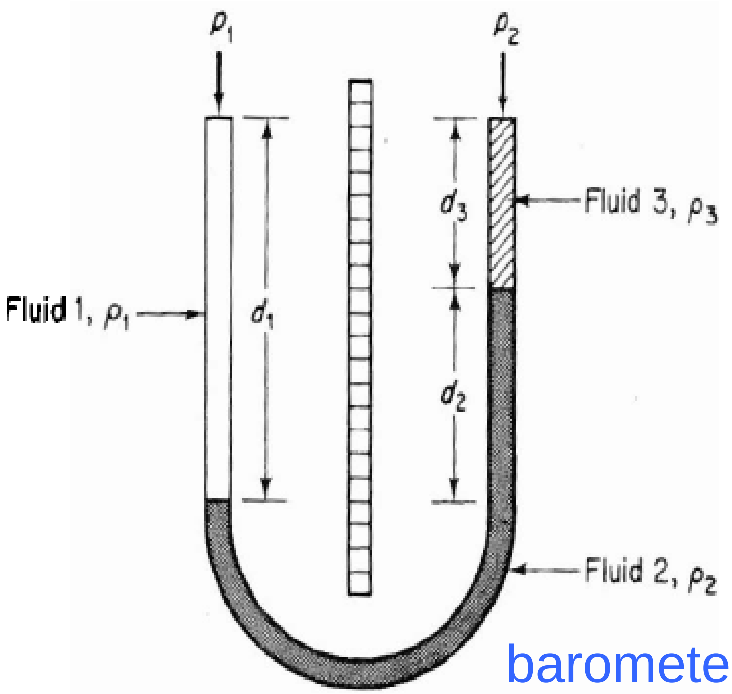
5.3 Differential Pressure Measurements

- **Pressure difference** The difference between the pressure at one point and another, usually as measured by an instrument.

$$p_1 + \rho_1 d_1 g = p_2 + \rho_2 g d_2 + \rho_3 g d_3$$

In case of $\rho_1 = \rho_3 = \rho$

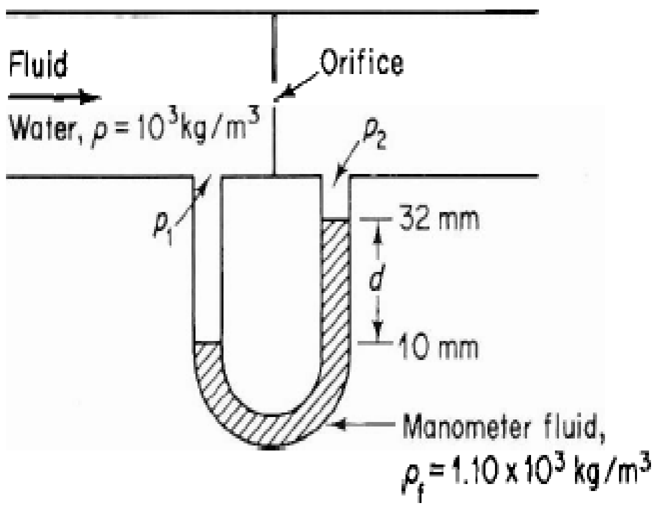
$$p_1 - p_2 = (\rho_2 - \rho) g d_2$$



barometer

EXAMPLE: In measuring the flow of fluid in a pipeline as shown in the next figure, a differential manometer was used to determine the pressure difference across the orifice plate.

The flow rate was to be calibrated with the observed pressure drop (difference). Calculate the pressure drop p_1-p_2 in pascals.



Solution:

$$p_1 - p_2 = (\rho_f - \rho)gd$$

$$= \frac{(1.10 - 1.00)10^3\ \text{kg}}{\text{m}^3}\left|\frac{9.807\ \text{m}}{\text{s}^2}\right|\frac{(22)(10^{-3})\text{m}}{}\left|\frac{1(\text{N})(\text{s}^2)}{(\text{kg})(\text{m})}\right|\frac{1(\text{Pa})(\text{m}^2)}{1(\text{N})}$$

$$= 21.6\ \text{Pa}$$