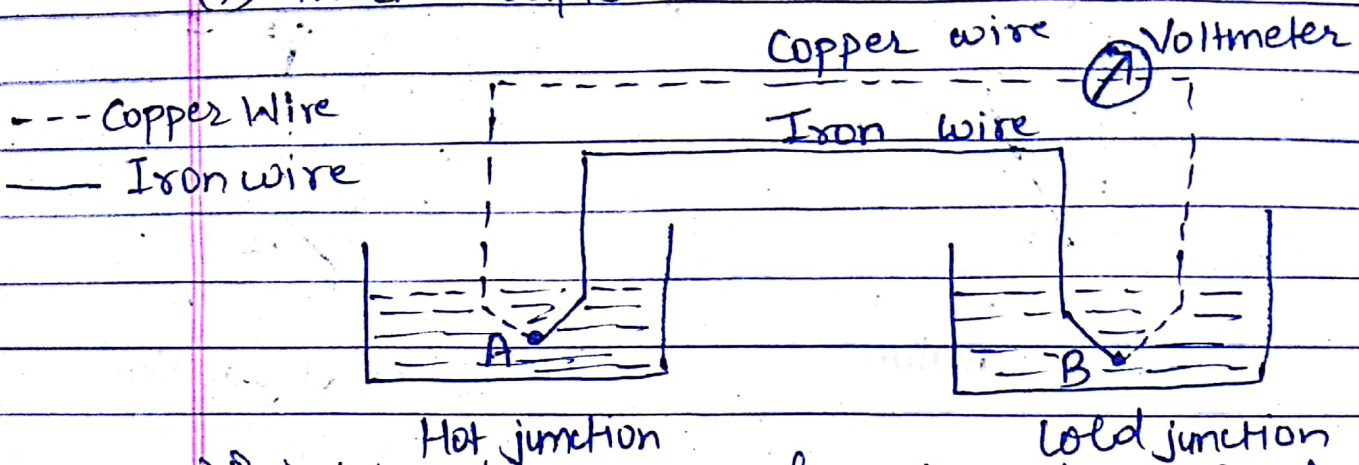
Temperature Measurement:-

(i) Thermocouple



→ Principle of Thermocouple is based on Seebeck effect
→ Thermocouple converts thermal energy into electrical energy.
→ Thermocouple is used to measure temperature of a given substance.
→ According to Seebeck effect, when the temperature at the junction of two different metals differ, then an EMF is generated in the closed loop.
→ In figure temperature of junction B is known and we have to determine the temperature at junction A.

$$V \propto (T_1 - T_2)$$
$$V = S(T_1 - T_2)$$

where, S = Overall seebeck coefficient.

(ii) Resistance Temperature Devices :- (RTD)

→ It work on the principle that the electrical resistance of a material changes with its temperature.
→ As the temperature of metal increases the

flow of electrons increases, current also increases. So, resistance decreases.

→ The variation of resistance R with temperature T(°K) can be represented by

$$R = R_0(1 + \alpha_1 T + \alpha_2 T^2 + \alpha_3 T^3 + \cdots \alpha_n T^n)$$

where, R_0 = Resistance at temperature, T = 0K

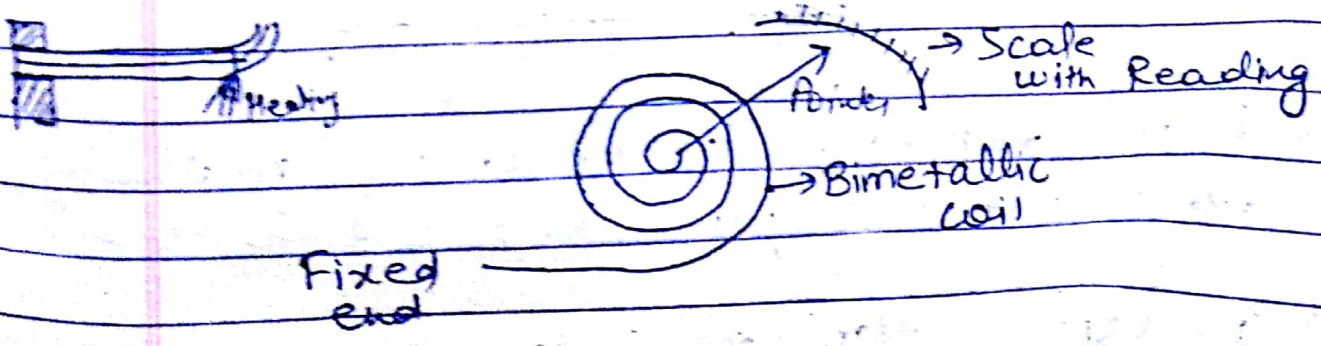
$\alpha_1, \alpha_2, \alpha_3 \cdots \alpha_n$ = Constants

→ Resistance thermometer uses the change in electrical resistance of conductors to determine the temperature.

