Pressure (Gauge, Absolute and Atmospheric)

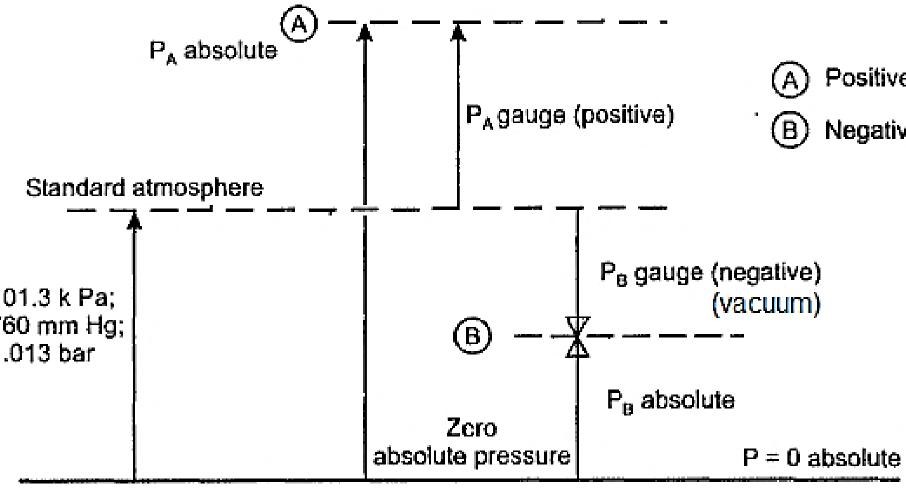
Pressure is defined as the normal force per unit area. The SI unit is (N/m^2) or Pascal (Pa).

$$P = \frac{Force}{\text{Area over which the force is applied}}$$

The ***gauge pressure*** is the pressure measured by a manometer relative to the atmospheric pressure.

The ***atmospheric pressure*** is the pressure caused by the weight of the atmosphere (air).

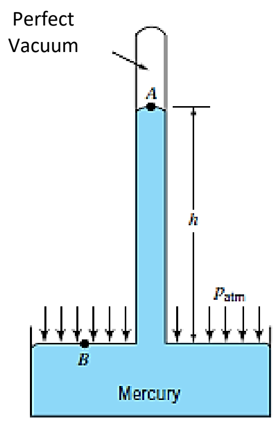
The ***absolute pressure*** is the pressure obtained relative to a perfect vacuum condition.



$$\mathbf{(P_A)_{absolute} = P_{atm} + (P_A)_{gauge}}$$

$$\mathbf{(P_B)_{absolute} = P_{atm} - (P_B)_{Vacuum}}$$

The **measurement of the Atmospheric Pressure** is usually accomplished with a ***mercury barometer***. A tube is initially filled with mercury and then turned upside down in a container of mercury. The column of mercury will come to an **equilibrium position** (@760mm) where the weight of the fluid **balances** the force due to the atmospheric pressure. Thus,



$$P_{atm} = \gamma_{mercury} \ x \ h$$

$$P_{atm} = S.G_{mercury} \ x \ \gamma_{Water} \ x \ h$$

$$P_{atm} = 13.6 \ x \ 9810 \ x \ 0.76 = 101.3 \ kpa$$

Measurement of Pressure

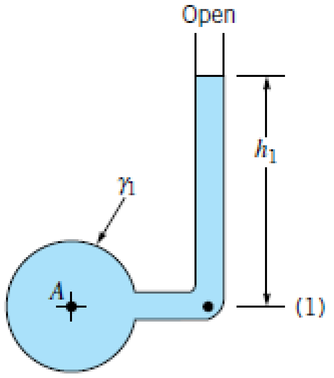
Manometers is a standard technique for measuring pressure which involves the use of liquid columns in vertical or inclined tubes. The common types of manometers are:

- Piezometer tube.
- U-tube manometer.
- Differential manometer.
- Inclined-tube manometer.

Piezometer Tube

The simplest type of manometer. It consists of a vertical tube opened at the top and attached to the container in which the pressure is desired to be measured.

$P_A = P_1 = \gamma_1 h_1$



Advantages and Disadvantages

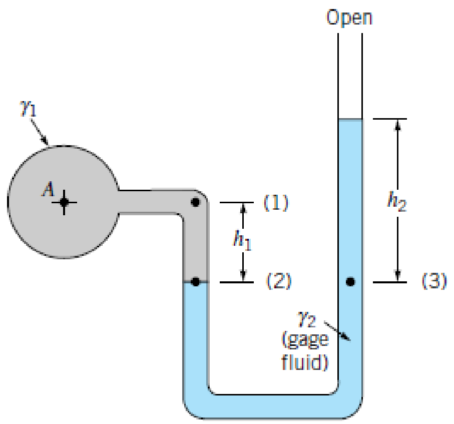
1. Very simple and accurate.
2. Measure **liquid pressure** only.
3. Only suitable if the pressure in the container is **greater** than atmospheric pressure.
4. Pressure must be relatively small so that the **height** of the column is reasonable.

