LECTURES NOTE

ON

HYDRAULICS & IRRIGATION ENGINEERING

FOR

3RD SEMESTER DIPLOMA CIVIL ENGG.

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QUALIFICATION: BTECH IN CIVIL ENGINEERING

HYDROSTATIC

Hydrostatic is the branch of fluid mechanics that studied about the fluid at rest where the fluid are at rest or in equilibrium condition. Here the pressure exerted by liquid at rest.

PROPERTIES OF FLUID &THEIR USES

DENSITY : -

Density is the amount of matter in a given volume and is defined as mass per unit volume. It is denoted as 'ρ' . And it's unit is kg/m^3 or gm/cm^3.

$$\rho = \frac{\text{mass}}{\text{volume}} = \frac{M}{V}$$

SPECIFIC GRAVITY : -

The ratio of a material density with that of water at 4°C. It has no unit. And is denoted by 'g' .

$$g = \frac{\text{density of any fluid}}{\text{density of water at 4°C}} = \frac{\rho}{\rho_w}$$

SURFACE TENSION : -

Surface tension is the elastic tendency of a fluid surface which makes it acquire the least surface area possible. At liquid air interfaces surface tension results from the greater attraction of liquid molecules to each other (due to cohesion) than to the molecules in the air (due to adhesion). It is represented by 'σ' and it's unit is KN/m .

For Droplet, $\sigma = \frac{pd}{4}$

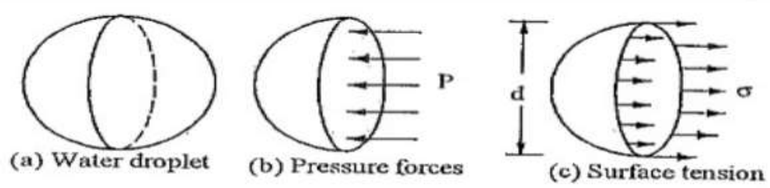


Fig 1.4 Forces on droplet.

Pressure force exerted on the area $\frac{\pi}{4}d^2$ is $= p \times \frac{\pi}{4}d^2$

For Soap bubble, $\sigma = \frac{pd}{8}$

$$p \times \frac{\pi}{4} d^2 = 2 \times (\sigma \times \pi d)$$

$$p = \frac{2\sigma \times \pi d}{\frac{\pi}{4} d^2}$$

$$\boxed{p = \frac{8\sigma}{d}}$$

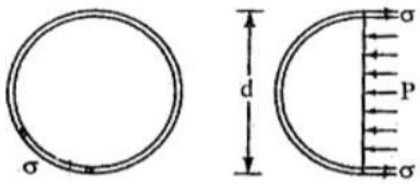


Fig 1.5 Forces on soap bubble

For liquid jet , $\sigma = \frac{pd}{2}$

$$p \times l \times d = \sigma \times 2l$$

$$\boxed{p = \frac{2\sigma}{d}}$$

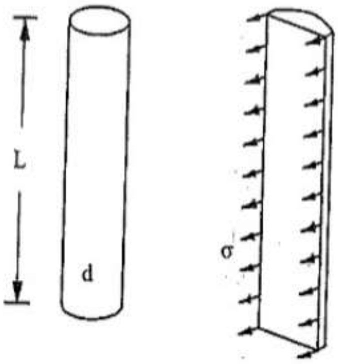


Fig 1.6 Forces on liquid jet

Where p = pressure intensity

d = diameter of small spherical droplet

CAPILLARITY : -

It is defined as the tendency of a liquid in a capillary tube or absorbent material to rise or fall as a result of surface tension.

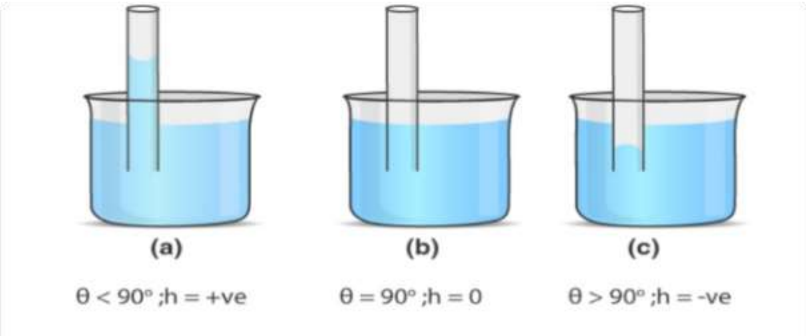
$$h = \frac{4\sigma\cos\phi}{wd}$$

Where σ = surface tension

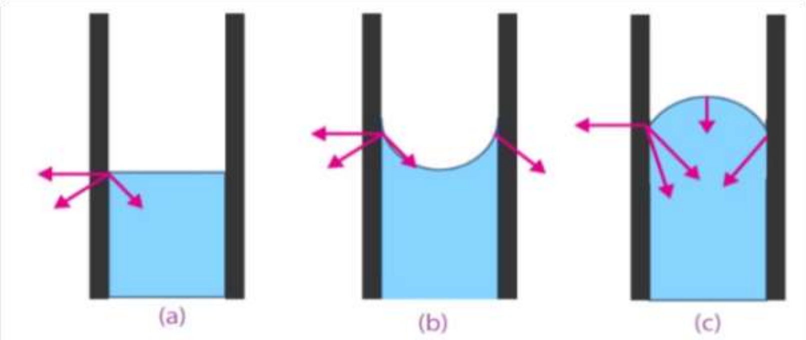
w = weight of liquid

ø = contact angle

d = diameter of capillary



Capillary with respect to angle at centre



VISCOSITY : -

The viscosity of a fluid is a measure of it's resistance to gradual deformation by shear stress or tensile stress. Viscosity is a measure of a fluid's resistance to flow.

There may be two types of viscosity.

1) Kinematic viscosity (v)

$$v = \frac{\mu}{\rho}$$

Where v = kinematic viscosity

μ = dynamic viscosity

ƒ = density of fluid

2) Dynamic viscosity(μ)

$$\tau = \mu \frac{du}{dy}$$

Where τ = shear stress

μ = dynamic viscosity

$\frac{du}{dy}$ = rate of shear deformation

SPECIFIC WEIGHT : -

It is defined as the ratio of total weight of fluid by unit volume. It is denoted as ‘w’. It’s unit is KN/m^3 or N/m^3.

$$w = \frac{Weight}{Volume} \quad \text{or} \quad w = ƒg$$

SPECIFIC VOLUME : -

It is the inverse of density, i.e the ratio of volume of fluid to it’s mass. It is denoted by ‘v’ . It’s unit is m^3/N.

$$v = \frac{Volume}{mass} \quad \text{or} \quad v = \frac{1}{ƒ}$$

Q. Calculate the specific gravity, weight, density of one litre of a liquid which weight 7N.

Ans:- Volume = 1 litre

Weight (W) = 7N

Specific weight (ω) = $\frac{Weight}{volume} = \frac{7}{1} = \frac{7 \times 10^{-3} kN}{1 \times 10^{-3} m^3}$

$= 7 kN/m^3$ or $= 7000 N/m^3$

$1 lit = \frac{1}{1000} m^3 = 0.001 m^3 = 10^{-3} m^3$

$1 kN = 10^3 N$

$1 N = 10^{-3} kN$

Density (ρ) = $\frac{w}{g} = \frac{7000}{9.81} = 0.71 kg/m^3 = 713.55 kg/m^3$

$1 kg = 9.81 N$

Specific gravity (G) = $\frac{\rho}{\rho_\omega} = \frac{713.55}{1000} = 0.71$

Q. Calculate the density, specific weight and weight of one litre of petrol of specific gravity = 0.7

Ans:- $V = 1 litre = 10^{-3} m^3$

$G = 0.7$

~~⇒ 0.7~~ - $G = \frac{\rho}{\rho_\omega}$

$\Rightarrow \rho = G \rho_\omega = 0.7 \times 1000 = 700 kg/m^3$

$\omega = \rho g$

$= 700 \times 9.81$

$= 6867 N/m^3$

$\omega = \frac{W}{V}$

$\Rightarrow W = \omega . V$

$= 6867 \times 10^{-3}$

$= 6.867 N$

Q. If the velocity distribution over a plate is given by $u = \frac{2}{3}y - y^2$ in which u is the velocity in m/sec. at a distance y metre above the plate, determine the shear stress at $y=0$ & $y = 0.15 m$. Take dynamic viscosity of fluid as 8.63 poises.

Unit

Kinematic - ν - stoke, m^2/s

Dynamatic - μ - Poise, NS/m^2

Ans :- Given data,

$u = \frac{2}{3}y - y^2$

$y = 0$, $y = 0.15m$

$\mu = 8.63$ poise

$\tau = ?$

1 Poise $= \frac{1}{10}$ $NS/m^2 = 10^{-1}$

1 Stoke $= 10^{-4} m^2/s$

poise 8.63×10^{-1}

$= 0.863 NS/m^2$

$u = \frac{2}{3}y - y^2$

differenciate both side w.r.t y

$\frac{d}{dx}c = 0$

$\frac{d}{dx}x = 1$

$\frac{d}{dx}x^n = n.x^{n-1}$

$$\frac{du}{dy} = \frac{d}{dy}\left(\frac{2}{3}y - y^2\right)$$

$$\Rightarrow \frac{du}{dy} = \frac{d}{dy}\frac{2}{3}y - \frac{d}{dy}y^2$$

$$\Rightarrow \frac{du}{dy} = \frac{2}{3}\frac{dy}{dy} - \frac{dy^2}{dy}$$

$$= \frac{2}{3}\cdot 1 - 2\cdot y^{2-1}$$

$$= \frac{2}{3} - 2y$$

$$\left.\frac{du}{dy}\right]_{y=0} = \frac{2}{3} - 2\cdot 0$$

$$= \frac{2}{3} = 0.667$$

$$\left.\frac{du}{dy}\right]_{y=0.15} = \frac{2}{3} - 2 \times 0.15$$

$$= 0.667 - 0.3$$

$$= 0.367 \text{ per sec.}$$

$$\tau = \mu \cdot \frac{du}{dy}$$

$= 0.863 \times 0.667$ when $\frac{du}{dy} = 0.667$

$= 0.575\ N/m^2$

$$\tau = \mu \cdot \frac{du}{dy}$$

$= 0.863 \times 0.367$ when $\frac{du}{dy} = 0.367$

$= 0.316\ N/m^2$

Q. Determine the viscosity of a liquid having kinematic viscosity 6 stokes & specific gravity 1.9.

Ans:- Given data,

$G = 1.9$

$\nu = 6$ stokes

$= 6 \times 10^{-4} m^2/s$

$\nu = \frac{\mu}{\rho}$

$\rho = G.\rho_w$

$= 1.9 \times 1000$

$= 1900 kg/m^3$

$\nu = \frac{\mu}{\rho}$

$\Rightarrow \mu = \nu \times \rho = 6 \times 10^{-4} \times 1900$

$= 1.14$ ~~Nm/s²~~ Ns/m^2

$\mu = 1.14 Ns/m^2$

$= 1.14 \times 10$

$= 11.4$ Poise

Q. Determine the viscosity of a liquid having kinematic viscosity 3 stokes & specific gravity 0.7.

Ans:- Given data,

$G = 0.7$

$\nu = 3$ stokes

$= 3 \times 10^{-4} m^2/s$

We know, $\nu = \frac{\mu}{\rho}$

$\rho = G\rho_w$

$= 0.7 \times 1000$

$= 700 kg/m^3$

$\nu = \frac{\mu}{\rho}$

$\Rightarrow \mu = \nu \times \rho = 3 \times 10^{-4} \times 700 = 0.21 Ns/m^2$

$\mu = 0.21 Ns \times m^2$

$= 0.21 \times 10$

$= 2.1$ Poise

Q. Determine the specific gravity of fluid having viscosity 0.05 poise & kinematic viscosity 0.035 ~~poi~~ stokes.

Ans:- $\nu = 0.035$ stoke $= 0.035 \times 10^{-4}\ m^2/s$

$\mu = 0.05$ Poise $= 0.05 \times 10^{-1}\ Ns/m^2$

$G = ?$

$$\nu = \frac{\mu}{\rho}$$

$$\Rightarrow 0.035 \times 10^{-4} = \frac{0.05 \times 10^{-1}}{\rho}$$

$$\Rightarrow \rho = \frac{0.05 \times 10^{-1}}{0.035 \times 10^{-4}} = 1428.57\ kg/m^3$$

$$G = \frac{\rho}{\rho_w}$$

$$= \frac{1428.57}{1000}$$

$$= 1.428$$

Q. Find the kinematic viscosity of an oil having density 981 kg/m³. The shear stress at a point in oil is 0.2452 N/m² and velocity gradient at that point is 0.2 per second.

Ans:- $\rho = 981\ kg/m^3$

$\tau = 0.2452\ N/m^2$

$\frac{du}{dy} = 0.2$ per second

$\nu = ?$

We know, $\tau = \mu \frac{du}{dy}$

$$\Rightarrow 0.2452 = \mu \times 0.2$$

$$\Rightarrow \mu = \frac{0.2452}{0.2} = 1.226\ Ns/m^2$$

$$\nu = \frac{\mu}{\rho}$$

$$= \frac{1.226}{981}$$

$$= 1.249 \times 10^{-3}\ m^2/s$$

$1.249 \times 10^{-3} \times 10^{4}$

$= 12.49$

Q. A flat plate of area $1.5 \times 10^{6}\ mm^2$ is pulled with a speed of 0.4 m/s relative to another plate located at a distance of 0.15 mm from it. Find the force and power required to maintain this speed, if the ~~field~~ fluid separating them is having viscosity as 1 Poise.

Ans:- Given data,

$A = 1.5 \times 10^{6}\ mm^2 = 1.5 \times 10^{6} \times 10^{-6}\ m^2$

$u = 0.4\ m/s$

$y = 0.15\ mm$

$F = ?$

$P = ?$

$\mu = 1\ \text{Poise} = 1 \times 10^{-1}\ Ns/m^2$

$\tau = \mu \dfrac{du}{dy}$ $\quad du = u - 0 = 0.4 - 0 = 0.4\ m/s$ $\quad dy = 0.15$

$\Rightarrow \tau = 1 \times 10^{-1} \dfrac{0.4}{0.15 \times 10^{-3}}$

$= 266.67\ N/m^2$

$F = \tau \times A$

$= 266.67 \times 1.5 \times 10^{6} \times 10^{-6}$

$= 400.005$

$= 400\ N$

$P = F \times V$

$= 400 \times 0.4 = 160$ watt

Q. A plate 0.025 mm distant from a fixed plate moves at 60cm/s and requires a forces of 2N per unit area i.e $2 N/m^2$ to maintain this speed. Determine the fluid viscosity between the plates.

Ans:- Given data,

$$F = 2 N/m^2$$

$$y = 0.025 \text{ mm} = 0.025 \times 10^{-3} m$$

$$u = 60 cm/s = 0.6 m/s$$

We know, $\tau = \mu \frac{du}{dy}$

Where τ = force per unit area

$= 2 N/m^2$

$\tau = \mu \frac{du}{dy}$ $\quad du = u - 0 = 0.6 - 0 = 0.6 m/s$ $\quad dy = 0.025 \times 10^{-3}$

$$\Rightarrow 2 = \mu \frac{0.6}{0.025 \times 10^{-3}}$$

$$\Rightarrow \mu = \frac{2 \times 0.025 \times 10^{-3}}{0.6}$$

$$= 8.33 \times 10^{-5} Ns/m^2$$

$$= 8.33 \times 10^{-5} \times 10$$

$$= 8.33 \times 10^{-4} \text{ Poise (Ans)}$$

Q. The velocity distribution for flow over a flat plate is given by $u = \frac{3}{4} y - y^2$ in which u is the velocity in metre per second at a distance y metre above the plate. Determine the shear stress at $y = 0.15$m. Take dynamic viscosity of fluid as 8.6 poise.