(iii) Infrared Temperature Measurement Devices :

Infrared sensors are non-contacting devices. They measure the temperature by measuring the thermal radiation emitted by a material.

(iv) Bimetallic Temperature Measurement Devices :



→ It works on the principle that different materials have different rate of thermal expansion.

→ Deflection is directly proportional to the temperature.

→ As temperature increases or decreases there is deflection in the bimetallic coil and temperature can be measured by the help of pointer..

→ It is not so much accurate as Thermocouple and Resistance temperature Devices..

(v) Fluid - expansion Temperature Measurement Devices :

→ Fluid - expansion devices can be divided into two main classes:- the mercury type and the organic - liquid type (consist of one or more carbon atom joined to other atoms via covalent bond.)

→ Mercury thermometer is based on the principle that mercury expand with increase in temperature.

→ Fluid expansion temperature measuring devices don't require any electric power.

Pressure Measurement devices :

(i) Manometers :

Manometer consist of a clear glass or plastic tube. ~~shaped into the~~ The tube is partially filled

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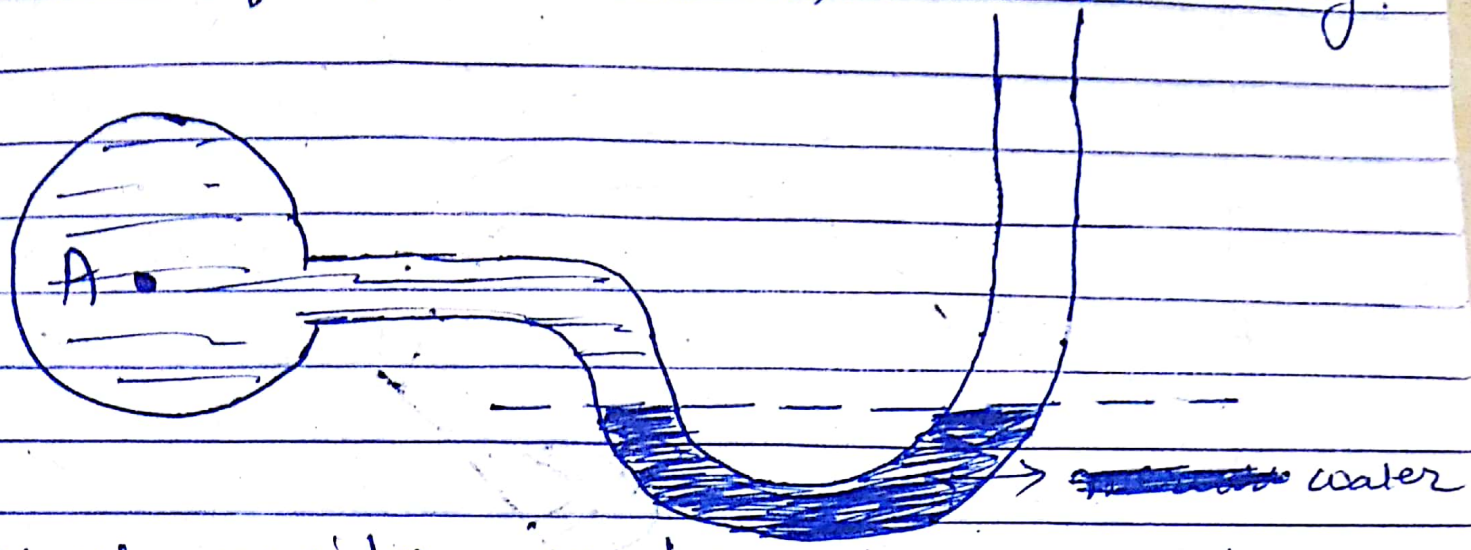
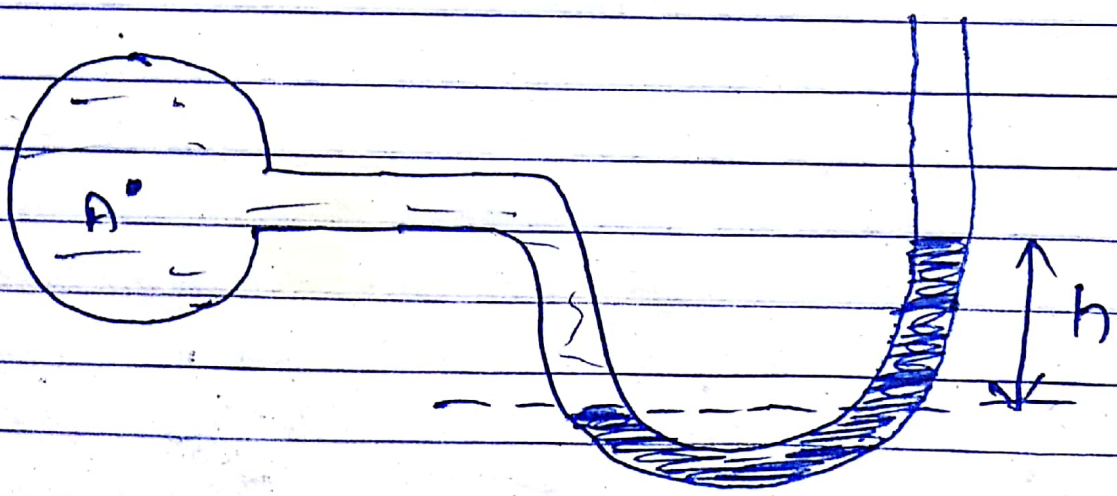
with a liquid, such as water, alcohol or mercury.



