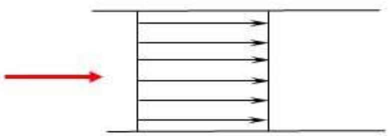
Semester- 3rd

FUNDAMENTALS OF
FLUID MECHANICS

Types of fluid Flow

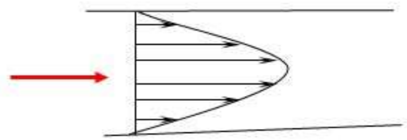
1. Real and Ideal Flow:

If the fluid is considered frictionless with zero viscosity it is called ideal.
In real fluids the viscosity is considered and shear stresses occur causing conversion of mechanical energy into thermal energy



Ideal

Friction = 0
Ideal Flow ($\mu = 0$)
Energy loss =0

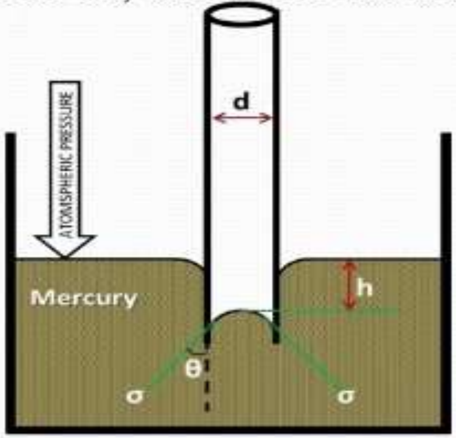


Real

Friction $\neq$ o
Real Flow ($\mu \neq 0$)
Energy loss $\neq 0$

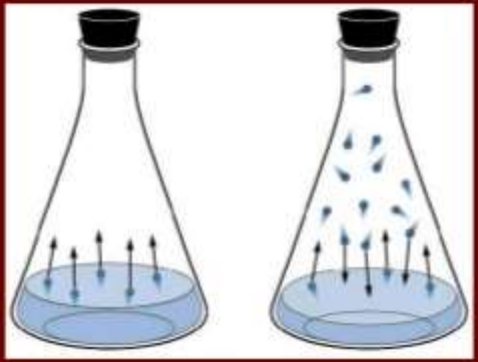
CAPILLARITY FALL

- Tendency of liquids to be depressed in tubes of small diameter in opposition to, external forces like gravity



Vapor Pressure and Boiling

- **Vapor Pressure** – the pressure exerted by a **vapor** in equilibrium with its **liquid** state.
- Liquid molecules at the surface **escape** into the **gas** phase.
- These gas particles create **pressure** above the **liquid** in a closed container.



Pascal's Law

Pascal's law states that a pressure exerted on a confined fluid is exerted equally in all directions throughout the fluid.

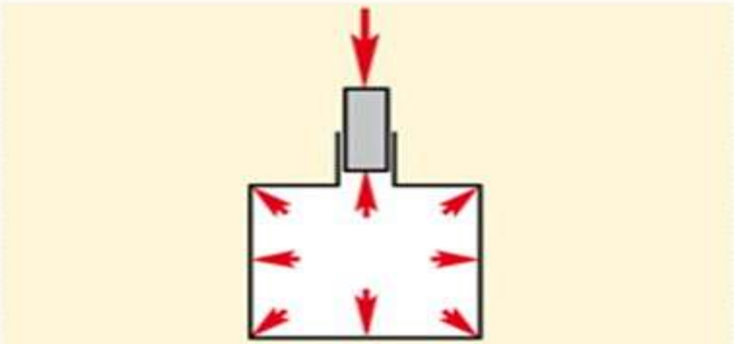
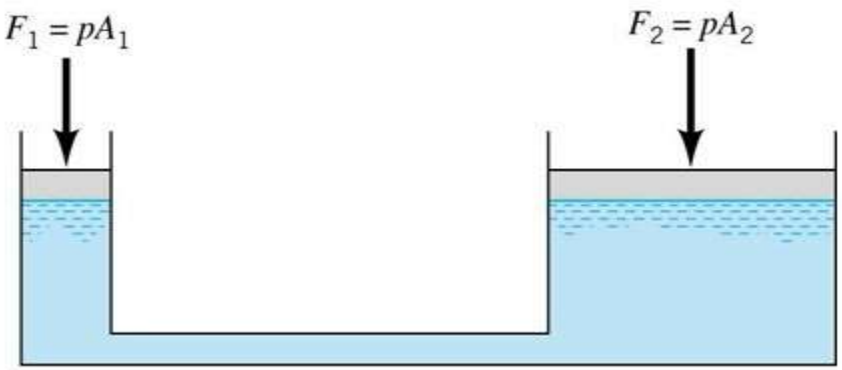