Ans:- Given data,

$$u = \frac{3}{4} y - y^2$$

$$y = 0.15 m$$

$$\mu = 8.6 \text{ poise}$$

$$\tau = ?$$

differentiate both side w.r.t y

$$\frac{du}{dy} = \frac{d}{dy}\left(\frac{3}{4}y - y^2\right)$$

$$\Rightarrow \frac{du}{dy} = \frac{3}{4}\frac{d}{dy}y - \frac{d}{dy}y^2$$

$$= \frac{3}{4}\cdot 1 - 2y^{2-1}$$

$$= \frac{3}{4} - 2y$$

$$\left.\frac{du}{dy}\right]_{y=0.15} = \frac{3}{4} - 2\times 0.15$$

$$= 0.75 - 0.3$$

$$= 0.45 \text{ Per sec.}$$

$$\tau = \mu \cdot \frac{du}{dy}$$

$$= ~~8.6 \times 0.45~~ \; 0.86 \times 0.45$$

$$= 0.387 \text{ N/m}^2 \quad \text{(Ans)}$$

Q. Find out the kinematic viscosity of fluid if its dynamic viscosity is 1.14 NS/m^2 and its specific gravity is 1.9.

Ans:- $\mu = 1.14 \, NS/m^2$

$G = 1.9$

$\nu = ?$

$$\nu = \frac{\mu}{\rho}$$

We know, $G = \frac{\rho}{\rho_w}$

$$\Rightarrow \rho = G\rho_w$$

$$= 1.9 \times 1000$$

$$= 1900 \, kg/m^3$$

$$\nu = \frac{\mu}{\rho}$$

$$\Rightarrow \nu = \frac{1.14}{1900} = 6 \times 10^{-4} \, m^2/s$$

Q. Calculate the specific weight, density and specific gravity of 2.5 litre of a liquid which weights 15N.

Ans:- volume = 2.5 litre

weight (W) = 15N

Specific weight (w) $= \frac{W}{V} = \frac{15}{2.5} = \frac{15 \times 10^{-3} \, kN}{2.5 \times 10^{-3} m^3} = 6000 N/m^3$

Density (ρ) $= \frac{w}{g} = \frac{6000}{9.81} = 611.62 \, kg/m^3$

Specific gravity (G) $= \frac{\rho}{\rho_w} = \frac{611.62}{1000} = 0.61$

Q. If the velocity distribution of a fluid over a plate is given by $u = \frac{3}{4}y - y^2$ where u is the velocity in metres per second at a distance of y metres above the plate. Determine the shear stress at $y = 0.15$ metre. Take Dynamic viscosity of a fluid as 8.34×10^{-4} NS/m².

Ans:- Given data, $u = \frac{3}{4}y - y^2$

$y = 0.15 \, m$

$\mu = 8.34 \times 10^{-4} \, NS/m^2$

$\tau = ?$

differentiate both side w.r.t y

$$\frac{du}{dy} = \frac{d}{dy}\left(\frac{3}{4}y - y^2\right)$$

$$\Rightarrow \frac{du}{dy} = \frac{3}{4}\frac{d}{dy}y - \frac{d}{dy}y^2$$

$$= \frac{3}{4} \times 1 - 2y^{2-1}$$

$$= \frac{3}{4} - 2y$$

$$\left.\frac{du}{dy}\right]_{y=0.15} = \frac{3}{4} - 2 \times 0.15$$

$$= 0.75 - 0.3$$

$$= 0.45 \text{ Per sec.}$$

$$\tau = \mu \frac{du}{dy}$$

$$= 8.34\times10^{-4}\times 0.45$$

$$= 3.753\times10^{-4}\ N/m^2 \text{ (Ans)}$$

Q. The velocity distribution for flow over a flat plate is given by $u = \frac{3}{2}y - y^{3/2}$, where u is the point velocity in metre per second at a distance 'y' metre above the plate. Determine the sheare stress at $y = 9cm$. Assume dynamic viscosity as 8 poise.

Ans:- Given data,

$u = \frac{3}{2}y - y^{3/2}$

$y = 9\,cm = 0.09\,m$

$\mu = 8$ Poise $= 8\times10^{-1} = 0.8\ Ns/m^2$

$\tau = ?$

differentiate both side w.r.t y

$$\frac{du}{dy} = \frac{d}{dy}\left(\frac{3}{2}y - y^{3/2}\right)$$

$$\Rightarrow \frac{du}{dy} = \frac{3}{2}\cdot\frac{d}{dy}y - \frac{d}{dy}y^{3/2}$$

$$= \frac{3}{2}\cdot 1 - \frac{3}{2}y^{\frac{3}{2}-1}$$

$$= \frac{3}{2} - \frac{3}{2}y^{0.5}$$

$$\left.\frac{du}{dy}\right]_{y=0.09} = \frac{3}{2} - \frac{3}{2}\times 0.09^{0.5}$$

$$= 1.05 \text{ per sec.}$$

$$\tau = \mu \frac{du}{dy}$$

$$= 0.8\times 1.05$$

$$= 0.84\ N/m^2 \text{ (Ans)}$$

Q. An unknown fluid in a 1 liter beaker has a mass of 3kg. Determine the density, the specific volume, the specific weight, and the specific gravity of the fluid.

Ans:- Given data,

$m = 3kg$

$V = 1\,litre = 0.001 m^3$

Density $(\rho) = \frac{m}{V} = \frac{3}{0.001} = 3000 kg/m^3$

Specific volume $(v) = \frac{1}{3000} = 3.33 \times 10^{-4} m^3/kgN$

Specific weight $(w) = \rho g$

$= 3000 \times 9.81$

$= 29430 N/m^3$

Specific gravity $(g) = \frac{\rho}{\rho_w} = \frac{3000}{1000} = 3$

Q. A liquid poured into a graduated cylinder is found to weight 8N when occupying a volume of 500ml. Calculate its Density, specific weight and specific gravity.

Ans:- Given data, $W = 8N$

$V = 500ml. = 500 \times 10^{-6} m^3$

$\rho = \frac{W}{V} = \frac{8}{500 \times 10^{-6}} = 16000 N/m^3 = 1600 KN/m^3$

Specific weight $(w) = \rho g = 1600 \times 9.81 = 15696 N/m^3$

Specific gravity $(g) = \frac{\rho}{\rho_w} = \frac{1600}{1000} = 1.6$

Q. The space between two square flat parallel plates is filled with oil. Each side of the plate is 60 cm. The thickness of the oil film is 12.5 mm. The upper plate, which moves at 2.5 metre per sec. requires a force of 98.1 N to maintain the speed. Determine the dynamic viscosity of the oil and the kinematic viscosity of the oil if the spacific gravity of the oil is 0.95.

Ans:- $G = 0.95$

$F = 98.1\ N$ $\qquad \tau = \frac{F}{A} = \frac{98.1}{0.36}$

$u = 2.5\ m/s$

$dy = 12.5\ mm = 12.5 \times 10^{-3}\ m$

Each side of square plate = 60 cm = 0.6 m

$A = 0.6 \times 0.6 = 0.36\ m^2$

$$\tau = \mu \frac{du}{dy}$$

$$\Rightarrow \frac{98.1}{0.36} = \mu \frac{2.5}{12.5 \times 10^{-3}}$$

$$\Rightarrow \mu = \frac{98.1 \times 12.5 \times 10^{-3}}{0.36 \times 2.5}$$

$= ~~2.4905~~\ Ns/m^2$
1.3635

$\mu = ~~0.4905\ Ns/m^2~~\ 1.3635\ Ns/m^2$

$= ~~0.4905 \times 10~~ \qquad = 1.3635 \times 10$

$= ~~4.9\ Poise~~ \qquad = 13.63\ Poise$

$\nu = \frac{\mu}{\rho}$

$\rho = G \rho_w$

$= 0.95 \times 1000$

$= 950$

$$\nu = \frac{\mu}{\rho} = \frac{1.3635}{950} = 1.435 \times 10^{-3}\ m^2/s$$

$\nu = 1.435 \times 10^{-3} \times 10^{4}$

$= 14.35$ stoke

Q. Calculate the capillary rise in a glass tube of 2.5mm diameter when immersed vertically in (a) water and (b) mercury. Take surface tension $\sigma = 0.0725$ N/m for water & $\sigma = 0.52$ N/m for mercury in contact with air. The specific gravity for mercury is given as 13.6 & angle of contact $= 130^\circ$.

Ans:- $\theta = 130^\circ$

$\sigma = 0.52$ N/m

$d = 2.5mm = 2.5 \times 10^{-3}$ m

σ for water $= 0.0725$ N/m

$G = 13.6$

$\rho = G\rho_w = 13.6 \times 1000 = 13600$ kg/m^3

For mercury, at angle of contact

$$h_m = \frac{4\sigma\cos\theta}{\rho g d}$$

$$= \frac{4 \times 0.52 \times \cos(130)}{13600 \times 9.81 \times 2.5 \times 10^{-3}}$$

$= -4.00 \times 10^{-3}$ mm

$= -0.004$ m

$= -0.4$ cm

For water,

$$h_w = \frac{4\sigma}{\rho g d}$$

$$= \frac{4 \times 0.0725}{1000 \times 9.81 \times 2.5 \times 10^{-3}}$$

$= 0.011$ m

$= 1.1$ cm

Q. Find out the minimum size of glass tube that can be used to measure water level if the capillary rise in the tube is to be restricted to 2mm. Consider surface tension of water in contact with air as 0.073575 N/m.

Ans:- $\sigma = 0.073575$ N/m

$h = 2mm$

density of water (ρ) = 1000kg/m^3

$\theta = 0$

$$h = \frac{4\sigma\cos\theta}{\rho g d} \Rightarrow 2 = \frac{4\times0.073575}{1000\times9.81\times d}$$

$$\Rightarrow d = \frac{4\times0.073575}{1000\times9.81\times2\times10^{-3}}$$

$= 0.015$ m

$= 15$mm

$= 1.5$ cm (Ans)

Q. The surface tension of water in contact with air at 20°c is 0.0725 N/m liquid jet. sure inside a droplet of water is to be 0.02 N/cm² greater than the outside pressure. Calculate the dia. of the droplet of water.

$\sigma = 0.0725$ N/m

$P = 0.02$ N/cm^2 $= 0.02\times10^4$ N/m^2

$\sigma = \frac{Pd}{4}$

$$\Rightarrow 0.0725 = \frac{0.02\times10^4\times d}{4}$$

$$\Rightarrow d = \frac{0.0725\times4}{0.02\times10^4}$$

$= 1.45\times10^{-3}$m $= 1.45$mm

$1m = 10^2 cm$

$1m^2 = 10^4 cm^2$

$1cm^2 = \frac{1}{10^4}m^2$

$= 10^{-4}m^2$

$1m = 10^3 mm$

Q. Find the surface tension in a soap bubble of 40mm dia. when the inside pressure is 2.5 N/m^2 above atmospheric pressure.

Ans:- $d = 40mm = 40 \times 10^{-3} m$

$P = 2.5 N/m^2$

$\sigma = ?$

$\sigma = \frac{Pd}{8} = \frac{2.5 \times 40 \times 10^{-3}}{8} = 0.0125 N/m$

Q. The pressure outside the droplet of water of dia. 0.04 mm is 10.32 N/cm^3 (atmospheric pressure). Calculate the Pressure within the droplet if surface tension is given as 0.0725 N/m of water

Ans:- $d = 0.04mm = 0.04 \times 10^{-3} m$

$P(outside) = 10.32 N/cm^2 = 10.32 \times 10^4 N/m^2$

$\sigma = 0.0725 N/m$

$P_{inside} = ?$

$\sigma = \frac{Pd}{4}$

$\Rightarrow P = \frac{4\sigma}{d}$

$= \frac{4 \times 0.0725}{0.04 \times 10^{-3}}$

$= 7250 N/m^2$

Total p of droplet $= 7250 + (10.32 \times 10^4 = 110450 N/m^2$

$= 11.0450 N/cm^2$

nuble.

Q. Calculate the capillary effect in millimeteres in a glass tube of 4mm dia., when immersed ~~vertically~~ in (i) water & (ii) mercury. The temp. of the liquid is 20°c & the values of the surface tension of water and mercury at 20°c in contact with air are 0.073575 N/m & 0.51 N/m respectively. The angle of contact for water is zero that for mercury 130°. Take density of water at 20°c as equal to 998 kg/m³

Ans:- Given data,

$d = 4mm = 4\times10^{-3} m$

where $h = \frac{4\sigma \cos\theta}{\rho \times g \times d}$

a) Capillary effect for water,

$\sigma = 0.073575 \ N/m, \ \theta = 0°$

$\rho = 998 \ kg/m^3$ at 20°c

$h = \frac{4\times0.073575\times\cos 0°}{998\times9.81\times4\times10^{-3}} = 7.51\times10^{-3}$

$= 7.51 \ mm$

b) Capillary effect for mercury:-

$\sigma = 0.51 \ N/m; \ \theta = 130°$

$\rho = 13.6\times1000 = 13600 \ kg/m^3$

$h = \frac{4\times0.51\times\cos 130°}{13600\times9.81\times4\times10^{-3}}$

$= -2.46\times10^{-3} m$

$= -2.46 mm$

Q. The capillary rise in the glass tube is not to exceed 0.2mm of water. Determine its minimum size, given that surface tension for water in contact with air = 0.0725 N/m.

$h = 2\,mm$

$d = ?$

$\sigma = 0.0725$ N/m (for water)

$\theta = 0$

$$h = \frac{4\sigma\cos\theta}{wd}$$

$$\Rightarrow d = \frac{4\sigma\cos\theta}{wh}$$

$$= \frac{4 \times 0.0725}{9810 \times 2 \times 10^{-3}}$$

$$= 0.014\,m$$

$$= 14\,mm$$

PRESSURE AND IT'S MEASUREMENT

PRESSURE:-

Pressure is defined as the force per unit area that a fluid exerts on it's surrounding. It is denoted by 'P' & it's unit is pascal(N/m^2).

$$P = \rho g h$$

INTENSITY OF PRESSURE:-

Intensity of pressure can be defined as the pressure at a point.

$$\text{Intensity of pressure} = p = \frac{\text{pressure}}{\text{area}} = \frac{P}{A}$$

TYPES OF PRESSURE:-

1) Absolute Pressure
2) Atmospheric Pressure
3) Gauge Pressure
4) Vaccum Pressure

ABSOLUTE PRESSURE:-

The clearest reference pressure is the zero pressure, which exists in the air free space of the universe. A pressure which is related to this reference pressure is known as absolute pressure.

ATMOSPHERIC PRESSURE:-

The atmospheric pressure exerted by the weight of atmosphere.

GAUGE PRESSURE:-

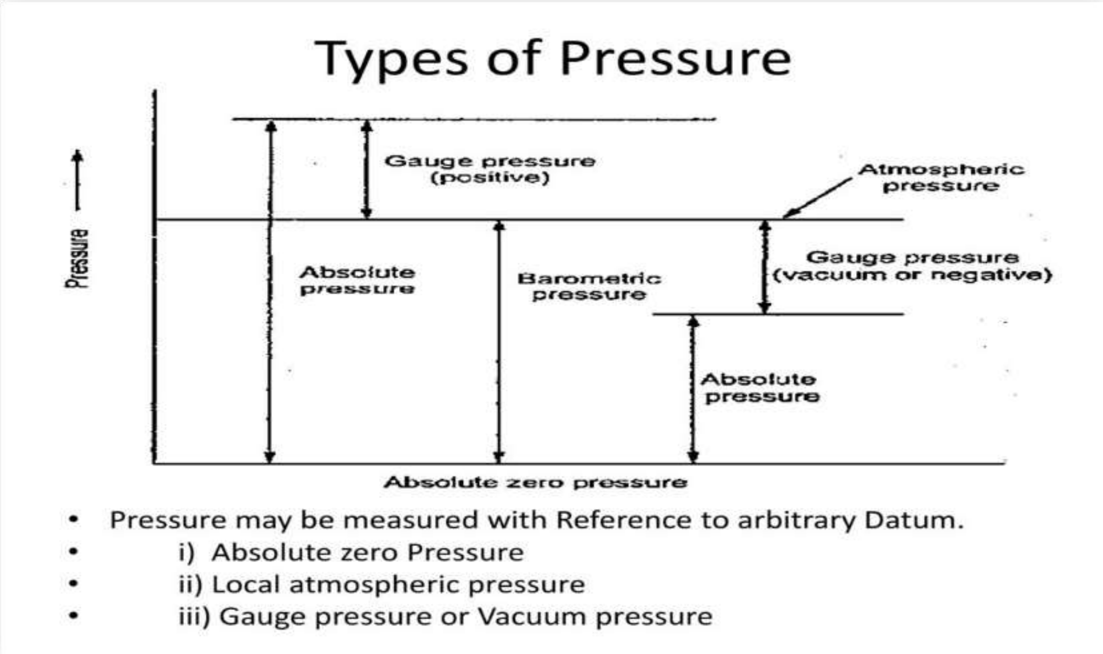
Gauge pressure is zero referenced against ambient air pressure. So it is equal to absolute pressure minus atmospheric pressure.

A gauge is often used to measure the pressure difference between a system & the surrounding atmosphere.

VACCUM PRESSURE:-

The pressure is measured below standard atmospheric pressure. That is called vaccum pressure.