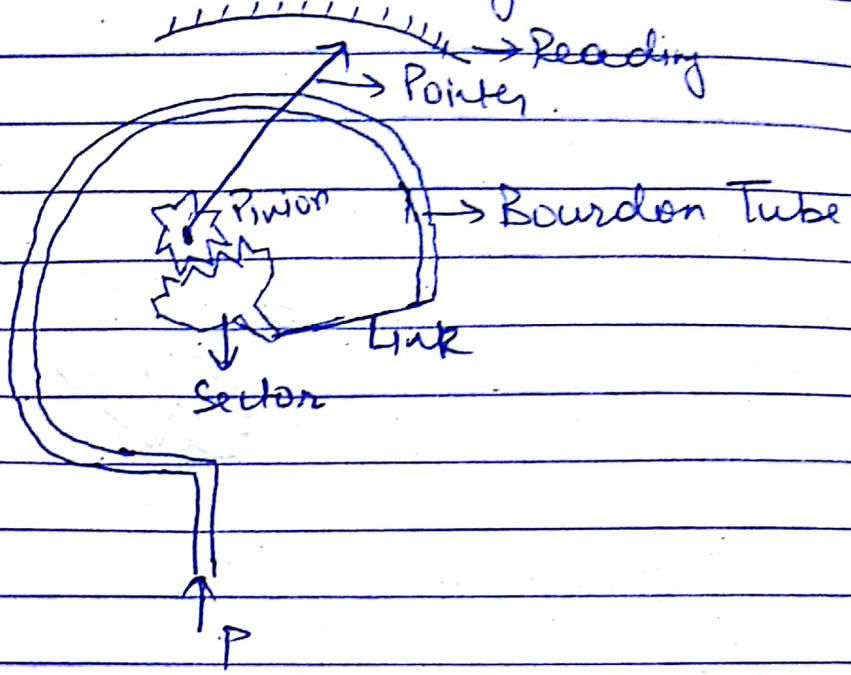
Let us consider we have to measure pressure of fluid in container A by using water in manometer. When the level of water is same then the pressure of container A is at atmosp. pressure.