Figure 1

Hydrostatic Application: Transmission of Fluid Pressure



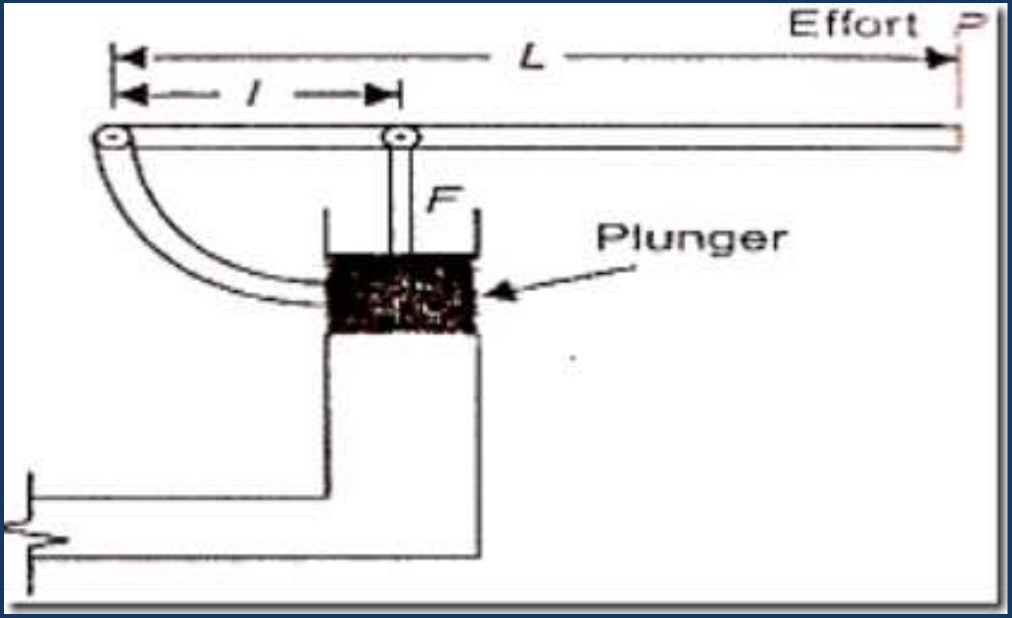
- Mechanical advantage can be gained with equality of pressures
- A small force applied at the small piston is used to develop a large force at the large piston.
- This is the principle between hydraulic jacks, lifts, presses, and hydraulic controls