RELATIONSHIP BETWEEN ATMOSPHERIC PRESSSURE, ABSOLUTE PRESSURE, GAUGE PRESSURE & VACCUM PRESSURE:-



$$P_{gauge} = P_{absolute} - P_{atmospheric}$$

$$P_{vaccum} = P_{atmospheric} - P_{absolute}$$

PRESSURE HEAD:-

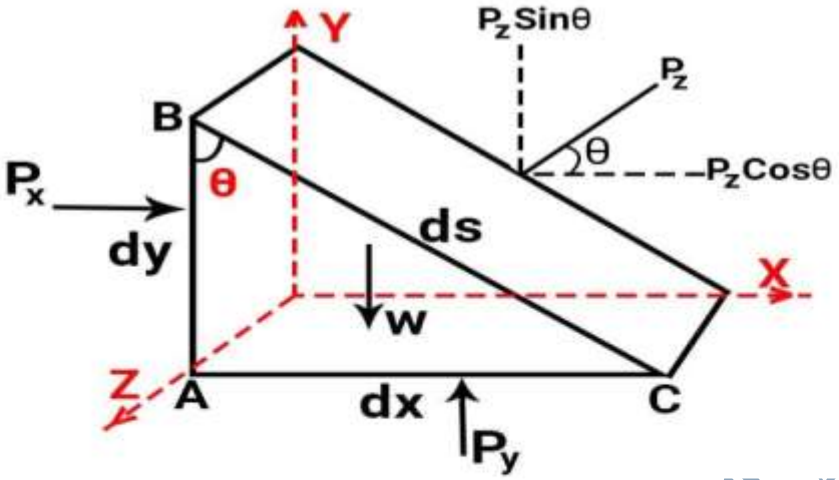
In fluid mechanics, pressure head is the internal energy of a fluid due to the pressure exerted on it's container.

PRESSURE GAUGE:-

Pressure measurement is the analysis of an applied force by a fluid on a surface. Instruments used to measure & display pressure in an integral unit are called pressure gauge or vaccum gauge.

PASCAL LAW:-

This law states that the pressure is acted on a body is equal in all direction. i.e, $P_X = P_y = P_z$



Let the thickness of membrane is a unity.

$$\sin\theta = \frac{dx}{dz}$$

$$dx = dz.\ \sin\theta$$

$$\cos\theta = \frac{dy}{dz}$$

$$dy = dz.\ \cos\theta$$

Consider the pressure in X-axis.

$F_X = P_Y*dx*1 = P_Y.dx$ (↑)

Consider the pressure in Y-axis.

$F_Y = P_X*dy*1 = P_X.dy$ (→)

Consider the pressure in Z-axis.

$F_X = P_Z*\cos\theta*dz*1 = P_Z.dy$ (←) (where $dy = dz.\cos\theta$)

$F_Y = P_Z*\sin\theta*dz*1 = P_Z.dx$ (↓) (Where $dx = dz.\sin\theta$)

By equilibrium condition,

Upward pressure = Downward pressure

$P_Y.dx = P_Z.dx$

$P_Y = P_Z$

Leftward pressure = Rightward pressure

$P_Z.dy = P_X.dy$

$P_Z = P_X$

$P_X = P_Y = P_Z$

Q. A hydraulic press has a ram of 30cm diameter and a Plunger of 4.5 cm dia. Find the weight lifted by the hydraulic press when the force applied at the plunger is 500N.

Ans:- Force of plunger $F = 500N$

Area of plunger $A = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 4.5^2 = 15.90 cm^2$

Pressure intensity of plunger $= \frac{F}{A} = \frac{500}{15.90} = 31.44 \, N/cm^2$

According to pascal law the pressure intensity of fluid is equal in all direction.

Hence, Pressure intensity of plunger on fluid is equal to Pressure intensity of fluid in ram.

Pressure intensity of ram $= 31.44 \, N/cm^2$

$\Rightarrow \frac{W}{A} = 31.44$

Area of ram $= \frac{\pi}{4} \times d^2$

$= \frac{\pi}{4} \times 30^2$

$= 706.85 cm^2$

$\frac{W}{706.85} = 31.44$

$\Rightarrow W = 706.85 \times 31.44$

$= 22223.364 N$

$= 22.223 N$

Q. A hydraulic press has a ram of 20cm diameter and a plunger of 3cm diameter. It is used for lifting a weight of 30KN. Find the force required at the plunger.

Given data,

Ans:- dia of ram = 20cm

Area of ram $= \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 20^2 = 314.15$

dia of plunger = 3cm

Area of plunger $= \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 3^2 = 7.06 cm^2$

According to pascal law the pressure intensity of Plunger ~~fluid~~ is equal in all direction.

Hence, pressure intensity of fluid ~~plunger~~ on ram is equal to pressure intensity of fluid on plunger. $W = 30kN$
$= 30 \times 10^3 N$

Pressure intensity of ram $= \frac{W}{A}$

$= \frac{30 \times 10^3}{314.15}$

$= 95.49 N/cm^2$

Pressure intensity of plunger $= \frac{F}{A}$

$= \frac{\text{Pressure intensity} \times \text{A. of plunger}}{\text{Area of ram}}$

$= \frac{30 \times 10^3 \times 7.06}{314.15} = 674.20N$

Q. Calculate the pressure dute to a column of 0.3m of water, (b) an oil of sp. gr. 0.8, and (c) mercury of sp.gr 13.6. Take density of water, $\rho = 1000 kg/m^3$.

Ans:- Given data,

height of liquid column = 0.3m

We know, $P = \rho g h$

$\rho = 1000 kg/m^3$

For water, $P = \rho g h$

$= 1000 \times 9.81 \times 0.3$

$= 2943 N/m^3$

For oil of sp. gr. 0.8

~~$P = \rho g h$~~

~~$= 1000 \times 9.81 \times 0.8$~~

Density of oil $=$ ~~G.f~~ $= 0.8 \times \rho = 0.8 \times 1000 = 800 kg/m^3$

Pressure, $P = \rho g h$

$= 800 \times 9.81 \times 0.3$

$= 2354.4 N/m^2$

For mercury sp.gr. = 13.6

Density = $13.6 \times 1000 = 13600\ kg/m^3$

Pressure = $\rho g h$

$= 13600 \times 9.81 \times 0.3$

$= 40024.8$

Q. The pressure intensity at a point in a fluid is given $3.924 N/cm^2$. Find the corresponding height of fluid when the fluid is (a) water and (b) oil of specific gravity. 0.9.

$P = 3.924 N/cm^2 = 3.924 \times 10^4 m^2$

$h = ?$

$\rho_w = 1000 kg/m^3$

$\rho_o = G \rho_w$

$= 0.9 \times 1000 = 900 kg/m^2$

$P = \rho g h$

$\Rightarrow h = \frac{P}{\rho g}$

height of water $h = \frac{P}{\rho_w g} = \frac{3.924 \times 10^4}{1000 \times 9.81} = 4$

height of oil $h = \frac{P}{\rho_o g} = \frac{3.924 \times 10^4}{900 \times 9.81} = 4.44$

Q. An oil of specific gravity 0.9 is contained in a vessel. At a point the height of oil is 40m. Find the corresponding height of water at the point.

Given data,

Specific gravity (G) = 0.9
height of oil = 40m
Density of oil = 0.9×1000
= 900 kg/m³

$P = \rho g h$

$= 900 \times 9.81 \times 40$

height of water = $\dfrac{P}{\text{Density of water} \times g}$

$= \dfrac{900 \times 9.81 \times 40}{1000 \times 9.81}$

$= 36m$

Q. An open tank container water upto a depth of 2m and above it on oil of sp.gr. 0.9 for a depth of 1m. Find the pressure intensity (i) at the interforce of the two liquids, and (ii) at the buttom of the tank.

Ans:- Given data,

oil of sp.gr. $G_o = 0.9$

$h_o = 1m$

$\rho_o = G_o . \rho_w$

$= 0.9 \times 100 = 900 kg/m^3$

water of $h_w = 2m$

$\rho_w = 1000 kg/m^3$

$g = 9.81 m^2/sec.$

Pressure intensity at interface at both liquid

$P = \rho g h$

$= \rho_o g h_o = 900 \times 9.81 \times 1 = 8829 N/m^2$

Pressure intensity at buttom of the tank

$P = \rho_o g h_o + \rho_w g h_w$

$= 8829 + 1000 \times 9.81 \times 2 = 8829 + 19620 = 28449 N/m^2$

Q. The diameter of a small piston and a large Piston of a hydraulic jack ate 3cm and 10cm respectively. A force of 80N is applied on the small piston. Find the load lifted by the large Piston when:- i) the piston are at the same level
ii) Small piston is 40cm above the large piston
The density of the liquid in the Jack is given as 1000 kg/m³.

Ans:- Given data,

Small piston, dia = 3cm

$A = \frac{\pi}{4} \times 3^2 = 7.06 \, cm^2$

$F = 80N$

Pressure intensity on small piston

$P = \frac{F}{A} = \frac{80}{7.06} = 11.33 \, N/cm^2$

Large piston, dia = 10cm

$A = \frac{\pi}{4} \times 10^2 = 78.53 \, cm^2$

$P = \frac{W}{A}$

$\Rightarrow W = PA = 11.33 \times 78.53 = 889.74 \, N$

ii) When the large piston is act 40cm on the small Piston.

Small piston, d = 3cm

$A = \frac{\pi}{4} \times 3^2 = 7.06 \, cm^2$

$F = 80N$

$P_1 = \frac{F}{A} = \frac{80}{7.06} = 11.33 \, N/cm^2$

Pressure intensity due to water of depth 40cm = 0.4m

$P_2 = \rho g h = 1000 \times 9.81 \times 0.4 = 0.3924 \, N/cm^2$

Total Pressure intensity at buttom level $= P_1 + P_2$

$= 11.33 + 0.3924$

$=$ ~~3938.88~~ N/m²
11.71

$P = \frac{W}{A}$

$\Rightarrow W = P \times A = 11.71 \times 78.53 = 919.58\ N$

Q. What are the gauge pressure and absolute pressure at a point 3m below the free surface of a liquid having a density of $1.53 \times 10^3\ kg/m^3$ if the atmospheric Pressure is equivalent to 750mm of mercury? The Specific gravity of mercury is 13.6 & density of water = $1000\ kg/m^3$.

Ans:-

$\rho = 1.53 \times 10^3\ kg/m^3$

P_{atm} = 750mm of mercury

$h = 750mm = 0.75mm$

$P_{atm} = \rho g h$

$= 13.6 \times 1000 \times 9.81 \times 0.75$

$= 100062\ N/m^2$

$P_{gauge} = \rho g h$

$= 1.53 \times 10^3 \times 9.81 \times 3 = 45027.9\ N/m^2$

Absolute pressure = $P_{atm} + P_{gauge}$

$= 100062 + 45027.9$

$= 145089.9\ N/m^2$

Manometer:-

Q. The right limb of a simple U-tube manometer containing mercury is open to the atmosphere while the left limb is connected to a pipe in which a fluid of sp. gr. 0.9 is flowing. The centre of the pipe is 12cm below the level of mercury in the right limb. Find the pressure of fluid in the pipe if the difference of mercury level in the two limb is 20cm.

Ans:- Given data,

Specific fluid ρ_1 = 0.9

Density of fluid = 0.9×1000 = 900 kg/m³

Sp. gr. of mercury = 13.6

Density of mercury = 13.6×1000 = 13600

Different of mercury level h_2 = 20cm = 0.2 m

Height of liquid h_1 = 20 − 12 = 8 cm = 0.08 m

Equating the pressure, we get,

$$p + \rho_1 g h_1 = \rho_2 g h_2$$

$$\Rightarrow P + 0.9 \times 1000 \times 9.81 \times 0.08 = 13.6 \times 1000 \times 9.81 \times 0.2$$

$$\Rightarrow P + 706.32 = 26683.2$$

$$\Rightarrow P = 25976.88 \ N/m^2$$

Q. A simple U-tube manometer containing mercury is connected to a pipe in which a fluid of sp. gr. 0.8 and having vacuum pressure is flowing. The other end of the manometer is open to atmosphere. Find the vaccum pressure in pipe, if the difference of mercury level in the two limbs is 40cm and the heigh of fluid in the left from the centre of pipe is 15cm below.

Ans:- Given data,

Sp. gr. of fluid = 0.8

Sp. gr. of mercury = 13.6

Density of fluid ρ = 0.8×1000 = 800

Density of mercury ρ = 13.6×1000 = 13600

difference of mercury level h_2 = 40cm = 0.4m

Height of liquid in left limb h_1 = 15 cm = 0.15 m

Equating pressure above datumn, we get,

$$P + \rho_1 g h_1 + \rho_2 g h_2 = 0$$

$$\Rightarrow P = -(\rho_1 g h_1 + \rho_2 g h_2)$$

$$\Rightarrow P = -(0.8 \times 1000) \times 9.81 \times 0.15 + (13.6 \times 1000) \times 9.81 \times 0.4$$

$$= -1177.2 + 53366.4$$

= ~~52,189.2~~

$$= -54543.6 \ N/m^2$$

2. A pipe contains an oil of sp. gr. 0.9. A differential manometer connected at the two points A & B shows a different in mercury level as 15 cm. Find the difference of pressure at the two points.

S:- Given data,

Sp. gr. of oil = 0.9

Density $\rho_1 = 0.9 \times 1000 = 900 \ kg/m^3$

Sp. gr. of mercury = 13.6

Density $\rho_2 = 13.6 \times 1000 = 13600 \ kg/m^3$

Difference in mercury level $h = 15 \ cm = 0.15 \ m$

We know,

$$P_A + \rho_1 g h_1 = P_B + \rho_2 g h_2$$

$$\Rightarrow P_A - P_B = \rho_2 g h_2 - \rho_1 g h_1$$

$$= 13600 \times 9.81 \times 0.15 - 900 \times 9.81 \times 0.15$$

$$= 20012.4 - 1324.35$$

$$= 18688.05 \text{ N/m}^2$$

Q. A differential manometer is connected at the two Points A & B of two pipes as shown in Fig 2.19. The Pipe A contains a liquid of sp. gr. = 1.5 while pipe B contains a liquid of sp. gr. = 0.9. The pressures at A & B are 1 kgf/cm² and 1.80 kgf/cm² respectively. Find the difference in mercury level in the differential manometer.

Ans:- Given data,

Sp. gr. of liquid at A = 1.5

Sp. gr. of liquid at B = 0.9

Density $\rho_1 = 1.5 \times 1000 = 1500$

Density $\rho_3 = 0.9 \times 1000 = 900$

Density $\rho_2 = 13.6 \times 1000 = 13600$

height $h_1 = 2 + 3 = 5$

$h_2 = h$

$h_3 = h + 2$

$P_A = 1 \times 9.81 \times 10^4 = 98100 \text{ N/m}^2$

$P_B = 1.8 \times 9.81 \times 10^4 = 176580 \text{ N/m}^2$

$P_A + \rho_1 g h_1 + \rho_2 g h_2 = P_B + \rho_3 g h_3$

$\Rightarrow P_A + 1500 \times 9.81 \times 5 + 13600 \times 9.81 \times h = P_B + 900 \times 9.81 \times h + 2$

$\Rightarrow 98100 + 73575 + 133416 \times h = 176580 + 8829(h+2)$

$\Rightarrow 171675 + 133416 \times h = 176580 + 8829(h+2)$

$\Rightarrow 133416h - 8829h - 176580 = 171675 + 17658$

$\Rightarrow 124587h = 225$

$\Rightarrow h = \dfrac{22563}{124587} = 0.181m$

PRESSURE EXERTED ON AN IMMERSED SURFACE

TOTAL PRESSURE (F):-

It is defined as the force exerted by a static fluid on a surface either plane or curved when the fluid comes in contact with the surfaces. This force always acts normal to the surface.

F = ƒgAh

RESULTANT PRESSURE:-

The center of pressure is the point where the total sum of a pressure force acts on a body, causing a force to act through that point. The total force vector acting at the center of pressure is the value of resultant pressure.