U-Tube Manometer

To overcome the difficulties in piezometer tube, U tube manometer is used which includes an additional liquid (gauge fluid).

$P_A + \gamma_1 h_1 - \gamma_2 h_2 = 0$ (See the note below)

$P_A = \gamma_2 h_2 - \gamma_1 h_1$



Note: Pressure ***increases (+)*** as we move ***downward*** and ***decreases (-)*** as we move ***upward***.

Advantages

- Measure **gas** and **liquid** pressures.
- Adjustable column height for different pressure ranges.

How do we adjust the measurement range?

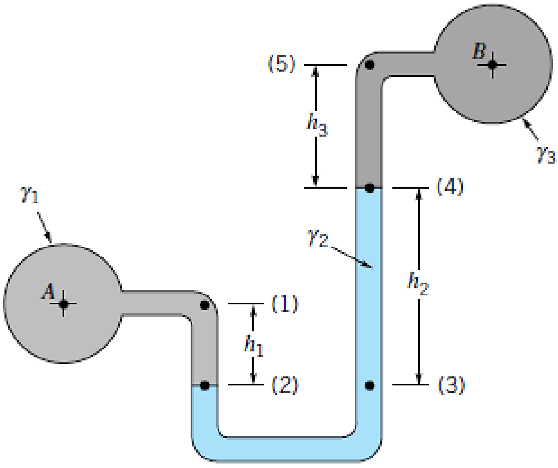
If the pressure P_A is **large**, then a **heavy gauge fluid** (such as mercury) can be used and a reasonable column height (not too long) can still be maintained. Alternatively, if the pressure P_A is **small**, a **lighter gage fluid** (such as water) can be used so that a relatively large column height (readable) can be achieved.

Differential manometer

It is basically a U type manometer connected from both sides with a gauge liquid in between.

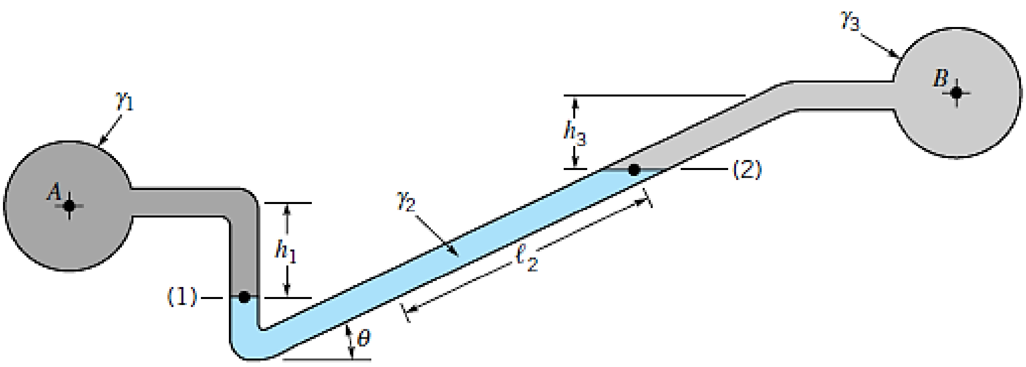
$P_A + \gamma_1 h_1 - \gamma_2 h_2 - \gamma_3 h_3 = P_B$

$P_A - P_B = \gamma_2 h_2 + \gamma_3 h_3 - \gamma_1 h_1$



Inclined-tube manometer

The inclined-tube manometer is often used to measure **small differences in gas pressures.**



$P_A + \gamma_1 h_1 - \gamma_2 L_2 \sin\Theta - \gamma_3 h_3 = P_B$

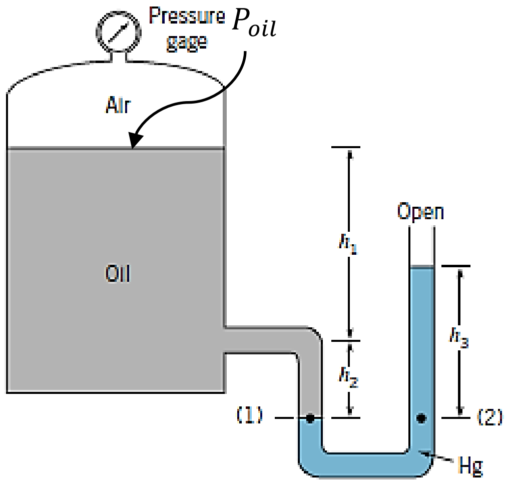
$P_A - P_B = \gamma_2 L_2 \sin\Theta + \gamma_3 h_3 - \gamma_1 h_1$