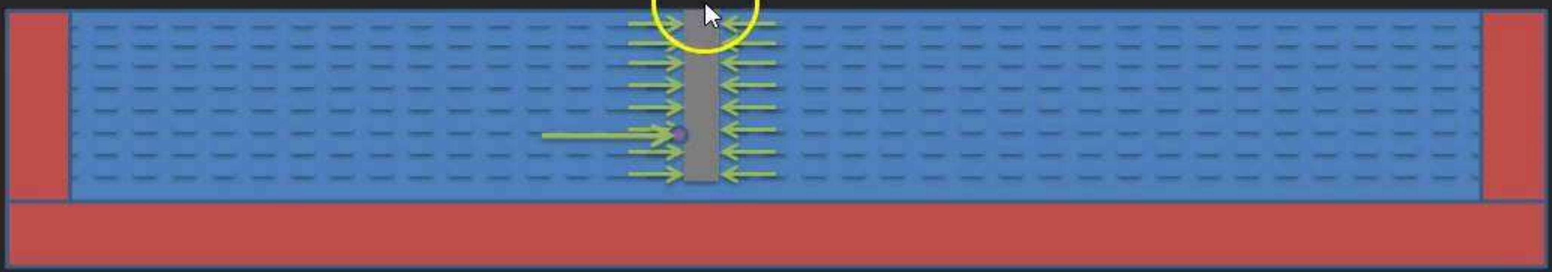
$$F_2 = \frac{A_2}{A_1} F_1$$

$$F_1 = \frac{A_1}{A_2} F_2$$

SECOND APPLICATION OF PASCAL's LAW

LEVRAGE OF HYDRAULIC PRESS





Total Pressure Force

It is the total force exerted by a fluid on a given plate or curved plate, when the fluid comes in contact with the plane.

Centre of Pressure

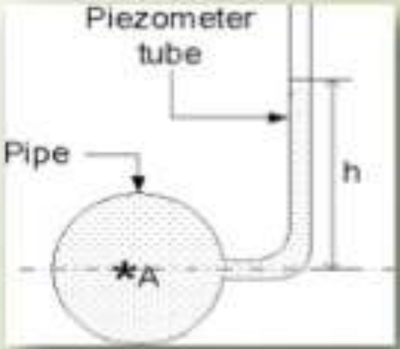
It is a point , where the total pressure force acts on the plate.

Piezometer:

- Simple type manometer, vertical L shape tube, open at top, attached to a container pipe
- P = sp wt * height + p(atm)   Absolute pressure.
- P= sp wt * height   Gauge pressure

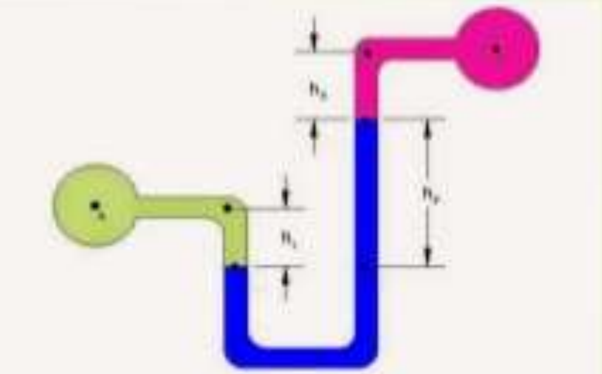
Vertical column for measuring static Pressures of liquids.

- It has a tube in which the Fluid(liquid) can rise freely, the height of the liquid in the tube will give the value of Pressure.
- Its diameter is kept at least 12mm in order to reduce the error.
- ADVANTAGES: easy technique, accurate,economical
- DISADVANTAGES: cannot measure...
  1) negative pressure
  2) pressure of gases
  3) control of column height



Differential Manometer:

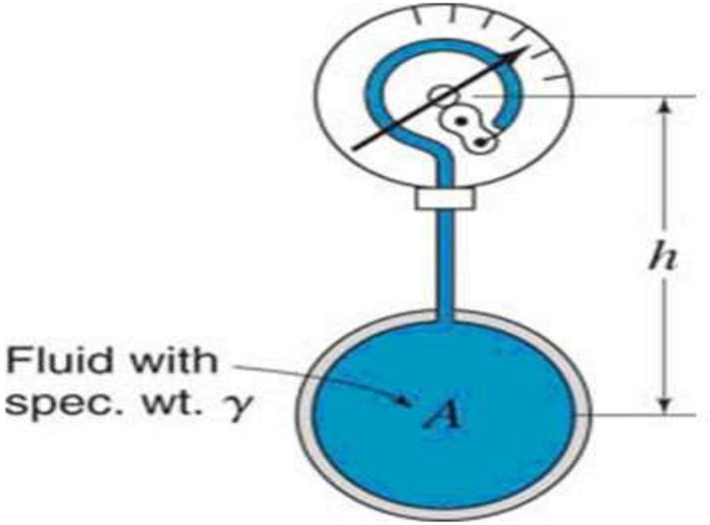
- In many cases we require the difference between two pressures. For such purposes we use a Differential manometer.
- In this arrangement of manometer we connect the two ends with different liquids whose pressure we want to measure.
- It is to be noted that only those liquids should be used who are immiscible with each other. Otherwise liquids will mix and we will not be able to measure the difference of their heights.
- Math equation:



Differential U - Tube Manometer

2. Bourdon Gauge:

- The pressure, above or below the atmospheric pressure, may be easily measured with the help of a bourdon's tube pressure gauge.
- It consists on an elliptical tube: bent into an arc of a circle. This bent up tube is called Bourdon's tube.
- Tube changes its curvature with change in pressure inside the tube. Higher pressure tends to "straighten" it.
- The moving end of tube rotates needle on a dial through a linkage system.



Continuity Equation

- For steady flow condition $d(M_{CV})/dt = 0$

$$\rho_1 A_1 V_1 - \rho_2 A_2 V_2 = 0 \Rightarrow \rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$M = \rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

- Hence, for stead flow condition, mass flow rate at section 1= mass flow rate at section 2. i.e., mass flow rate is constant.
- Similarly $G = \rho_1 g A_1 V_1 = \rho_2 g A_2 V_2$
- Assuming incompressible fluid, $\rho_1 = \rho_2 = \rho$

$$A_1 V_1 = A_2 V_2 \Longrightarrow Q_1 = Q_2 \Longrightarrow Q_1 = Q_2 = Q_3 = Q_4$$

- Therefore, according to mass conservation for steady flow of incompressible fluids volume flow rate remains same from section to section.

Forms of Energy

- **(1). Kinetic Energy:** Energy due to motion of body. A body of mass, *m*, when moving with velocity, *V*, posses kinetic energy,

$$KE = \frac{1}{2} m V^2$$

m and *V* are mass and velocity of body

- **(2). Potential Energy:** Energy due to elevation of body above an arbitrary datum

$$PE = mgZ$$

Z is elevation of body from arbitrary datum
m is the mass of body

- **(3). Pressure Energy:** Energy due to pressure above datum, most usually its pressure above atmospheric

$$\mathrm{PrE} = \gamma h \qquad !!!$$

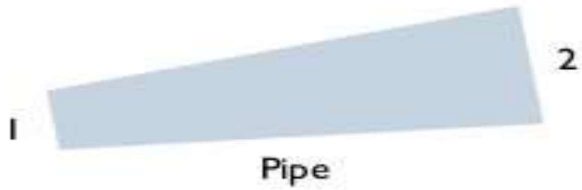
Bernoulli's Equation

- *It states that the sum of kinetic, potential and pressure heads of a fluid particle is constant along a streamline during steady flow when compressibility and frictional effects are negligible.*
- *i.e., For an ideal fluid, Total head of fluid particle remains constant during a steady-incompressible flow.*
- *Or total head along a streamline is constant during steady flow when compressibility and frictional effects are negligible.*

$$\text{Total Head} = Z + \frac{P}{\gamma} + \frac{V^2}{2g} = constt$$

$$Z_1 + \frac{P_1}{\gamma} + \frac{V^2{}_1}{2g} = Z_2 + \frac{P_2}{\gamma} + \frac{V^2{}_2}{2g}$$