TOTAL PRESSURE EXERTED ON HORIZONTAL AND VERTICAL SURFACE:-

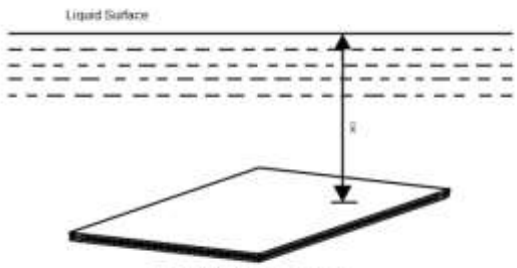


Fig 1: Horizontally Immersed Surface

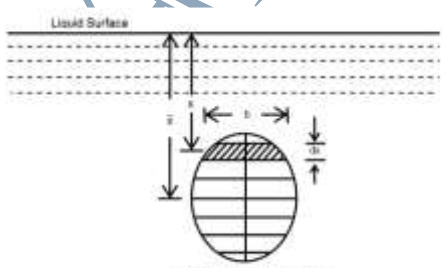


Fig 2 : Vertically immersed surface

TOTAL PRESSURE:-

F = ƒgAh

Where

ƒ = Density

g = Acceleration due to gravity in m/sec^2

A = Area of surface

h = Distance of C.G from free surface of liquid

CENTER OF PRESSURE:-

$$h^* = \frac{I_G}{Ah} + h$$

Where

h^* = Distance of center of pressure from free surface of liquid

I_G = Moment of Inertia about C.G parallel to free suface of liquid

A = Area of Surface

h = Distance of C.G from free surface of liquid

Q. A rectangular plane surface is 2m wide and 3m deep. It lies in vertical plane in water. Determine the total pressure and posistion of centre of pressure on the plane surface when its upper edge is horizontal & (a) coincides with water surface, (b) 2.5m below the free water surface.

Ans:- $\rho = 1000\ kg/m^3$

$g = 9.81\ m/s^2$

$A = 2 \times 3 = 6\ m^2$

$\bar{h}$ = C.G distance $= \frac{d}{2} = \frac{3}{2} = 1.5m$

Case-(i) horizontal surface of rectangular block co-inside with the liquid surface.

$\bar{h} = 1.5m$

Total pressure $= F = \rho g A \bar{h} = 1000 \times 9.81 \times 6 \times 1.5 = 88290\ N$

$= 88.290\ kN$

Centre of pressure (CP) $= h^* = \frac{I_G}{A\bar{h}} + \bar{h}$

$I_G = \frac{bd^3}{12} = \frac{2 \times 3^3}{12} = 4.5\ m^4$

$h^* = \frac{4.5}{6 \times 1.5} + 1.5 = 2m$

Case-(ii) horizontal surface of rectangular block the liquid surface.

$\bar{h} = 2.5 + x = 2.5 + 1.5 = 4m$

Total pressure $= F = \rho g A \bar{h} = 1000 \times 9.81 \times 6 \times 4 = 235440N$

$= 235.44KN$

Centre of pressure (C.P) $= h^* = \frac{4.5}{6 \times 4} + 4 = 4.18m$

Q. Determine the total pressure on a circular plate of diameter 1.5m which is placed vertically in water in such a way that the centre of the plate is 3m below the free surface of water. Find the position of centre of pressure also.

Ans:- $\rho = 1000 kg/m^3$

$g = 9.81 m/s^2$

$A = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 1.5^2 = 1.76 m^2$

$\bar{h} = 3m$

Total pressure $= F = \rho g A \bar{h} = 1000 \times 9.81 \times 1.76 \times 3 = 51796.8$

centre of pressure (CP) $= h^* = \frac{I_G}{A\bar{h}} + \bar{h}$ $\qquad I_G = \frac{\pi}{64} \times 1.5^4 = 0.248$

$= \frac{0.248}{1.76 \times 3} + 3$

$= 3.04m$

Q. A rectangular sluice gate is situated on the vertical wall of a lock. The vertical side of the sluice is 'd' m in the length and depth of centroid of the area is 'P' m below the water surface. Prove that the depth of the pressure is equal to $\left(P + \frac{d^2}{12P}\right)$.

Ans:- Given data,

depth of Vertical side $= d m$

width $= b m$

Area $= d \times b m^2$

Depth of CG from free surface $= \bar{h} = P m$.

Centre of pressure $= h^* = \frac{I_G}{A\bar{h}} + \bar{h}$

$I_G = \frac{bd^3}{12}$

$h^* = \left(\frac{bd^3}{12} / b \times d \times P\right) + P = \frac{d^2}{12P} + P$

Q. A circular opening, 3m dia. in a vertical side of a tank is closed by a disc of 3m dia. which can rotate about a horizontal dia. Calculate i) The Force on the disc, and ii) the torque required to maintain the disc in equilibrium in the vertical position when the head of water above the horizontal dia. is 4m.

Ans:- Given data,

$d = 3m$

$\text{Area} = \frac{\pi}{4} \times 3^2 = 7.06\, m^2$

Depth of CG = 4m

i) Total pressure $\bar{F} = \rho g A \bar{h} = 1000 \times 9.81 \times 7.06 \times 4$

$= 277034.4\, N = 277.03\, kN$

ii) $h^* = \frac{I_G}{A\bar{h}} + \bar{h}$, $I_G = \frac{\pi}{64} d^4$

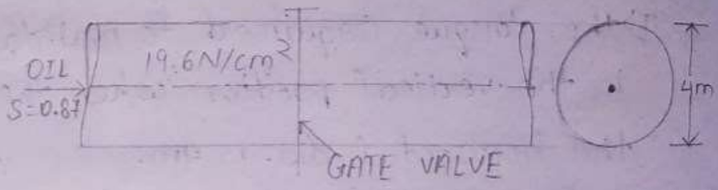
$= \frac{\frac{\pi}{64} d^4}{\frac{\pi}{4} \times d^2 \times 4} + 4$

$= \frac{d^2}{16 \times 4} + 4$

$= 0.14 + 4$

$= 4.14m$

Q. A pipe line which is 4m in diameter contains a gate valve. The pressure at the centre of the pipe is $19.6 N/cm^2$. If the pipe is filled with oil of sp. gr. 0.87, find the force exerted by the oil upon the gate and position of centre of pressure.



Ans:-

Given data,

$P = 19.6 N/cm^2 = 19.6 \times 10^4 N/m^2$

$G = 0.87$

$\rho = 0.87 \times 1000 = 870 kg/m^3$

$g = 9.81 m/s^2$

$d = 4m$

$F = ?$

$A = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 4^2$

$P = \rho g h$

$\Rightarrow 19.6 \times 10^4 = 870 \times 9.81 \times \bar{h}$

$\Rightarrow \bar{h} = \frac{19.6 \times 10^4}{870 \times 9.81} = 22.96$

Pressure head $= 22.96$

Total pressure $F = \rho g A \bar{h}$

$= 870 \times 9.81 \times \frac{\pi}{4} \times 4^2 \times 22.96$

$= 2462464.66$

$= 2462.464$

Centre of pressure $h^* = \frac{I_G}{A\bar{h}} + \bar{h}$ $\qquad A = \frac{\pi}{4} \times 4^2 = 12.56$

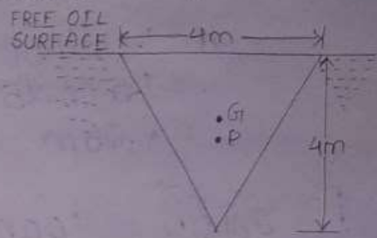
$I_G = \frac{\pi}{64} \times d^4$

$= \frac{\pi}{64} \times 4^4$

$= 12.56 m^4$

$h^* = \frac{12.56}{12.56 \times 22.96} + 22.96 = 23m$ (Ans)

Q. Determine the total pressure and centre of pressure on an isosceles triangular plate of base 4m & altitude 4m when it is immersed vertically in an oil of sp. gr. 0.9. The base of the plate coincides with the free surface of oil.



Ans:- Given data,

$b = 4m$

$h = 4m$

$\bar{h} = \frac{h}{3} = \frac{4}{3} = 1.33m$

$G = 0.9$

$\rho = 0.9 \times 1000 = 900 kg/m^3$

$A = \frac{1}{2} \times b \times h = \frac{1}{2} \times 4 \times 4 = 8m^2$

Total pressure $F = \rho g A \bar{h} = 900 \times 9.81 \times 8 \times 1.33 = 93940.56 N$
$= 93.94 kN$

Center of pressure $h^* = \frac{I_G}{A\bar{h}} + \bar{h}$

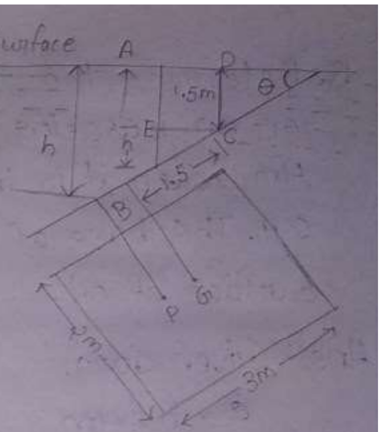
$I_G = \frac{bh^3}{36}$ $\Rightarrow \frac{7.11}{8 \times 1.33} + 1.33$

$= \frac{4 \times 4^3}{36}$ $= 1.99m$

$= 7.11 m^4$

$$h^* = \frac{I_G \sin^2\theta}{A\bar{h}} + \bar{h}$$

Q. A rectangular plan surface 2m wide & 3m deep lies in water in such a way that its plane makes an angle of 30° with the free surface of water. Determine the total pressure & position of centre of pressure when the upper edge is 1.5m below the free water surface.



Ans:- Given data,

$d = 3m$

$b = 2m$

$\theta = 30°$

$\bar{h} = 1.5 + 1.5\sin 30 = 0.75$

$= 1.5 + 0.75$

$= 2.25m$

$F = \rho g A\bar{h} = 1000 \times 9.81 \times 2.25 \times 6 = 132435N$

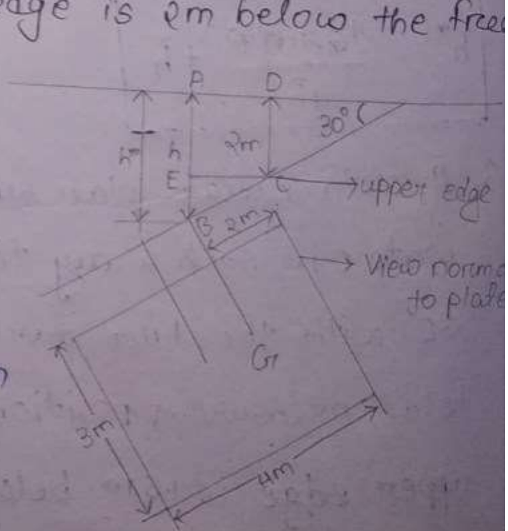
$I_G = \frac{bd^3}{12} = \frac{2 \times 3^3}{12} = 4.5m^4$

$h^* = \frac{I_G \sin^2\theta}{A\bar{h}} + \bar{h}$

$= \frac{4.5(\sin 30)^2}{6 \times 2.25} + 2.25$

$= 2.33\ m$ (Ans)

Q. A rectangular plane surface 3m wide & 4m deep lies in water in such a way that its plane makes an angle of 30° with the free surface of water. Determin the total pressure force and position of centre of Pressure, when the upper edge is 2m below the free Surface.



Ans:- Given data,

$b = 3m$

$d = 4m$

$\theta = 30°$

$\bar{h} = 2 + 2\sin 30 = 3m$

$F = \rho g A\bar{h} = 1000 \times 9.81 \times 3 \times 12$

$= 353160\ N$

$$I_G = \frac{bd^3}{12} = \frac{3\times4^3}{12} = 16m^4$$

$$h^* = \frac{I_G \sin^2\theta}{A\bar{h}} + \bar{h}$$

$$= \frac{16(\sin 30)^2}{12\times 3} + 3$$

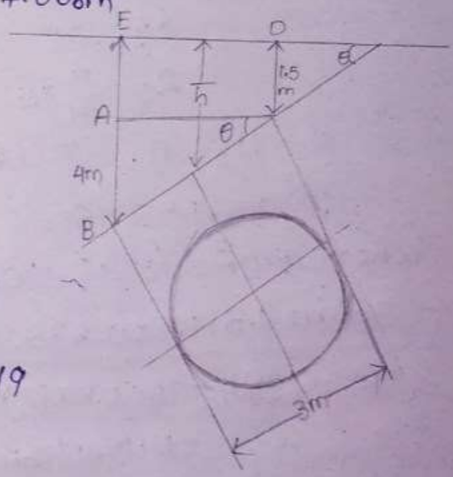
$$= 3.11\ m.$$

Q. A circular plate 3.0 dia. is immersed in water in such a way that is greatest and least depth below the free surface are 4m & 1.5m respectively. Determine the total pressure on one face of the plate and position of the centre of pressure.

Ans:- Given data, $d = 3.0\ m$

$$A = \frac{\pi}{4}d^2 = \frac{\pi}{4}\times 3^2 = 7.068 m^2$$

~~AD = 1.5m~~ , ~~BE = 4m~~



$$\bar{h} = 1.5 + 1.5\sin\theta$$

where $\sin\theta = \frac{4-1.5}{3} = 0.833$

$$\bar{h} = 1.5 + 1.5\times 0.833 = 2.749m$$

$$F = \rho g A\bar{h} = 1000\times 9.81\times 7.068\times 2.749$$

$$= 190607\ N$$

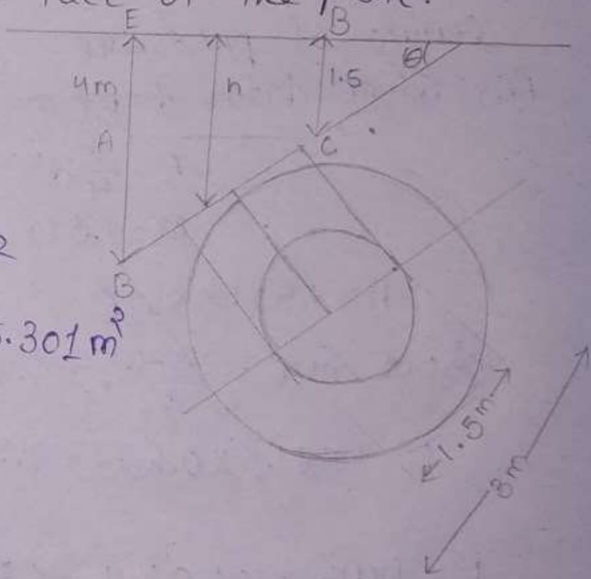
$$I_G = \frac{\pi}{64}d^4 = 3.976\ m^4$$

$$h^* = \frac{I_G \sin^2\theta}{A\bar{h}} + \bar{h}$$

$$= \frac{3.976\times(0.833)^2}{7.068\times 2.749} + 2.749$$

$$= 2.890\ m.$$

Q. If in the above problem, the given circular plate is having a concentric circular hole of diameter 1.5m then calculate the total pressure & position of the centre of pressure on one face of the plate.



Ans:- Given data,

$d_1 = 1.5\,m$

$A_1 = \frac{\pi}{4} \times d^2 = 1.767\,m^2$

$d_2 = 3\,m$

$A_2 = \frac{\pi}{4} \times d^2 = 7.068\,m^2$

$A = A_2 - A_1 = 7.068 - 1.767 = 5.301\,m^2$

$\bar{h} = 1.5 + 1.5 \sin\theta$

where $\sin\theta = \frac{4-1.5}{3} = 0.833$

$\bar{h} = 1.5 + 1.5 \times 0.833 = 2.749\,m$

$F = \rho g A \bar{h} = 1000 \times 9.81 \times 5.301 \times 2.749$

$= 142487\,N$

$= 142.487\,kN$

$I_G = \frac{\pi}{64}(d_2^4 - d_1^4) = 3.497\,m^4$

$h = \frac{I_G \sin^2\theta}{A\bar{h}} + \bar{h}$

$= \frac{3.497 \times 0.833^2}{5.301 \times 2.749} + 2.749$

$= 2.915\,m$ (Ans)

KINEMATICS OF FLUID FLOW

BASIC EQUATION OF FLUID FLOW & THEIR APPLICATION

KINEMATICS:-

It is defined as the branch of science which deals with the motion of fluid particle with considering the force causing the motion.

ENERGY OF A LIQUID IN MOTION:-

- The energy in general may be defined as the capacity of a body to do work. Though the energy existing in many form.
- There are three types of energy.
    1. Potential Energy
    2. Kinetic Energy
    3. Pressure Energy

POTENTIAL ENERGY OF LIQUID PARTICLE IN MOTION

- It is the energy possessed by liquid particle by virtue of its position.
- If the liquid particle is 'Z' above the horizontal datum, the potential energy of particle will be **Z** of liquid.
- The potential head of the liquid at a point will be **Z** of the liquid.

KINETIC ENERGY OF LIQUID PARTICLE IN MOTION

- It is the energy possessed by liquid particle by virtue of its motion or velocity.
- If a liquid particle is flowing with a mean velocity of '**V**' m/s', then kinetic energy of particle will be $\frac{V^2}{2g}$ of liquid.
- Then kinetic head of the liquid at a point will be $\frac{V^2}{2g}$ of the liquid.