The contributions of the gas columns ($\gamma_1 h_1$ & $\gamma_3 h_3$) can be neglected which gives:

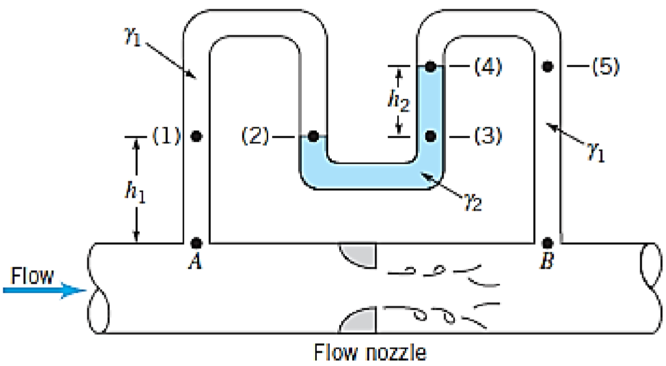
$$\boldsymbol{L_2 = \frac{P_A - P_B}{\gamma_2 sin\Theta}}$$

For a given pressure difference, the **sensitivity** can be changed by **adjusting** the manometer's angle. Thus, for relatively small angles the differential reading along the inclined tube (L**2**) can be large even for small pressure differences.

Ex) A closed tank contains compressed air and oil (SG = 0.9). A U-tube manometer using mercury (SG = 13.6) is connected to the tank. For column heights h_1 = 140 cm, h_2 = 24 cm and h_3 = 36 cm, determine the pressure reading of the gage.



Ex) Determine the value of the pressure drop (ΔP) created by the nozzle shown. For γ_1 = 9.8 KN/m^3, γ_2 = 15.6 KN/m^3, h_1 = 1 m and h_2 = 0.5 m.

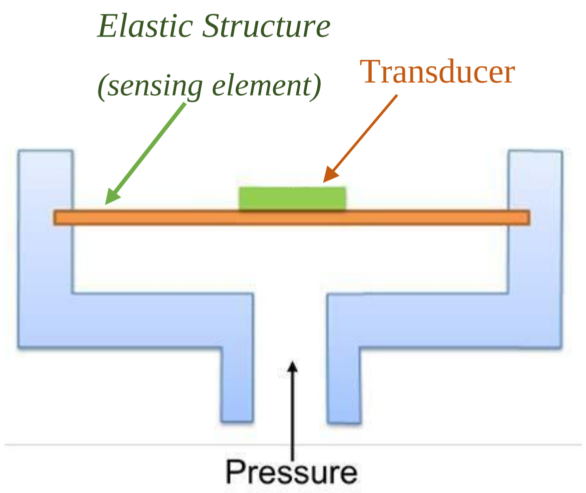


Pressure Sensor

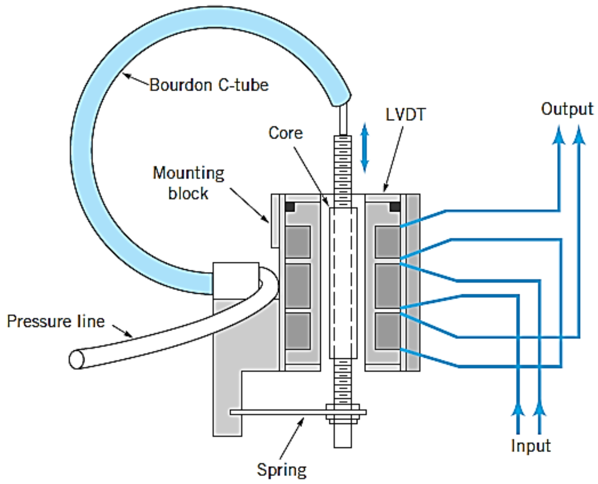
Although manometers are widely used, they have some disadvantages:

- They are not well suited for measuring very high pressures.
- Not suitable for pressures that are changing rapidly with time.
- They require the measurement of one or more column heights which can be time consuming.

To overcome these problems, other types of pressure measuring instruments have been developed. Most of these instruments make use of the idea that when a pressure acts on an elastic structure, the structure will deform and this deformation can be related to the magnitude of the pressure.



The most familiar device is the Bourdon Tube Pressure Sensor. The essential mechanical element in this devise is the hollow, elastic curved tube Bourdon tube which is connected to the pressure source. As the pressure within the tube increases the tube tends to straighten. This deformation can be translated into an electrical output using linear variable differential transformer (LVDT).



Because of the relatively high stiffness of the Bourdon tube**, it cannot respond to rapid changes in pressure**. To overcome this difficulty, the sensing element is replaced by a thin, elastic diaphragm. Also, a strain gauge is attached on the surface of the diaphragm. As the pressure changes, the diaphragm deflects and this deflection can be sensed by strain gage and