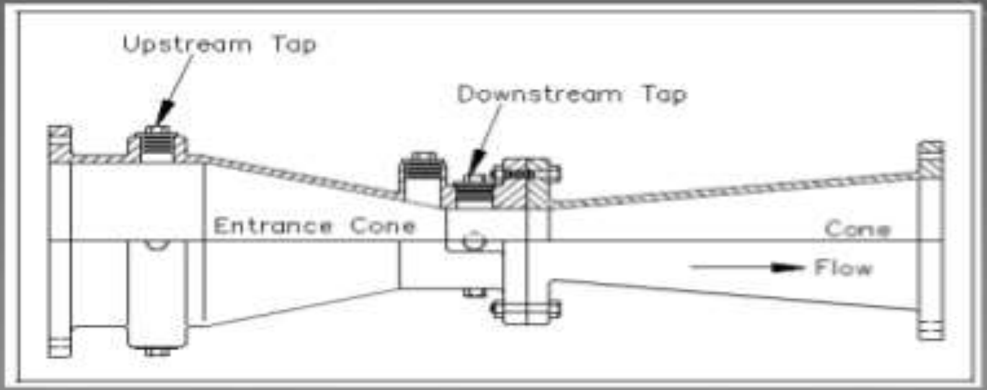
$$H_1 = H_2$$



VENTURIMETER

- It's a device, used to measure the rate of flow of fluid through a pipe
- It consists of :

1. Inlet section.
2. Convergent section,
3. A cylindrical throat.
4. A gradually divergent cone.



Notches

- A notches is defined as an opening in the side of a vessel or tank in such a manner that the liquid surface in the tank.
- A notch is generally made of metallic plate.
- It is used for measuring the discharge rate of a liquid from a small channel or tank.

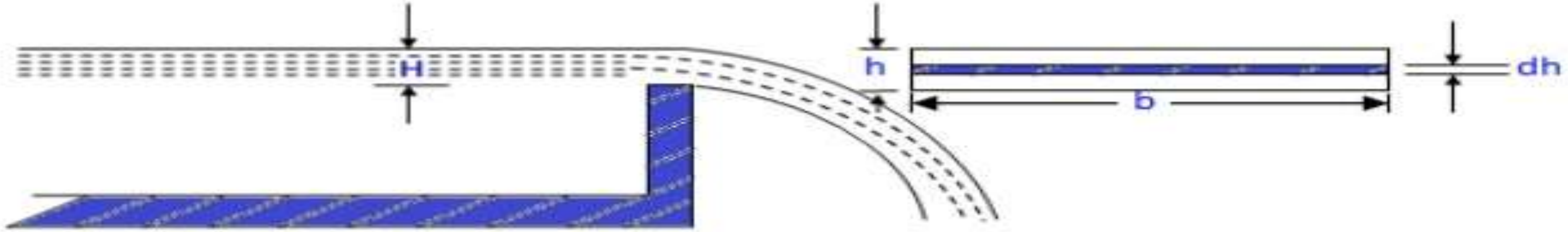


Fig : Rectangular Notch

Weir

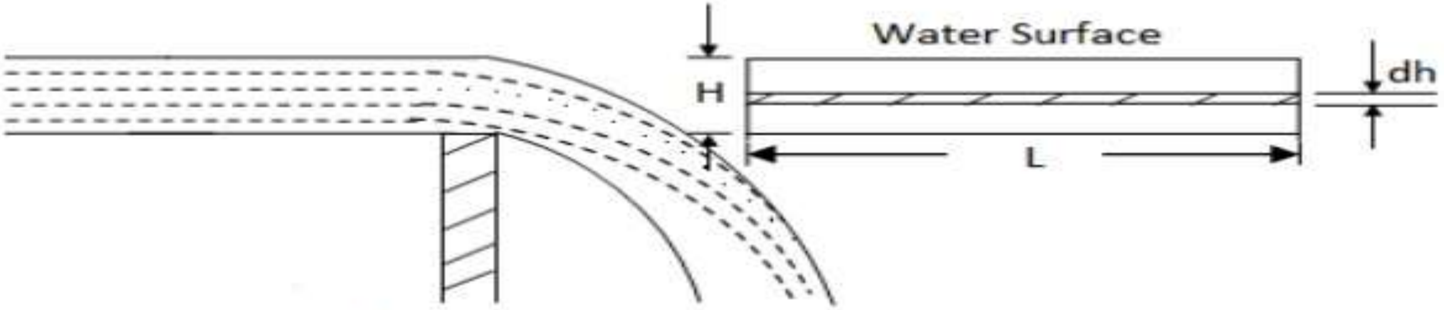


Fig : Rectangular weir

- A weir is basically an obstruction in the flow path in an open channel.
- The weir will cause an increase in the water depth as the water flows over the weir.
- In general, the greater the flow rate, the greater will be the increase in depth of flow, The height of water above the top of the weir is the measurement usually used to correlate with flow rate.