PRESSURE ENERGY OF LIQUID PARTICLE IN MOTION

- It is the energy possessed by a liquid particle by virtue of its existing pressure.
- If a liquid particle is under the pressure of **P** KN/m^2, then the pressure energy of particle will be $\frac{P}{W}$ of liquid, where W is the specific weight of liquid.
- Pressure head of liquid under that pressure will be $\frac{P}{W}$ of the liquid.

TOTAL ENERGY OF LIQUID PARTICLE IN MOTION:-

- The total energy of a liquid in motion is the sum of its potential energy, kinetic energy & pressure energy.
- Total Energy (E) = $\left(Z + \frac{V^2}{2g} + \frac{P}{W}\right)$ metre of a liquid.

TOTAL HEAD OF LIQUID PARTICLE IN MOTION:-

- The total head of liquid particle in motion is the sum of its potential head, kinetic head & pressure head.
- Total Head (H) = $\left(Z + \frac{V^2}{2g} + \frac{P}{W}\right)$ metre of a liquid.

BERNUILLIES EQUATION:-

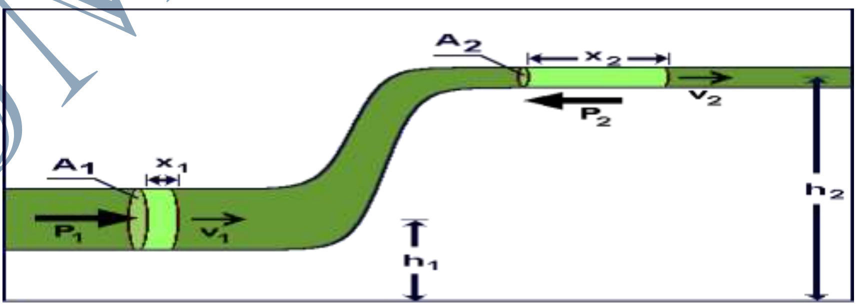
- It states that for a perfect incompressible liquid flowing in a continuous stream, the total energy of a particle remains the same while the particle moves from one point to another.
- The statement is based on assumption that there are no loss due to friction in the pipe.

$$Z + \frac{V^2}{2g} + \frac{P}{W} = K$$

$$Z_1 + \frac{V_1^2}{2g} + \frac{P_1}{W} = Z_2 + \frac{V_2^2}{2g} + \frac{P_2}{W} \quad \textbf{(Bernuillies Equation)}$$

PROOF:-

- Consider a perfect incompressible liquid flowing through non-uniform pipe.
- Let us consider two section of the pipe.
- We know that,



Specific weight = $\frac{\text{weight}}{\text{volume}}$, $w = \frac{W}{V}$

$w = \frac{W}{A_1 x_1} \rightarrow \frac{W}{w} = A_1x_1$

$w = \frac{W}{A_2 x_2} \rightarrow \frac{W}{w} = A_2x_2$

$$A_1x_1 = A_2x_2 = \frac{W}{w}$$

WORKDONE

Workdone at Section 1 = Force*Displacement

$= F*S = P_1A_1x_1$

Workdone at Section 2 = Force*Displacement

$= F*S = - P_2A_2x_2$

Total Workdone = $P_1A_1x_1 + (- P_2A_2x_2)$

$= P_1A_1x_1 - P_2A_2x_2$

$= P_1 \frac{W}{w} - P_2 \frac{W}{w}$

$= (P_1 - P_2) \frac{W}{w}$

Total Workdone = $\mathbf{(P_1 - P_2) \frac{W}{w}}$

POTENTIAL ENERGY(P.E)

P.E at Section 1 ,

$P.E_1 = mgh = Wh_1$ $(W = mg \ \& \ h = h_1)$

P.E at Section 2 ,

$P.E_2 = mgh = Wh_2$ $(W = mg \ \& \ h = h_2)$

Losses due to P.E = $Wh_1 - Wh_2 = \mathbf{W(h_1 - h_2)}$

KINEMATIC ENERGY(K.E)

K.E at Section 1,

$K.E_1 = \frac{1}{2}mv^2 = \frac{W}{2g}V_1^2$ $(m = \frac{W}{g})$

K.E at Section 2,

$K.E_2 = \frac{1}{2}mv^2 = \frac{W}{2g}V_2^2$ $(m = \frac{W}{g})$

Losses due to K.E = $\frac{W}{2g}V_2^2 - \frac{W}{2g}V_1^2 = \mathbf{\frac{W}{2g}(V_2^2 - V_1^2)}$

Losses due to K.E = Workdone + Loss due to P.E

$$\frac{W}{2g}(V_2^2 - V_1^2) = (P_1 - P_2)\frac{W}{w} + W(h_1 - h_2)$$

$$\frac{W}{2g}(V_2^2 - V_1^2) = W\left(\frac{P_1}{w} - \frac{P_2}{w} + h_1 - h_2\right)$$

$$\frac{V_2^2 - V_1^2}{2g} = \frac{P_1}{w} - \frac{P_2}{w} + h_1 - h_2$$

$$\frac{V_2^2}{2g} - \frac{V_1^2}{2g} = \frac{P_1}{w} - \frac{P_2}{w} + h_1 - h_2$$

$$\frac{V_2^2}{2g} + \frac{P_2}{w} + h_2 = \frac{V_1^2}{2g} + \frac{P_1}{w} + h_1$$

$$\boldsymbol{\frac{V_1^2}{2g} + \frac{P_1}{w} + h_1 = \frac{V_2^2}{2g} + \frac{P_2}{w} + h_2} \qquad \text{(proved)}$$

LIMITATION OF BERNAULLIES EQUATION:-

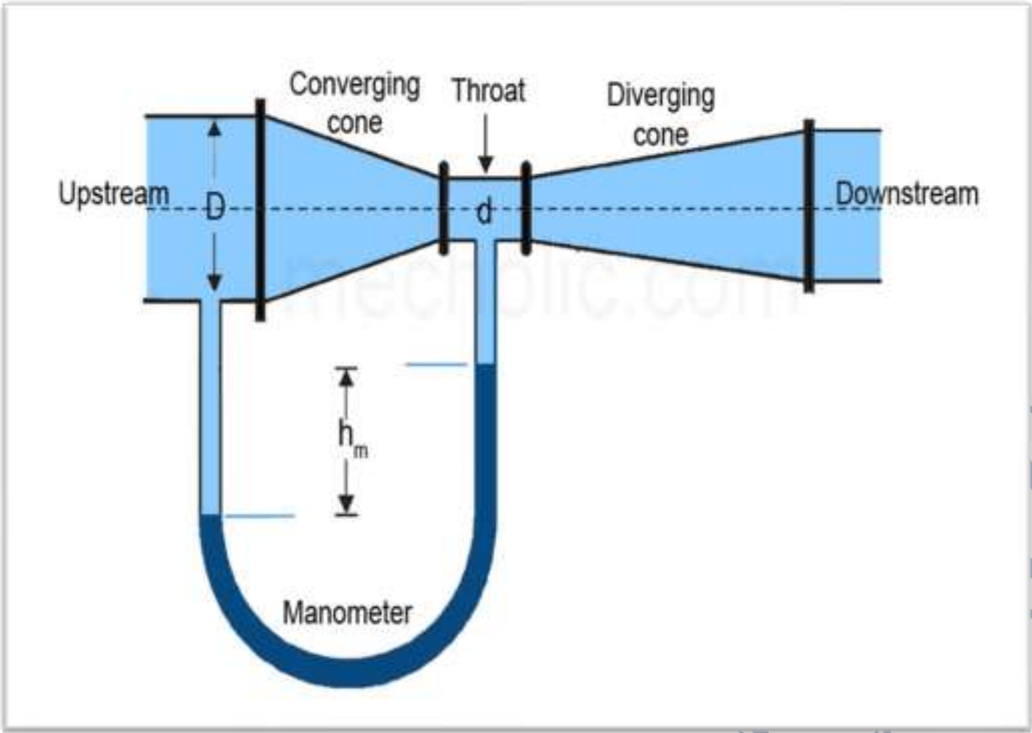
- The bernaulies equation has been derived under the assumption that velocity of every liquid particle across any c/s of pipe is uniform. But in actual practice it is not so.
- The velocity of liquid particle in the center of pipe is maximum and gradually decrease towards the wall of pipe due to pipe friction. Thus while using the bernaulies equation only the mean velocity of liquid is taken into account.
- The bernaulies equation has been derived under the assumption that no external force except the gravity force is acting on the liquid . But in actual practice it is not so. There are always an external force such as pipe friction etc. acting on the liquid which affect the flowing of liquid. Thus while using the bernaulies equation all such external force should be neglected.
- The bernaulies equation has been derived under the assumption that there is no loss of energy of liquid particle while flowing.
- If the liquid is flowing in a curved path the energy due to centrifugal force should also be taken into account.

PRACTICAL APPLICATION OF BERNAULIES EQUATION:-

- The bernaulies equation or theorem is the basis equation which has the widest application in hydraulics and applied hydraulics. Since this equation is applied for the derivation of many formula.
- The application of bernaulies equation on the following hydraulic device.
  1. Ventury meter
  2. Orifice meter
  3. Pitot tube

VENTURI METER:-

- A venturimeter is an apparatus used for finding out the discharge of liquid flowing in a pipe. A venturimeter consists of following three parts.
  i. Convergent Cone
  ii. Throat
  iii. Divergent Cone



CONVERGENT CONE

- It is a short pipe which convergent from a diameter 'D' to a smaller diameter 'd'. The convergent cone is also known as inlet of venturimeter.
- The slope of converging side is between 1 in 4 and 1 in 5.

THROAT

- It is a small portion of pipe in which diameter 'd' is constant is called throat.

DIVERGENT CONE

- It is a pipe which diverges from a diameter 'd' to a large diameter 'D' . The divergent cone is also known as outlet of venturimeter.
- The length of divergent cone is about 3 to 4 times than that of convergent cone.

DISCHARGE THROUGH A VENTURIMETER

$$Q = \frac{C_d a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh_m}$$

Where

C_d – Coefficient of discharge

a_1 – Area of Inlet

a_2 – Area of Throat

h_m – Pressure Head

CASE 1

- If the differential manometer contains liquid which is heavier than the liquid flowing through the pipe, The value of h_m is

$$h_m = x\left(\frac{S_h}{S_o} - 1\right)$$

CASE 2

- If the differential manometer contains liquid which is lighter than the liquid flowing through the pipe, The value of h_m is

$$h_m = x\left(1 - \frac{S_h}{S_o}\right)$$

Where

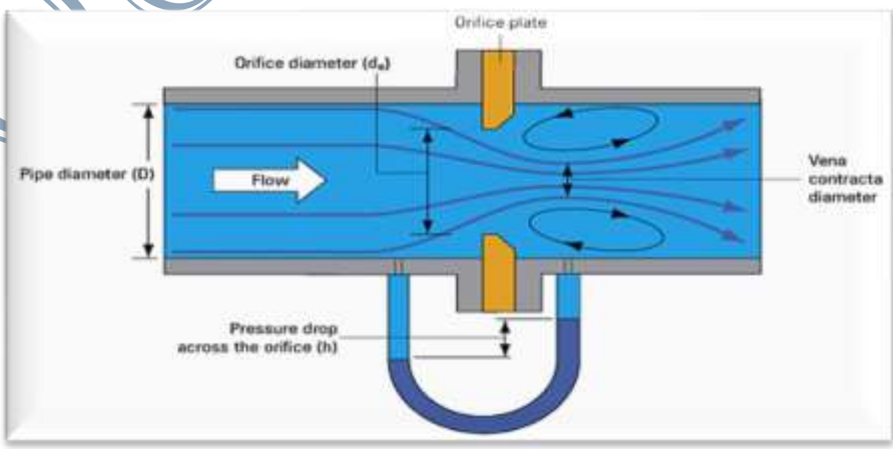
X – reading of manometer

S_h – Specific gravity of heavier liquid

S_o – Specific gravity of lighter liquid

ORIFICE METER:-

- It is a device used for measuring the rate of flow of a liquid through a pipe.
- An orifice meter in its simplest form consist of plate having a sharp as circular whole known as orifice. This plate is fixed inside a pipe.
- A mercury manometer is inserted to know the difference of pressure between the pipe and throat.



DISCHARGE THROUGH AN ORIFICE METER

$$Q = \frac{C_d a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

Where

C_d – Coefficient of discharge

a_1 – Area of Inlet

a_2 – Area of Throat

h – Pressure Head

PRESSURE HEAD OF LIQUID THROUGH AN ORIFICE METER

$$h = \frac{P_1}{ʃg} - \frac{P_2}{ʃg}$$

Where

h – Pressure Head

P_1 – Inlet Pressure

P_2 – Pressure at Orifice

ʃ - Density of liquid in kg/m^3

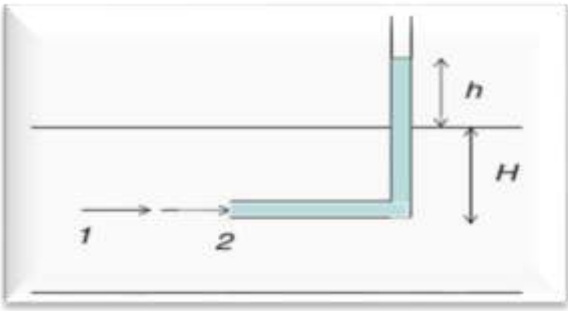
g – Acceleration due to gravity in m/s^2

PITOT TUBE:-

- A pitot tube is an instrument used to determined the velocity of flow or used for measuring the velocity of flow at any point in a pipe or a channel.
- It is based on the principle that if the velocity of flow at any point become zero, the pressure there is increase due to convergent of kinetic energy into pressure energy.
- Pitot tube consists of glass tube bent at right angle towards lowered and which is bent through 90° is directed in the upstream direction.
- Then liquid rises up in the tube due to convergent of kinetic energy into pressure energy.

VELOCITY OF LIQUID THROUGH PITOT TUBE

- The velocity is determined by measuring the rise of liquid in the tube.



Consider two point ① and ② at same level in such a way that the point ② is just at the inlet of pitot tube and point ① is far away from the inlet.

Let,

P_1 – Intensity of Pressure at point 1

P_2 – Intensity of Pressure at point 2

P_1 – Intensity of Pressure at point 1

V_1 – Velocity of Flow at point 1

V_2 – Velocity of Flow at point 2

H – Depth of tube in the Liquid

h – Rise of Liquid in the tube above the free surface

By applying Bernaulies Equation at point 1 & 2

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

Here $Z_1 = Z_2$ as point 1 and 2 are on the same line ($V_2 = 0$)

$$\frac{P_1}{\rho g} = H$$

$$\frac{P_2}{\rho g} = H + h$$

Then,

$$Z_1 + \frac{V_1^2}{2g} + H = Z_1 + 0 + H + h$$

$$\frac{V_1^2}{2g} = h$$

$V_1^2 = 2gh$

$V_1 = \sqrt{2gh}$ (Theoritical Velocity)

$$V = C_v \sqrt{2gh} \qquad \text{(Actual Velocity)}$$

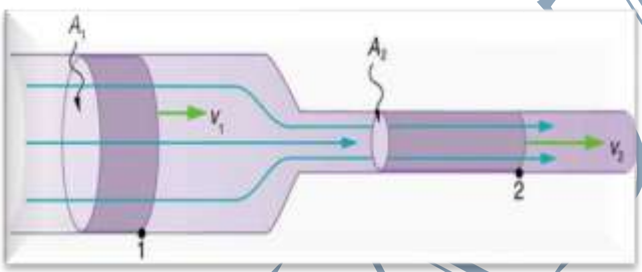
Where

V – Velocity at any point

C_v – Co-efficient of velocity

EQUATION OF CONTINUITY OF LIQUID FLOW:-

- If an incompressible liquid is continuously flowing through a pipe or a channel (whose cross section are may or may not be constant) the quantity of liquid passing per second is the same in all direction.
- This is known as equation of quantity of liquid flow.
- It is the first and fundamental equation of flow.



Consider a tapering pipe through which some liquid is flowing .

Let,

A_1 – C/S Area of Pipe at section 1-1
V_1 – Velocity of Liquid at section 1-1
A_2 – C/S Area of Pipe at section 2-2
V_2 – Velocity of Liquid at section 2-2

We know that the total quantity of the liquid passing through the section 1-1,

$Q_1 = A_1V_1$ ……eq(1)

Similarly total quantity of liquid passing through the section 2-2,

$Q_2 = A_2V_2$ ……eq(2)

From the law of conservation of matter, we know that the total quantity of liquid passing through the section 1-1 and 2-2 is the same.