When container A gains pressure more than that of atm. pressure then the level of water rises and then we can calculate the pressure of fluid in container A by the help of raise in height of water i.e, $P = \rho g h$

where, ρ = Density of water

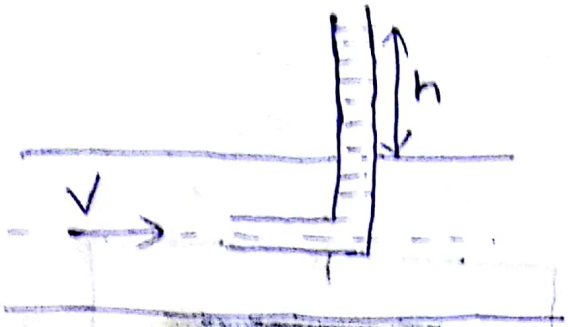
(ii) Bourdon Tube Pressure Gauge :-

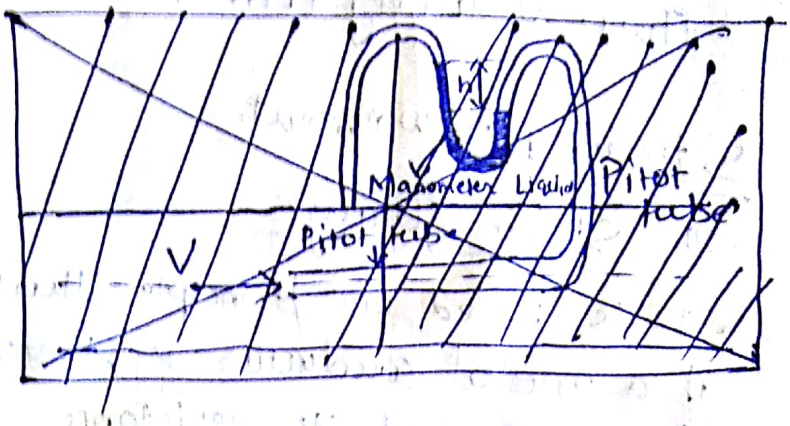


Bourdon Tube pressure gauge consist of C-shape hollow tube which is called Bourdon Tube. When hot fluid entered the hollow tube then Bourdon Tube expand due to which pinion rotate by the help of sector & link. Due to rotation of pinion pointer show the pressure reading in the closed container. Bourdon Tube is made of metal alloy such as stainless steel or brass. It is used in boilers of thermal power plant.

Velocity Measurement:

(i) Velocity Measurement of fluid with Pitot tube:-





→ Pitot tube is a flow measurement device used to measure fluid flow velocity.

→ Pitot tube consists of a tube pointing directly into the fluid flow. ~~Due to velocity of fluid, some~~ Fluid obtain some height in the tube due to velocity of fluid. By the help of height of fluid we can find the flow velocity.

$$(P_{\blacksquare} - P_0) = \frac{1}{2}\rho V^2$$

P = Pressure sense by Pitot tube $= \rho g h$

P_0 = Static pressure

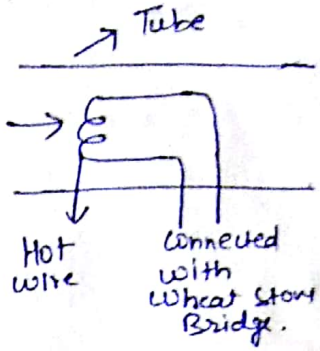
ρ = Density of fluid.

$$\boxed{V = \sqrt{\frac{2(P-P_0)}{\rho}}}$$

→ Pitot tube is widely used in the aircrafts by which aircraft's speed can be determined.

(ii) Hot Wire Anemometer :-

→ In this flow measurement of fluid is done by the help of hot wire. When fluid passes through the hot wire, then hot wire gives the heat to the fluid. Due to which some changes in temp. take place in hot wire.

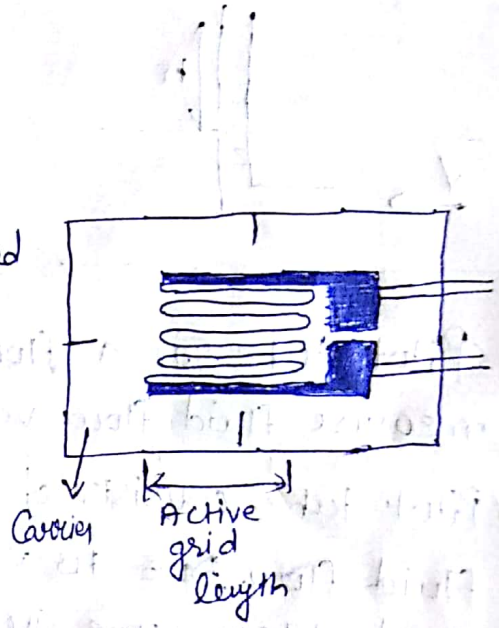


Due to change in temperature of wire resistance also changes. By the change in resistance of wire flow velocity can be measured.