Difference between Notch & Weir

NOTCH

- A notch may be defined as an opening provided in one side of a tank or reservoir, with u/s liquid level below the top edge of the opening.
- The bottom edge of notch over which water flows is known as sill or crest.
- A notch is usually made of a metallic plate.
- A notch is used to measure small discharge of small stream or canal.
- Notches are of small size.

WIER

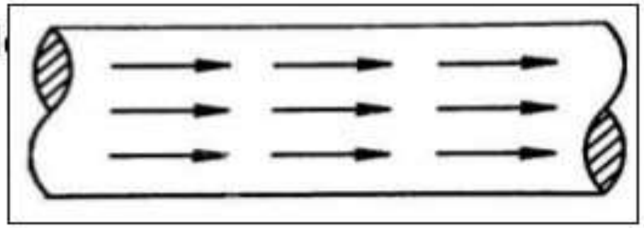
- A weir may be defined as a structure constructed across a river or canal to store water on the upstream side.
- The top of the weir over which water flows is known as crest.
- A weir is made of cement concrete or masonary.
- A weir is used to measure large discharge of rivers and large canals.
- Weirsd are of bigger size.

1. Laminar Flow:-

Laminar flow is defined as that type of flow in which the fluid particles move along well-defined paths or stream lines and all the stream lines are straight and parallel.

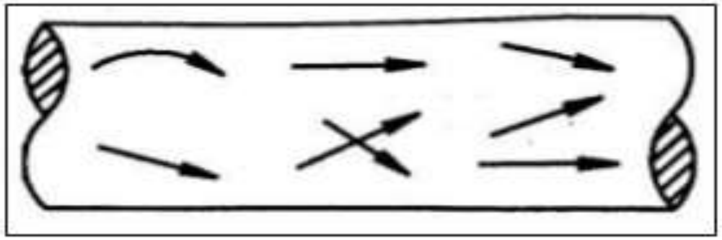
Factors responsible for laminar flow are:-

- High viscosity of fluid.
- Low velocity of fl
- Less flow area.



2. Turbulent Flow:-

Turbulent flow is defined as that type of flow in which the fluid particles move is a zigzag way. The Fluid particles crosses the paths of each other.



For example,

- Flow in river at the time of flood.
- Flow through pipe of different cross- section.

Energy Principles in Open Channel Flow

Rectangular Channel

For rectangular section

At critical Flow

$$F_r = \frac{V}{\sqrt{gD_h}} = \frac{V}{\sqrt{gD}}$$

a) Critical depth, ***yc , is defined as that depth of flow of liquid at which the specific*** energy is minimum, *Emin,*

$$F_r = 1 = \frac{V}{\sqrt{gD_h}}$$

$$y_c = \left(\frac{Q^2}{B^2 g}\right)^{\frac{1}{3}}$$

q=Q/B

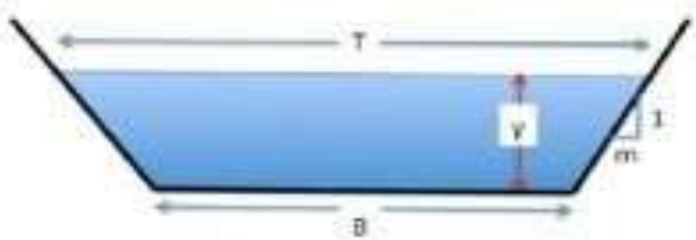
$$y_c = \left(\frac{q^2}{g}\right)^{1/3}$$

b) Critical velocity, Vc , is the velocity of flow at critical depth.