Therefore,

$Q_1 = Q_2$

$\mathbf{A_1V_1 = A_2V_2}$

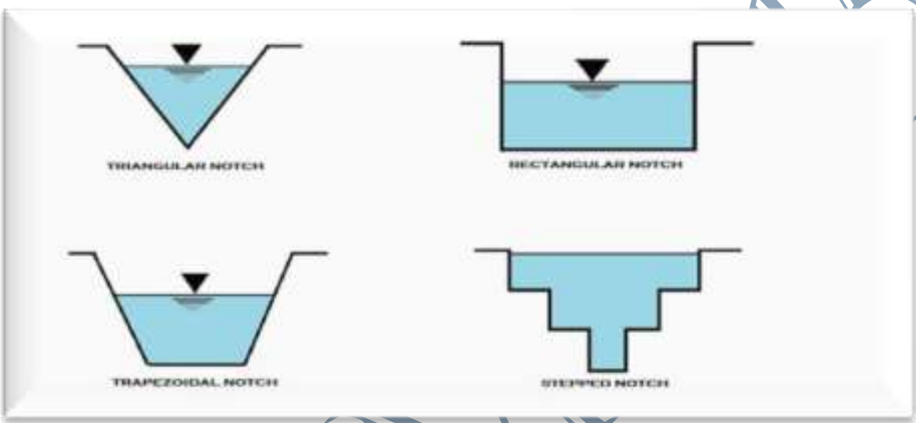
FLOW OVER NOTCHES & WEIR

NOTCH:-

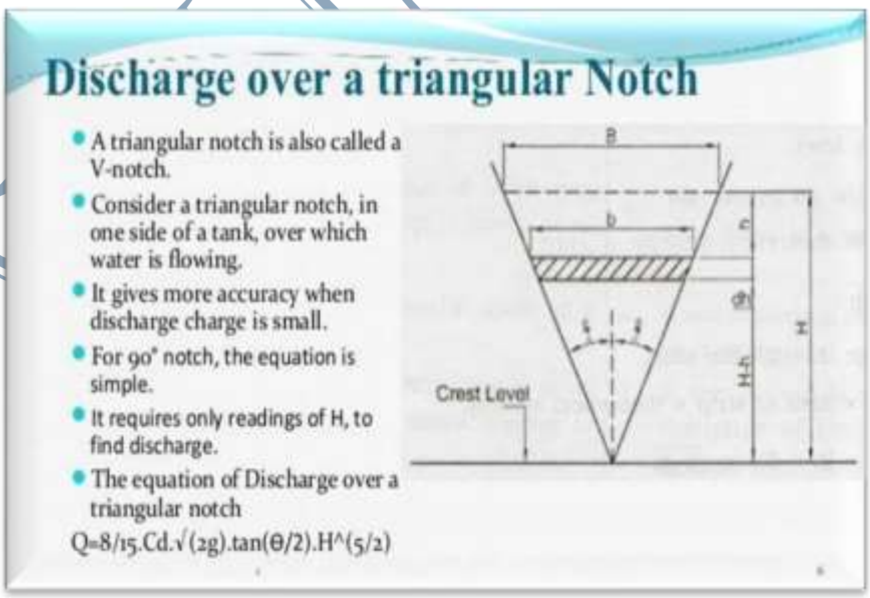
- A notch may be defined as an opening in one side of a tank or a reservoir, like a large orifice, with the upstream liquid level below the top edge of the opening.
- Since the top edge of the notch above the liquid level serves no purpose therefore a notch may have only the bottom edge & sides.
- The bottom edge over which the liquid flows, is known as sill or crest of the notch & the sheet of liquid flowing over a notch (or a weir) is known as nappe or vein.
- A notch is usually made of a metallic plate & is used to measure the discharge of liquid.

TYPE OF NOTCH:-

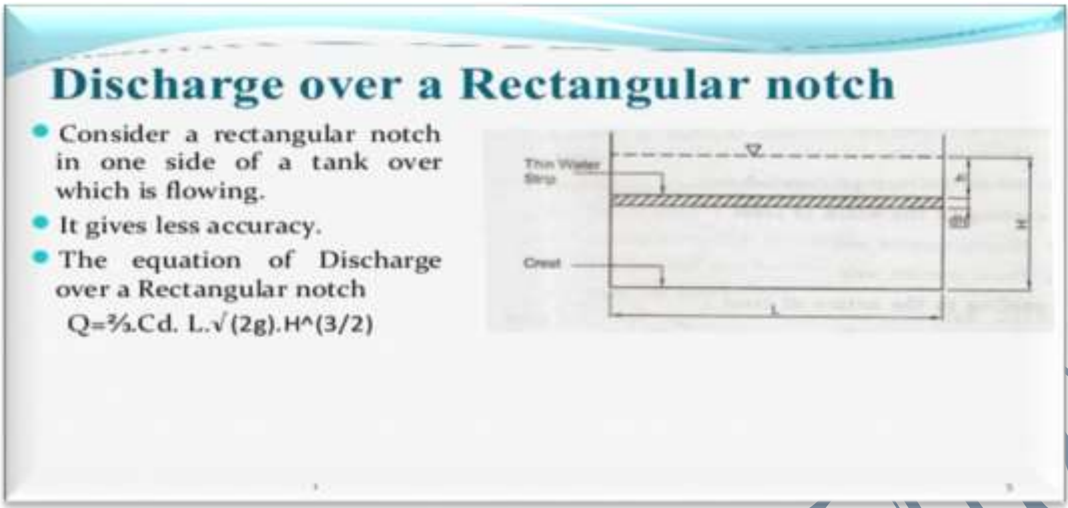
There may be of following types of notch.



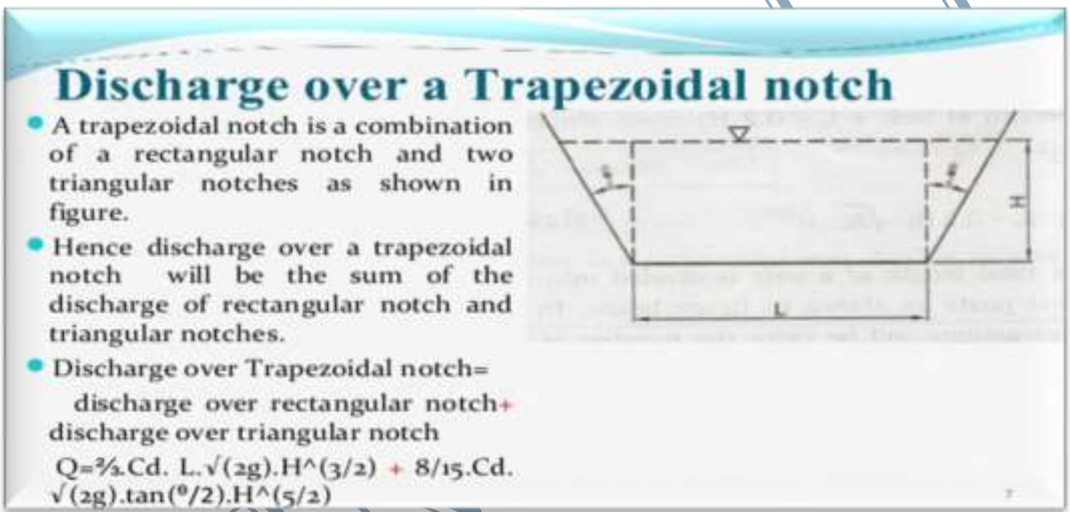
- **Triangular Notch**



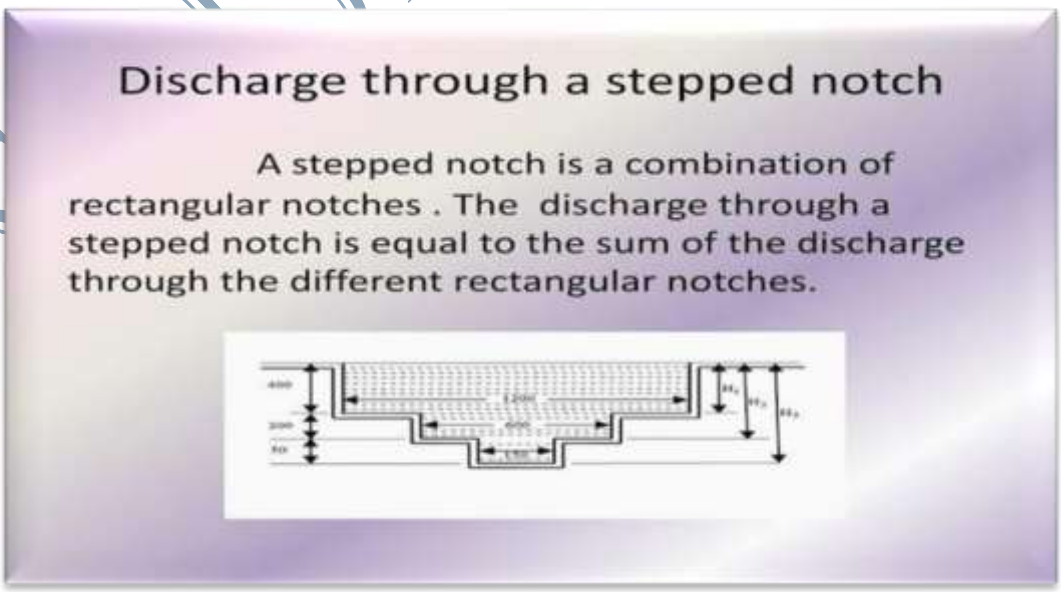
- **Rectangular Notch**



- **Trapezoidal Notch**



- **Stepped Notch**



Where,

Q = Discharge

C_d = Co-efficient of Discharge

H = Head of Liquid

L = Length of Notch

Θ = Angle of V-notch

g = Acceleration due to gravity

WEIR

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

TYPES OF WEIR

- According to Shape
  1. Rectangular
  2. Trapezoidal
- According to Nature of Discharge
  1. Ordinary
  2. Submerged
- According to Width of Crest
  1. Narrow Crest
  2. Broad Crest
- According to Nature of Crest
  1. Sharp Crest
  2. Ogee

DIFFERENCE BETWEEN NOTCH & WEIR

NOTCH	WEIR
1. 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.	1. A weir may be defined as a structure constructed across a river or canal to store water on the upstream side.
2. The bottom edge of notch over which water flows is known as Sill or Crest.	2. The top of the weir over which water flows is known as Crest.
3. A notch is usually made of a metallic plate.	3. A weir is made of cement concrete or masonry.
4. A notch is used to measure small discharge of small stream or canal.	4. A weir is used to measure large discharge of rivers and large canal.
5. Notchs are of small size.	5. Weirs are of bigger size.

TYPES OF FLOW THROUGH THE PIPE

UNIFORM FLOW:-

- The flow in which velocity at a given time does not change with respect to space (length of direction of flow) is called as uniform flow.

$$\frac{dv}{ds} = 0$$

NON-UNIFORM FLOW:-

- The flow in which velocity at a given time changed with respect to space (length of direction of flow) is called as non-uniform flow.

$$\frac{dv}{ds} \neq 0$$

STEADY FLOW:-

- Steady flow is the flow whose properties doesn't change with respect to time.
- For steady flow all fluid flows properties (e.g velocity, temperature, pressure & density) are independent of time.

UNSTEADY FLOW:-

- A flow in which quantity of liquid flowing per second is not constant is called unsteady flow.
- For unsteady flow all fluid flows properties are dependent on time.

LAMINAR FLOW:-

- The flow of a fluid when each particle of the liquid follows a smooth path, paths which never interfere with one another, the velocity of flow is constant at any point is called laminar flow.
- The fluid layers move parallel to each other & do not cross each other.

TURBULENT FLOW:-

- The flow of a fluid when the particle of liquid follows a zigzag path, the velocity is not constant is known as turbulent flow.
- The fluid layers cross each other & do not move parallel to each other.

REYNOLD'S NUMBER:-

- The Reynold's number is the ratio of inertia forces to viscous forces.

$$R_e = \frac{Inertia\ force}{Viscous\ force}$$

$$\text{Or} \quad R_e = \frac{fVD}{\mu}$$

$$\text{Or} \quad R_e = \frac{VD}{\nu}$$

Where

ƒ = Density of Fluid (kg/m^3)

V = Velocity of Flow (m/s)

D = Characteristic Linear Dimension

μ = Dynamic Viscosity (Ns/m^2)

ν = Kinematic Viscosity (m^2/s) $= \frac{f}{\mu}$

R_e < 2000 (Laminar Flow)

R_e > 4000 (Turbulent flow)

LOSS OF HEAD OF A LIQUID FLOWING THROUGH A PIPE

- A pipe is a close coduct or channel which is used for carrying fluid under pressure.
- Pipes are commonly circular in section.
- As the pipe carries fluid under pressure, the pipe always run full will be consider.

LOSS OF ENERGY DUE TO FRICTION

- The loss of energy due to friction is classified as measured loss because in the case of long pipe lines it is usually much more than the loss of energy incurred be other causes.
- Darcy's formula

$$h_f = \frac{4FlV^2}{2gd}$$

Where,

h_f =Head loss due to friction

F = Co-efficient of friction

l = Length of pipe

V = Velocity of flow

g = Acceleration due to gravity

d = Diameter of pipe

- When $R_e < 2000$

$$F = \frac{16}{Re}$$

- When $4000 < R_e < 10^6$

$$F = \frac{0.079}{Re^{1/4}}$$

And $$R_e = \frac{VD}{\nu}$$

Where

R_e = Reynold's Number

V = Velocity

D = Diameter of Pipe

ν = Kinematic Viscosity

MINOR ENERGY LOSS

- The minor losses of energy are those which are caused on account of the change in the velocity of flowing fluid. (Either in magnitude or in direction)
- In case of long pipe these losses are usually quite small as compared with a loss of energy due to friction, which may even being neglected without serious error.
- However in short pipe these losses may sometime more than friction losses.

LOSS OF ENERGY DUE TO SUDDEN ENLARGEMENT : -

$$h_e = \frac{(V_1 - V_2)^2}{2g}$$

LOSS OF ENERGY DUE TO SUDDEN CONTRACTION : -

$$h_e = \frac{{V_2}^2}{2g}\left(\frac{1}{C_C} - 1\right)^2 = \frac{{V_2}^2}{2g}*0.5 = 0.5\ \frac{{V_2}^2}{2g}$$

LOSS OF HEAD AT ENTRANCE OF PIPE : -

$$h_i = 0.5\ \frac{{V_2}^2}{2g}$$

LOSS OF HEAD AT THE EXIT OF PIPE : -

$$h_o = \frac{V^2}{2g}$$

Where

h = Head loss

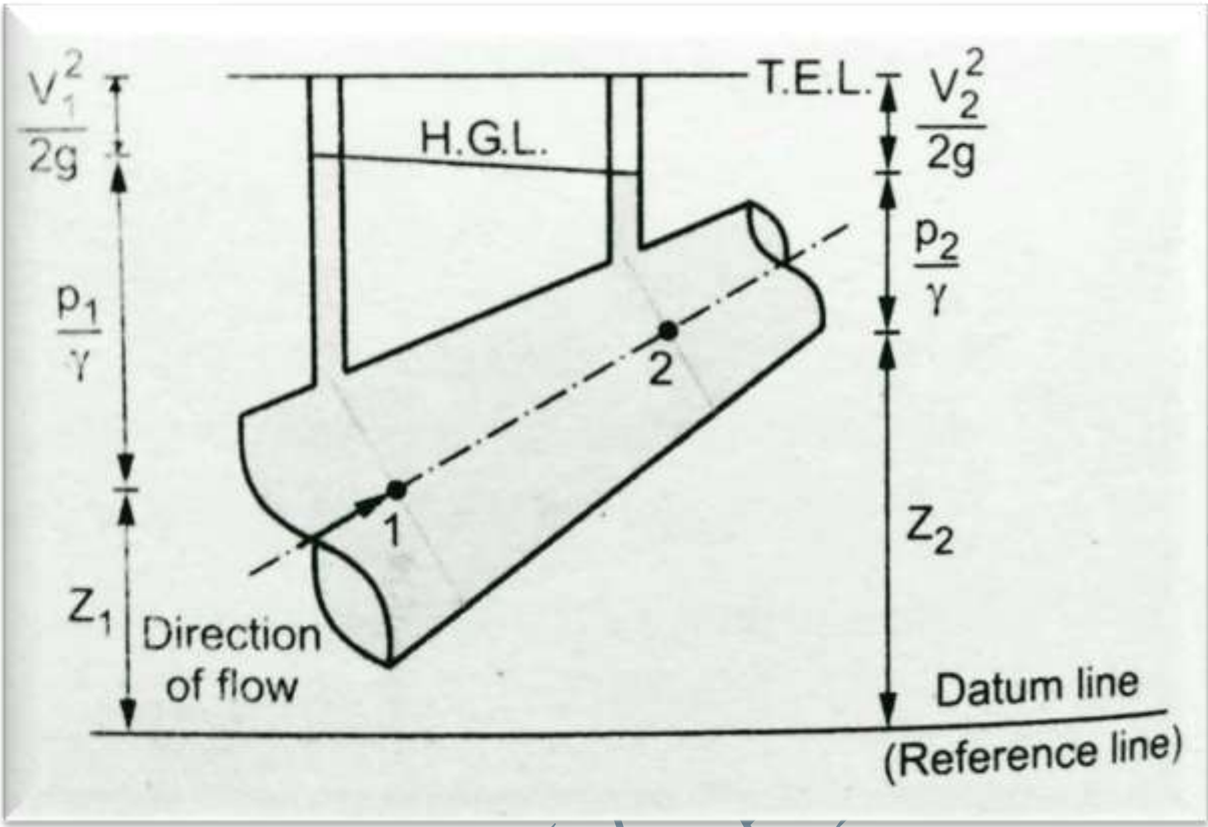
V_1 = Velocity at section-1

V_2 = Velocity at section-2

V = Velocity

HYDRAULIC GRADIENT LINE & TOTAL ENERGY LINE (HGL & TEL)

- The hydraulic gradient line & total energy line are the graphical representation of the longitudinal variation in total head & piezometric head at salient point of a pipe line.
- The total head with respect to any arbitrary datum is described by the total pressure head ($\frac{P}{\rho g}$), velocity head ($\frac{V^2}{2g}$) & datum head (Z).