Strain Measurement

Strain Gauge :-

→ It is based on principle that if a metal conductor is stretched or compressed, its resistance changes because of its
(i) length change
(ii) Diameter change
(iii) Resistivity change.



i.e; $R = \rho \frac{L}{A}$

where, R = Resistance
ρ = Resistivity of material
L = length of Material.
A = Cross sectional area of material.

→ The metallic strain gauge consists of very fine wire and arranged in a grid pattern.

→ The strain experienced by test specimen is transferred directly to the strain gauge which respond with a change in electric resistance.

→ It is very important that strain gauge be properly mounted on the test specimen so that the strain is accurately transferred from the test specimen.

→ Strain can be determine by following equation :-

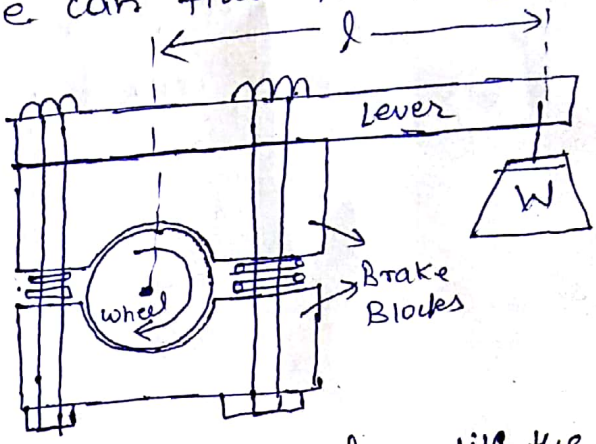
$$G.F = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

where, G.F = Metallic strain gauge.

Torque Measurement :-

(i) Prony Break Dynamometer

→ Dynamometer is a brake but in addition it has a device to measure the frictional resistance. By knowing the frictional resistance, we can find the torque transmitted.



→ Prony Brake develops mechanical friction on the periphery of ~~moving~~ rotating wheel by the means of brake blocks.

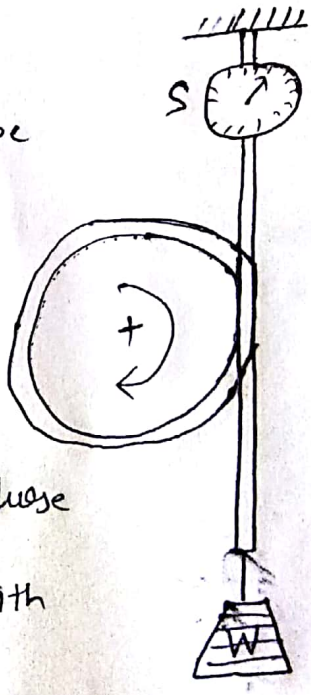
→ Break blocks squeezed against the wheel until the friction torque F.R balance the torque W.L.

$$\text{Torque} = F \times R = W \times L$$

(ii) Rope Brake Dynamometer :-

$$T = (W - S)\left(\frac{D+d}{2}\right)$$

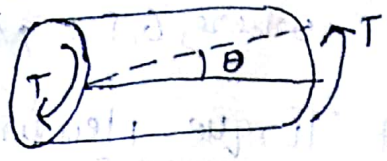
where, W = Weight at the end of rope
S = Stiffness of spring
D = Diameter of pulley
d = Diameter of rope.



Rope brake dynamometer consist of rope coound round the pulley fixed to the shaft of the engine whose torque is to be measured. The upper end of rope is attached with the spring and lower end of the rope is attached with the weight.