$$V_c = \sqrt{g \times y_c}$$

Trapezoidal Channel

- The trapezoidal conduit is a reasonably common geometry
  - triangular channel and rectangular channel are special cases of the trapezoidal conduit.
- Engineered (improved) natural channels are reasonably well approximated by trapezoidal equations
  - the geometry is important in drainage engineering



B = Bottom width;
T = Top width;
y = Depth;
m = Side slope (H:V), i.e. (m:1).

$$A_{trap}(y) = y(B + my)$$

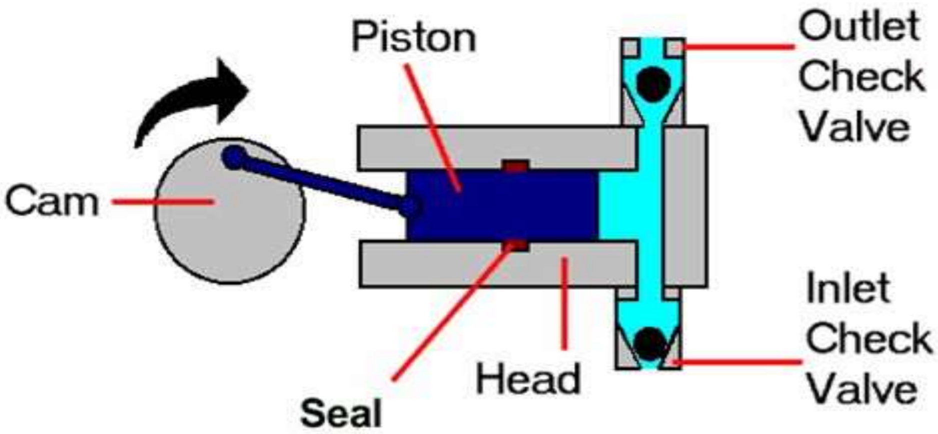
$$T_{trap}(y) = B + 2my$$

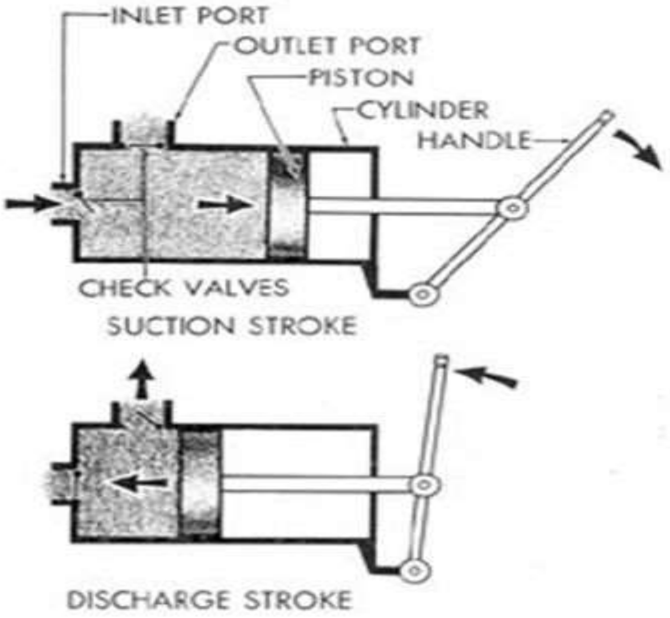
$$P_{w\ trap}(y) = B + 2y\sqrt{1 + m^2}$$

$$R_{h\ trap}(y) = \frac{y(B + my)}{B + 2y\sqrt{1 + m^2}}$$

Reciprocating pumps.

- In the reciprocating pump a piston sucks the fluid into a cylinder then pushes it up causing the water to rise.





Centrifugal Pump:

- Centrifugal pumps (radial-flow pumps) are the most used pumps for hydraulic purposes. For this reason, their hydraulics will be studied in the following sections.