T.E.L.
H.G.L.
$\frac{V_1^2}{2g}$
$\frac{p_1}{\gamma}$
Z_1
$\frac{V_2^2}{2g}$
$\frac{p_2}{\gamma}$
Z_2
1
2
Direction of flow
Datum line
(Reference line)

FLOW OVER OPEN CHANNEL

Q = AV

Where

Q – Discharge of Fluid flow (m^3/s)

A – Area of Open Channel (m^2)

V – Velocity of Flow (m^2/s)

CHEZY'S CONSTANT: -

$$V = C\sqrt{mi}$$

MANNING'S CONSTANT: -

$$V = \frac{1}{N}(m^{2/3})(i^{1/2})$$

Where

N – Manning's Constant

m – Hydraulic Mean Depth

i – Bed Slope

C – Chezy's Constant , $C = \frac{1}{N} m^{1/6}$

$$m = \frac{A}{P_w}$$

Where

A = Area of Open Channel at Depth of Flow

P_w = Wetted Perimeter

MOST ECONOMICAL SECTION OF CHANNEL

- A section of channel is said to be most economical, When the cost of construction of channel is minimum .
- The condition to be most economical for the following shape of channel will be considered.

1. Rectangular Channel

Rectangular Channel will be most economical, When

B = 2d and $m = \frac{d}{2}$

2. Trapezoidal Channel

Trapezoidal Channel will be most economical, When

$$\mathbf{m} = \frac{d}{2} \text{ and } \frac{\mathbf{b+2nd}}{\mathbf{2}} = \mathbf{d}\sqrt{\mathbf{n^2+1}}$$

3. Circular Channel

In case of circular channels for most economical section, two conditions are obtained.

- Condition for maximum Velocity
- Condition for maximum Discharge

Condition for Maximum Velocity:-

Velocity of Flow, **V = C** $\sqrt{mi}$

- Velocity of Flow(**V**) is maximum, When hydraulic mean depth(**m**) is maximum.
- The depth of flow for maximum Velocity , **d = 0.81D**

  Where D= Diameter of Circular channel & d = Depth of Flow
- Hydraulic mean depth For maximum Velocity , **m = 0.3D**

Condition for Maximum Discharge:-

Depth of flow for maximum discharge , **d = 0.95D**

Where D= Diameter of Circular channel & d = Depth of Flow

Irrigation :-

→ It is the process of artificial application of water to the soil for the growth of agricultural crops.

Necessity of irrigation :-

The following are the factors which govern the necessity of irrigation:-

i) **Insufficient Rain fall :-** When the seasonal rain fall is less than the minimum requirement for the satisfactory growth of crops, the irrigation system is essential.

ii) **Uneven Distribution of Rain fall :-**
When the rainfall is not evenly distributed during the crop period or throughout the culturable area, the irrigation is extremly necessary.

iii) **Improvement of perennial crops :-**
Some perennial crops like sugarcane, cotton, etc. require water throughout the major part of the year. But the rainfall may fulfil the water requirement in rainy season only, so, for the remaining part of the year, irrigation becomes necessary.

... Area:-

iv) Development of Agriculture in Desert Area:-

In desert area where the rainfall is very scanty, irrigation is required for the development of agriculture.

Benefits of irrigation

The following are the important benefits of irrigation :-

(a) Yield of crops:-

In the period of low rainfall or drought, the yield of crop may be increased by the irrigation system.

(b) Protection from Famine:-

The food production of a Country can be improved by ensuring the growth of crops by availing the irrigation facilities. This helps a country to prevent famine situation.

(c) Improvement of Cash crops:-

Irrigation helps to improve the cultivation of cash crops like vegetables, fruits, tobacco, etc.

(d) Prosperity of Farmers:-

When the supply of irrigation water is assured, the farmers can grow two or more crops in a year on the same land. Thus the farmers may earn more money and improve their living standard.

(e) Source of Revenue:-

When irrigation water is supplied to the cultivators in lieu of some taxes, it helps to earn revenue which may be spent on other development schemes.

(f) Navigation:-

The irrigation canals may be utilised for inland navigation which is further useful for communication and transportation of agricultural goods.

(g) Hydroelectric power Generation:-

In some river valley projects, multipurpose reservoirs are formed by constructing high dams where hydroelectric power may be generated along with the irrigation system.

(h) Water supply:-

The irrigation canals may be the source of water supply for domestic and industrial purposes.

(i) General Communication:-

The inspection road along the canal banks may serve as a communication link with the otherwise remote villages.

(j) Development of Fishery:-

The reservoir and the canals can be utilised for the development of fisher projects.

Ill-Effects of Irrigation:-

The following are the ill-effects of irrigation.

(a) Rising of Water Table:-

Due to the excessive seepage of water through the bed and banks of the canals, the water table in the surrounding area may be raised which may constantly saturate the root zone of the crops and the soil may develop alkaline property which is harmful to the crops.

(b) Formation of Marshy Land:-

Excessive seepage and leakage of water from the irrigation canals may lead to formation of marshy lands along the course of the canals. These marshy lands from the colonies of mosquitos which may be responsible for diseases.

(c) Dampness in weather:-

The temperature of the commanded area of an irrigation project may be lowered considerably and the area may become damp. Due to dampness, the people residing around the area may suffer from cold, cough and other such diseases originating from dampness.

(d) Loss of valuable Lands:-

Valuable land may get submerged when storage reservoirs are formed by constructing barrages ... may be lost while constructing irrigation canals.

Types of Irrigation

- Flow Irrigation
  - Inundation Irrigation
  - Perennial irrigation
    - Direct irrigation
    - Storage irrigation
- Lift Irrigation
  - By man or animal power
    - Doon
    - Mote
    - Persian wheel
    - Swinging basket
    - Rati or pulley
    - Wind lass.
  - By mechanical or electrical power
    - open well
    - shallow tube well
    - Deep tube well

Flow Irrigation

→ When water flows under gravitational pull through the artificial canal towards the agricultural land, it is termed as flow irrigation.

→ In this system, the head of the canal should always be at higher elevation than the land to be irrigated.

1. Inudation Irrigation System

→ In this system, a canal is excavated from the bank of the inundation river (that is the river which overflows in rainy season but nearly dried up in summer and winter).

→ In this case water flows to the agricultural land in rainy season only.

2. Perennial System Irrigation

-> In this system, a weir or a barrage is constructed across the perennial river (that is the river which flows throughout the year in its full capacity) to raise the water level on the up stream side or a dam is constructed to form a storage reservoir.

-> This system is reliable as water is available throughout the year.

(a) Direct Irrigation System:-

-> In this system, a weir is generally constructed across a perennial river to raise the water level on the up stream side up to a certain limit, so that the water can flow through the canal.

-> Sometimes, a barrage is constructed, in place of weir, to regulate the water level on the upstream side.

V.V.I -> The hydraulic structure which is constructed in direct irrigation system is known as Diversion ~~Hed~~ Head works.

Storage Irrigation

-> In this system a dam is constructed across a river valley to form a storage reservoir.

-> This storage reservoir is also known as multipurpose reservoir as it serves the following purpose :-

(a) Irrigation
(b) Water supply
(c) Hydro-electric power generation.
(d) Fishery
(e) Flood control

Lift Irrigation

-> When water is lifted from surface sources or underground sources by man or animal power, mechanical or electrical power and directly supplied to the agricultural land, then it is known as lift irrigation.

-> In this method isolated small areas can be irrigated and the vast areas can not be

i) Lifting of water by man or animal power

-> When mechanical or electrical powers are not available in villages or the economic condition of the farmers is not good enough to afford this expensive method, the lifting of water is done by the following method from the surface sources. like ponds, lakes rivers etc.

(i) Doon
(ii) Mote
(iii) Persian wheel
(iv) Swinging busket
(v) Rati or pulley
(vi) Wind lass

ii) Lifting of water by mechanical or electrical power

-> When mechanical or electrical power is available in villages or the farmers can afford the expenditure for the installation of the same, the underground water is lifted by pumps and directly supplied to the agricultural land.

-> The underground water may be available from the following sources:-

(i) Open wall
(ii) Shallow tube well
(iii) Deep tube well

of Crops and Soil-Water

Relationship

Introduction:-

-> For proper growth and maturity of the crops, water is of vital importance through out, the crops period.

-> Again, the total water requirement for a crop is not supplied at a time, but at a fixed interval. so that the root zone of the crop may remain saturated throughout the crop period.

-> Generally, the seasonal rainfall can not meet the total water requirement, ~~Hence~~

-> Intensity of Irrigation for wheat $= \frac{250}{1000} \times 100 = 25\%$

So, area to be irrigated = C.C.A × Intensity of irrigation.

Definition of Important Terms.

Gross Command Area (G.C.A):-

-> The whole area enclosed between an imaginary boundary line which can be included in an ~~irrigatio~~ irrigation project for supplying water to agricultural land by the network of canals is known as ~~G~~ Gross Command Area (G.C.A)

Culturable Command Area (C.C.A)

-> The total Area within an irrigation project the cultivation can be done and crops can be grawn is known as culturable Command Area (C.C.A).

-> C.C.A may be two Categories.

a. ~~Cultivo~~ Culturable cultivated Area.

-> It is the area within C.C.A. where the cultivation has been actually done at present.

b. Culturable uncultivated Area

-> It is the area within the C.C.A. where cultivation is possible but it is not being cultivated at present due to some reasons.

Intensity of Irrigation:-

-> The intensity of Irrigation may be defined as a ratio of cultivated land for a particular crop to the total culturable command area. It is expressed as a percentage of C.C.A.

-> Intensity of irrigation for wheat $= \frac{250}{1000} \times 100 = 25$

so, area to be irrigated = C.C.A. × Intensity of irrigation.

→ It is defined as the ratio of the areas of the two main crop seasons kharif and Rabi.
→ For example, if the area under kharif crop is 2500 hectares and the area under Rabi crop is 5000 hectares. Crop ratio of kharif to Rabi 1:2 $\left(C.R. = \frac{2500}{5000} = 1:2\right)$

Crop Season :-
→ The period during which some particular types of crops can be grown every year on the same land is known as crop season.

(a) Kharif Season :-
→ This season ranges from June to October. The crops are sown in the very beginning of monsoon and harvested at the end of autumn.
→ The major kharif crops are - Rice, Millet, Maize, Jute, Groundnut, etc.

(b) Rabi Season :-
→ This season ranges from October to March. The crops are sown in the very beginning of winter and harvested at the end of spring. The major Rabi crops are - Wheat, Gram, Mustard, ~~Rep~~ Rapeseed, Linseed, Pulses, Onion, etc.

Cash Crop :-
→ The crops which are cultivated by the farmers to sell in the market to meet their financial requirements are known as cash crops.

-> The crops like vegetables, fruits, etc are considered as cash crops.

Crop Rotation:-

-> The process of changing the type of crop for the cultivation on the same land is known as crop rotation.

-> It is found that if same crop is cultivated on the same land every year, the fertility of the land gets reduced and the yield of crop also gradually reduces.

Crop period:-

-> The crop period is defined as the total period from the time of sowing a crop to the time of harvesting it. That, means, it is the period in which the crop remains in the field.

Overlap Allowance

-> Sometimes a crop of one season may overlap the next crop season by a few days more which it requires to mature.

-> During the period of overlapping the irrigation water is to be supplied. Simultaneously to the crops of both the seasons.

Time factor

-> The ratio of the number of days the canal has actually been kept open to the number of days the canal was designed to remain open during the ... time factor, ... is known as

For example :- a canal was designed to be kept open for 15 days, but it was practically kept open for 10 days for supplying water to the culturable area. Then the time factor is $\frac{10}{15}$.

$$\text{Time factor} = \frac{\text{No. of days the canal practically kept open}}{\text{No. of days the canal was designed to keep open.}}$$

$$= \frac{\text{Actual discharge}}{\text{designed discharge.}}$$

Number of watering :-

-> The total depth of water required by a crop is not supplied at one time.

-> But, it is supplied over the base period by stages depending upon the requirement.

-> The initial watering which is done on the land to provide moisture to the soil just before sowing any crop is known as paleo or paleva.

Cumec Day :-

-> The quantity of water flowing continuously for one day at the rate of one cumec is known as cumec - day.

$$1 \text{ cumec - day} = \frac{1m^3}{sec} \times 24 \times 60 \times 60 \text{ secs.}$$

$$= 24 \times 60 \times 60 m^3$$

$$= \frac{24 \times 60 \times 60}{10,000} \times 1m.$$

$$= 8.64 \text{ hectare - metre}$$

Base :- The base is defined as the period from the first to the last watering of the crop just before its maturity.

→ It is also known as base period.

→ It is denoted by 'B' and expressed in number of days.

Crop	Base in days
Rice	120
Wheat	120
Maize	100
Cotton	200
Sugarcane	320

Delta :-

→ Each crop requires certain amount of water per hectare for its maturity.

→ If the total amount of water supplied to the crop (from first to last watering) is stored on the land without any loss, ~~then~~ there will be a thick layer of water standing on that land.

Kharif crop	Delta in cm
Rice	125
Maize	45
Ground nut	30
Millet	30

Rabi crop	Delta in cm
Wheat	
Mustard	40

Duty:

→ The duty of water is defined as number of hectares that can be irrigated by constant supply of water at the rate of one cumec throughout the base period.

Crop	Duty in hectares/cumec
Rice	900
Wheat	1800
Cotton	1400
Sugarcane	800

✓ Relation between Base, Delta and Duty:

D - Duty of water in hectares / cumec

B - Base in days.

Δ - Delta in m.

From definition, one cumec of water flowing continuously for 'B' days gives a depth of water Δ over an area 'D' hectares, that is

1 cumec for B days gives Δ over D hectares.

or 1 cumec for 1 days gives Δ over $\frac{D}{B}$ hectares.

or 1 cumec for 1 day = $\frac{D}{B} \times \Delta$ hectare - metre.

so, 1 cumec-day = $\frac{D}{B} \times \Delta$ hectare

Again, 1 cumec day = $1 \times 24 \times 60 \times 60 = 86400 m^3$

$= 8.64$ hectare - metre.

(1 hectare $= 10,000 m^2$)

From (1) and (2)

$\frac{D}{B} \times \Delta = 8.64$

Field capacity:-

-> The field capacity is defined as the amount of maximum moisture that can be held by the soil against gravity. It is expressed as percentage.

Permanent wilting point:-

-> The permanent wilting point is defined as the amount of ~~moisture~~ moisture held by soil which cannot be extracted by the plant roots for transpiration.

-> At this point the wilting of the plant occurs.

-> It is also expressed in percentage.

Numericals

Problem - 1

A channel is to be designed for irrigating 5000 hectares in kharif crop and 4000 hectares in Rabi crop. The water requirement for kharif and Rabi are 60cm and 25cm, respectively. The kor period for kharif is 3 weeks and for Rabi is 4 weeks. Determine the discharge of the channel for which it is to be designed.

=> Given data.

Kharif crop

CCA = 5000 hactares.