(iii) Torque Measurement by pointer & Scale :-

Suppose the angle of twist on the shaft due to application of torque T is θ, which can be directly read by pointer & Scale. The value of torque applied is directly related to angle of twist as



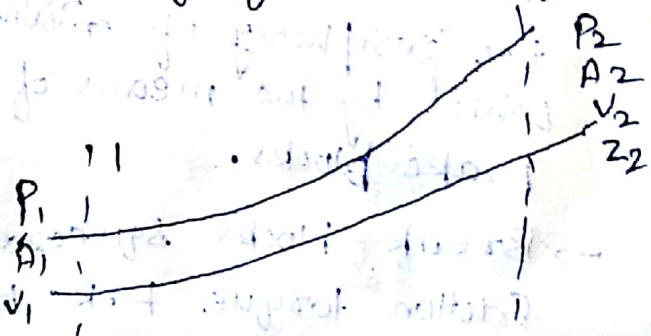
$$\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{l}$$

$$\Rightarrow \frac{T}{J} = \frac{G\theta}{l} \Rightarrow \boxed{\theta = \frac{Tl}{GJ}}$$

For shaft $J = \frac{\pi d^4}{32}$

Flow Measurement :-

(i) Flow Measurement through Velocity of fluid Over Known Area :-



Let us consider the fluid flow through a closed channel of variable cross-section. Let the pressure, velocity, cross-sectional area and height above the datum as P_1, V_1, A_1 & Z_1 for section 1 and corresponding values for section 2 be P_2, A_2, V_2, Z_2 respectively. We can find the final velocity V_2 by help of Bernoulli's equation

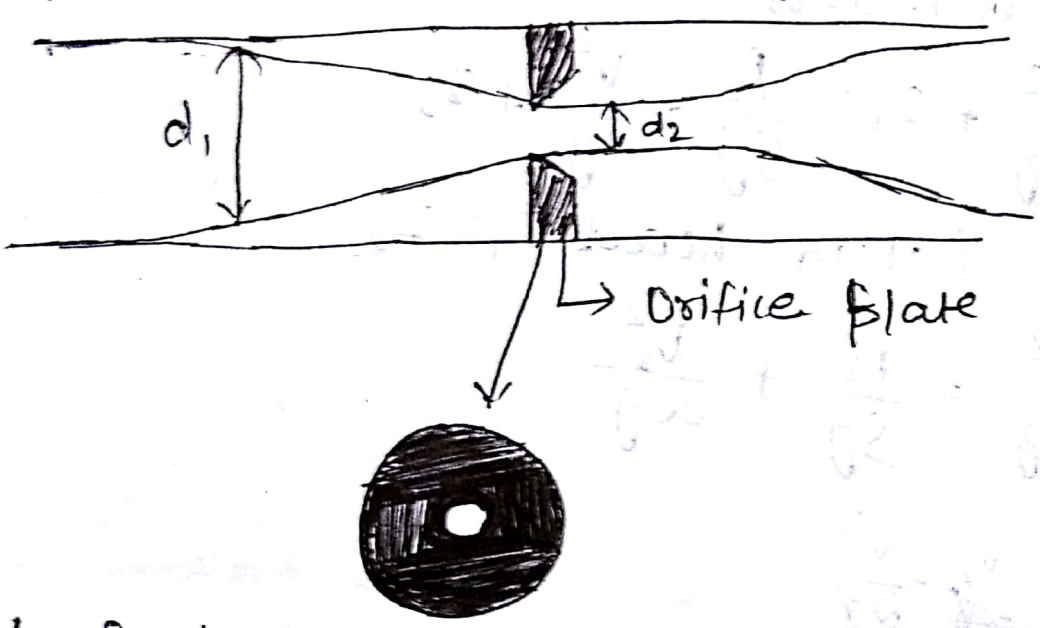
$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

After finding the value of V_2, we can find ~~the value of~~ flow of fluid through passage.

$$\boxed{Q = A_2 V_2}$$

(ii) Orificemeter

In orificemeter, an orifice plate is placed in the pipe line as shown in figure.



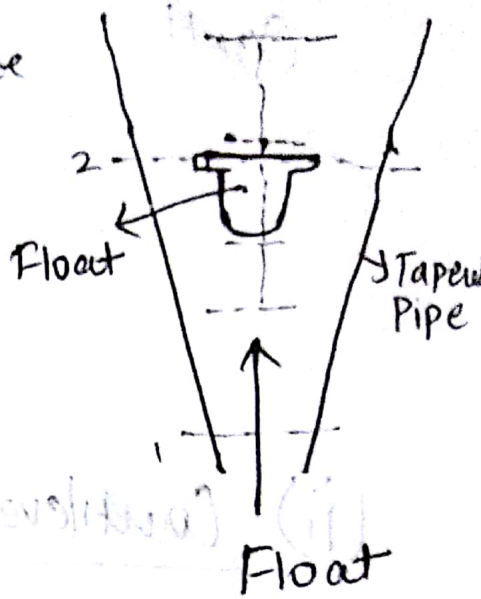
If d_1 & d_2 are the diameters of the pipe line and the orifice opening. Then we have find V_2 by Bernolli's equation:-

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

After finding the value of V_2 we can find Flow by $\boxed{Q = A_2 V_2}$

(iii) Rotameter

→ Rotameter is only used for vertical pipeline. It is less accurate than that of other flow meter. On this the vertical pipe is tapered. Flow of fluid is from bottom to the top. There is a cylindrical type metallic float inside the tube. When fluid goes upward with high velocity then float move upward. If velocity of fluid is low then float comes downward. On this case first we find velocity at section 2 by Bernolli's eqn.



$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

After that we find discharge by equation.

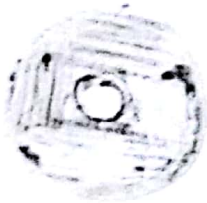
$$\boxed{Q = A_2 V_2}$$

We have to desire this equation for all flowmeters :-

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

For same Datum head $Z_1 = Z_2$

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$



$$\frac{P_1}{\rho g} - \frac{P_2}{\rho g} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

$$\frac{2(P_1 - P_2)}{\rho} = V_2^2 - V_1^2$$

$$\Rightarrow \frac{2(P_1 - P_2)}{\rho} = Q^2\left[\frac{1}{A_2^2} - \frac{1}{A_1^2}\right]$$

$$\Rightarrow Q^2 = \frac{2(P_1 - P_2)}{\rho} \cdot \frac{A_1^2 A_2^2}{A_1^2 - A_2^2}$$

$$\Rightarrow Q = \sqrt{\frac{2(P_1 - P_2)}{\rho}} \times \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}}$$

For orificimeter & Rotameter

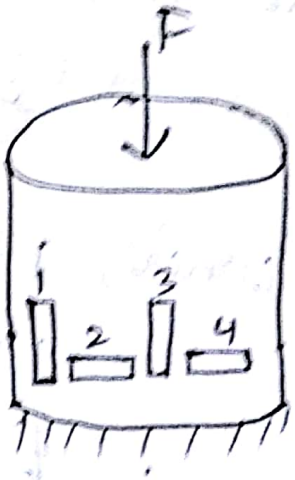
$$\Rightarrow Q = C_d \sqrt{\frac{2(P_1 - P_2)}{\rho}} \times \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}}$$

where C_d = Coefficient of discharge.

Force Measurement :-

(1) Load Cell :-

Force can be measured easily from a load cell. Here two strain gauges are fixed to measure longitudinal strain, while other two measuring the transverse strain. Strain gauge 2 and 4 measure the longitudinal strain.



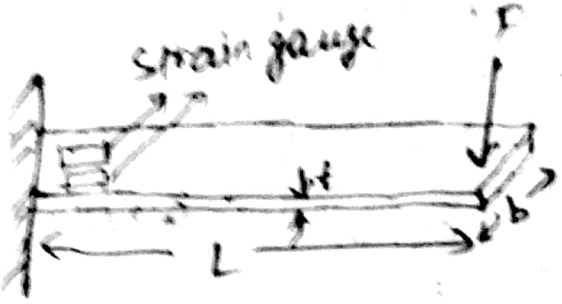
$$\varepsilon_1 = \frac{-F}{AE}$$

Strain gauge 1 and 3 measure the transverse strain.

$$\varepsilon_2 = +\frac{\nu F}{AE}$$

where ν = Poisson's ratio
F = Force applied
A = C/S Area
E = Modulus of Elasticity of material.

(ii) Cantilever Beam:



→ Cantilever Beam can be used for measurement upto 10 kg of weight. One end of cantilever beam is fixed and other is free as shown in figure. Strain gauge are used to measure the strain. By the help of strain we can find force applied on the cantilever.

$$\varepsilon = \frac{6FL}{Ebt^2}$$

where, F = Force applied on cantilever beam
L = Length of Cantilever beam
E = Modulus of Elasticity of material
b = width of cantilever beam
t = thickness of cantilever beam.