A = 60cm = 0.6m

B = 3 weeks = 3×7 = 21 days.

$$A = \frac{8.64 \times B}{D}$$

$$0.6 = \frac{8.64 \times 21}{D}$$

$$D = \frac{8.64 \times 21}{0.6}$$

$= 302.4$ heactare/cumec.

$$D = \frac{CCA}{Q}$$

$$Q = \frac{CCA}{D} = \frac{5000}{302.4} = 16.53 \text{ cumec.}$$

Rabi crop

CCA = 4000 hectares

A = 25 cm = 0.25 m.

B = 4 weeks

= 4 × 7 = 28 days.

$$D = \frac{8.64B}{A}$$

$$= \frac{8.64 \times 28}{0.25} = 967.68 \text{ hectares/cumec.}$$

$$Q = \frac{CCA}{D} = \frac{4000}{967.68} = 4.13 \text{ cumec.}$$

So, the channel is to be design as per the max^m discharge, i.e the discharge of kharif crop.

Problem - 2

The gross command area of an irrigation project is 1.5 lakh hectares, where 7,500 hectares are unculturable. The area of kharif crop is 60,000 hectares and that of Rabi crop is 40,000 hectares, The duty of kharif is 3000 hectares/cumec and the duty of Rabi is 4000 hectares/cumec.

Find (a) The design discharge of channel assuming 10% transmission loss.

(b) Intensity of irrigation for kharif and Rabi

⇒ Given data,

GCA = 150000 hectare

unculturable Area = 7500 hectare.

CCA = GCA − UCA

= 150000 − 7500 = 142500 hectare.

Kharif crop

A = 60,000 hectare

D = 3000 hectare/cumec.

$Q = \frac{A}{D} = \frac{60,000}{3000} = 20$ cumec.

Considering 10% transmission loss.

Design discharge $= \frac{110}{100} \times 20 = 22$ cumec.

Rabi crop

A = 40,000 hectare

D = 4000 hectare/cumec.

$Q = \frac{A}{D} = \frac{40,000}{4000} = 10$ cumec.

Considering 10% transmission loss.

Design discharge $= \frac{110}{100} \times 10 = 11$ cumec.

i) The design discharge of the channel is the max^m discharge of Rabi & Kharif crop. i.e 22 cumec.

ii) Intensity of irrigation for Kharif (a)

$= \frac{A}{CCA} \times 100$

$= \frac{60,000}{142500} \times 100 = 42.11\%$

Intensity of irrigation for Rabi (a)

$= \frac{40,000}{142500} \times 100 = 28.07\%$

Problem-3

The gross command area of an irrigation project is 1 lakh hectares. The culturable command area is 75% of G.C.A. The intensities of irrigation for Kharif and Rabi are 50% and 55% respectively. If the duties for Kharif and Rabi are 1200 hectare/cumec and 1400 hectares/cumec respectively determine the discharge at the head of the canal considering 20% provisions for transmission loss, overlap allowance, evaporation loss etc.

→ Given data,

GCA = 100000 hectare

CCA = 75% of GCA

$= \frac{75}{100} \times 100000$

= 75000 hectare

η kharif = 50%

η Rabi = 55%

D kharif = 1200 hactare / cumec

D Rabi = 1400 hactare / cumec

<u>Kharif crop</u>

$$\eta = \frac{A}{CCA} \times 100$$

$$50 = \frac{A}{75000} \times 100$$

$$A = \frac{50 \times 75000}{100} = 37500 \text{ hectare.}$$

$$Q = \frac{A}{D} = \frac{37500}{1200} = 31.25 \text{ cumec.}$$

<u>Rabi crop</u>

$$\eta = \frac{A}{CCA} \times 100 .$$

$$A = \frac{\eta \times CCA}{100}$$

$$= \frac{55 \times 75000}{100} = 41250 \text{ hectare.}$$

$$Q = \frac{A}{D} = \frac{41250}{1400} = 29.46 \text{ cumec.}$$

Discharge = 31.25 cumec.

Required discharge at the head of canal

$$= \frac{120}{100} \times 31.25 = 37.5 \text{ cumec.}$$

Determine the head discharge of a canal from the following data. The value of time factor may be assumed as 0.75.

Crop	Base Period in days	Area in hectare	Duty in hectares/cumec
Rice	120	4000	1500
Wheat	120	3500	2000
Sugarcane	310	3000	1200.

⇒ Given data,

Time factor = 0.75.

Rice

B = 120 days

A = 4000 hectare

D = 1500 hectare / cumec.

$$\text{Discharge}(Q) = \frac{A}{D}$$

$$= \frac{4000}{1500} = 2.667 \text{ cumec. (Kharif)}$$

$$\Delta = \frac{8.64 \times B}{D} = \frac{8.64 \times 120}{1500} = 0.69\text{m}.$$

Wheat

B = 120 days

A = 3500 hectare

D = 2000 hectare / cumec.

$$Q = \frac{A}{D} = \frac{3500}{2000} = 1.750 \text{ cumec (Rabi.)}$$

$$\Delta = \frac{8.64 \times B}{} = \frac{8.64 \times 120}{} = 0.51\text{m}$$

Sugar Cane

A = 3000 hectare

B = 310 days

D = 1200 hectare / cumec

$Q = \frac{A}{D} = \frac{3000}{1200} = 2.5$ cumec (Perennial)

Kharif season = Rice + Sugarcane.

Discharge required in kharif season

$= 2.667 + 2.5$

$= 5.167$ cumec

Discharge required in Rabi season = wheat + sugar cane $= 1.750 + 2.5$

$= 4.200$ cumec.

So, the maximum discharge in kharif season i.e 5.167 cumec.

Design discharge

Time factor = $\frac{\text{Actual discharge}}{\text{Design discharge}}$

$= 0.75 = \frac{5.167}{\text{Design discharge}}$

⇒ Design discharge $= \frac{5.167}{0.75} = 0.889$ cumec.

Problem - 5

Find out the Capacity of a reservoir from the following data, The culturable command area is 80,000 hectares.

Crop	Base in days	Duty in hect/cumec	Intensity of irrigation in percentage
Rice	120	1800	25
Wheat	120	2000	30
Sugarcane	320	2500	20.

⇒ Given data,

CCA = 80,000 hectares.

Rice

B = 120 days

~~A = 1800 hect.~~

D = 1800 hectare/cumec.

$\eta = 25\ \%$

$$A = \frac{8.64 \times B}{D} = \frac{8.64 \times 120}{1800} = 0.576 m.$$

$$\eta = \frac{A}{CCA} \times 100$$

$$25 = \frac{A}{80,000} \times 100$$

$$A = \frac{25 \times 80,000}{100}$$

= 20,000 hectare.

volume of water for rice

$= A \times \Delta$

$= 20,000 \times 0.576$

= 11520 hectare-m

Wheat

B = 120 days

D = 2000 h/m.

η = 30%

$$\Delta = \frac{8.64 \times B}{D} = \frac{8.64 \times 120}{2000}$$

$= 0.518 m.$

$$\eta = \frac{A}{CCA} \times 100.$$

$$30 = \frac{A}{80,000} \times 100$$

$$A = \frac{30 \times 80,000}{100} = 24000 \text{ hectare.}$$

Volume of water for wheat

$= A \times \Delta$

$= 24000 \times 0.518$

$= 12432$ hectare - m.

<u>Sugarcane</u>

B = 320 days

D = 2500 h/m

η = 20%

$$\Delta = \frac{8.64 \times 320}{2500} = 1.106 m$$

$$\eta = \frac{A}{CCA} \times 100$$

$$20 = \frac{A}{80,000} \times 100$$

$$= \frac{20 \times 80,000}{100} = 16000 \text{ hectare}$$

Volume of water for Sugarcane

$= A \times \Delta$

$= 17696$ hectare - m.

Total volume = 11520+12432+17696

= 41648 hectare-metre.

Considering 5% canal loss,

Total volume in canal = $\frac{105}{100} \times 41648$

= 43730.4 hectare-m.

Considering 10% reservoir loss,

$= \frac{110}{100} \times 43730.4 = 48103.44$ h-m.

The capacity of reservoir is 48103.44 h-m.

Problem - 6

The command area of a channel is 4000 hectare. The intensity of irrigation of a crop is 70%. The crop requires 60cm of water in 15 days, when the effective rainfall is recorded as 15 cm during that period.

Find, (a) The duty at the head of field.

(b) The duty at the head of channel.

(c) The head discharge at the head of channel.

⇒ Given data,

CCA = 4000 hectare.

$\eta = 70\%$

The depth of water required = 60 cm = 0.6 m.

B = 15 days,

$\Delta = 60 - 15 = 45$ cm

= 0.45 cm.

$\Delta = \frac{8.64 \times B}{}$

$$D = \frac{8.64 \times B}{\Delta}$$

$$= \frac{8.64 \times 15}{0.45} = 288 \text{ hectare.}$$

The Duty at the head of feild is 288 h/cumec

ii) Duty at the head of channel by considering 15% total loss,

$$\frac{85}{100} \times 288 = 244.8 \text{ hectare/cumec.}$$

$$\eta = \frac{A}{CCA} \times 100$$

$$70 = \frac{A}{4000} \times 100$$

$$A = \frac{4000 \times 70}{100}$$

$$= 2800 \text{ hectare}$$

iii) Head discharge at the head of channel

$$(Q) = \frac{A}{D} = \frac{2800}{244.8} = 11.438 \text{ cumec.}$$

Hydrology

→ Hydrology is the science of which deals with the occurance distribution & movement of water of the earth including that in the atmosphere & below the Surface of the earth.

→ Water occurs in the atmosphere in the form of vapour, on the surface as water, snow or ice & below the surface as ground water occuping all the voids.

Precipitation / Rain fall :-

→ The water which comes back to the surface of the earth in its various forms like rain, snow, hail etc is known as precipitation.
hail = small pieces of ice.

Hydrological cycle :-

i) Precipitation
ii) Evaporation
iii) Infiltration
iv) condensation

} key words.

→ It is the process of depletion & replanishment of water resources.

→ The water of the universe always changes from one state to another state under the effect of the sun.

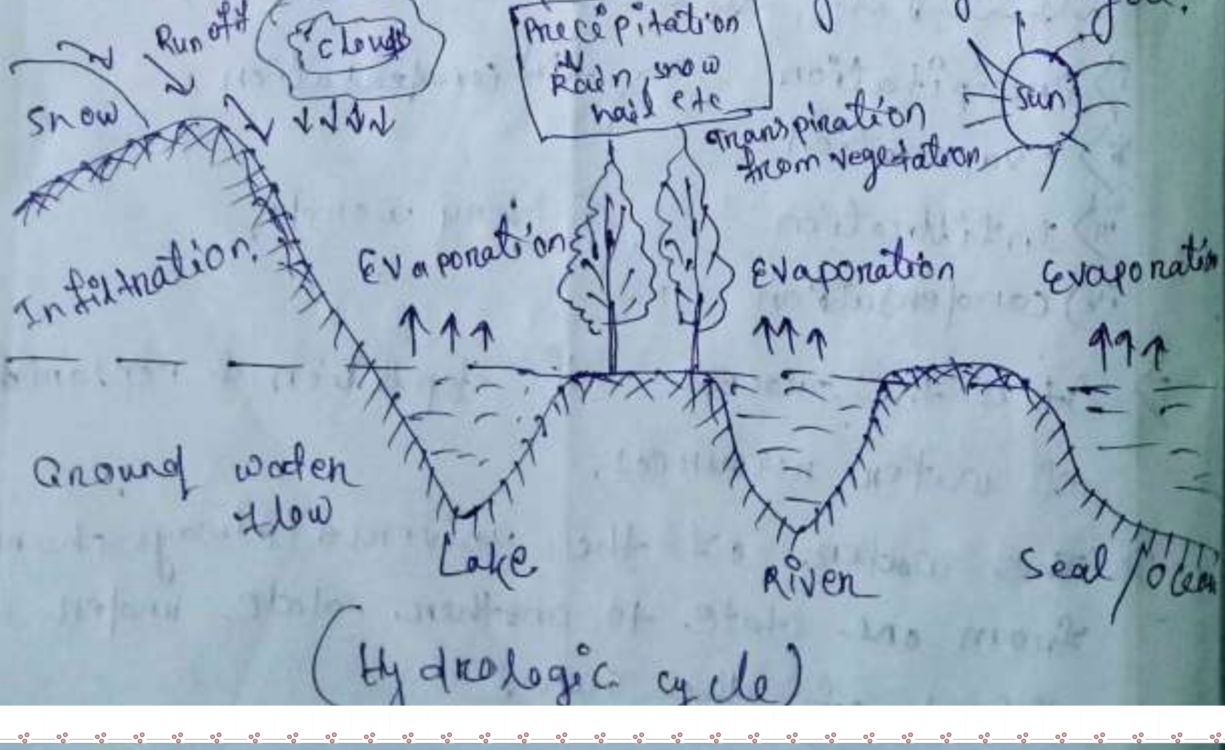
-> The water from the surface sources like lakes, rivers, oceans etc. converts to vapour by evaporation due to solar heat.

-> The vapour goes on accumulating continuously in the atmosphere.

-> This vapour is again condensed due to the sudden fall of temperature & pressure. Thus clouds are formed. These cloud again cause the precipitation.

-> Some of the vapour is converted to ice at the peak of the mountains.

-> The ice again melts in summer & close as river to meet the sea or ocean. This process of evaporation precipitation & melting of ice goes on - continuously like an end less chain & ~~thees a~~ thus a balance is maintain in the atmosphere. this ~~phenomea~~ phenomenon is known as hydrologic cycle.



(Hydrologic cycle)

Precipitation & rain fall & its measurement :-

-> From the principle of hydrology cycle, water goes on evaporation continuously from the water surface on earth by the effects of sun.

-> The water vapour goes on collecting in the atmosphere up to a certain limit. when this limit exceed & temperature & pressure called to contain vals the water vapour will get condensed & their by cloud is formed & return to the earth in the form rain, snowfall, hail etc.

-> this is known as rainfall or precipitation.

Types of rainfall :-

i) cyclonic precipitation
ii) convective precipitation.
iii) Orographic precipitation.

- Depending upon the various atmospheric condition the precipitation & rain fall may be of the above type.

i) cyclonic precipitation :-

-> This type of precipitation is caused by the difference of pressure with in the air mass on the surface on the earth. If low pressure is generated at some place the warm moisture from the surrounding area

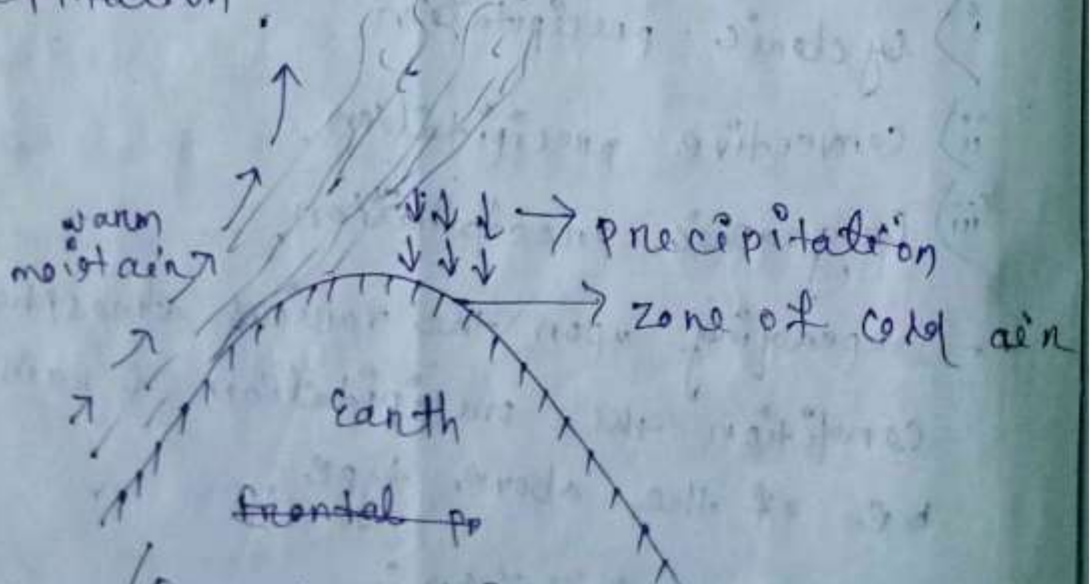
moves to the zone of low pressure with

violent fone, the warm moist air rises up with whirling motion, & gets condensed at higher altitude & ultimately heavy rainfall occur.

-> It is of two types.
(a) Frontal
(b) Non-frontal.

(a) Frontal precipitation:-

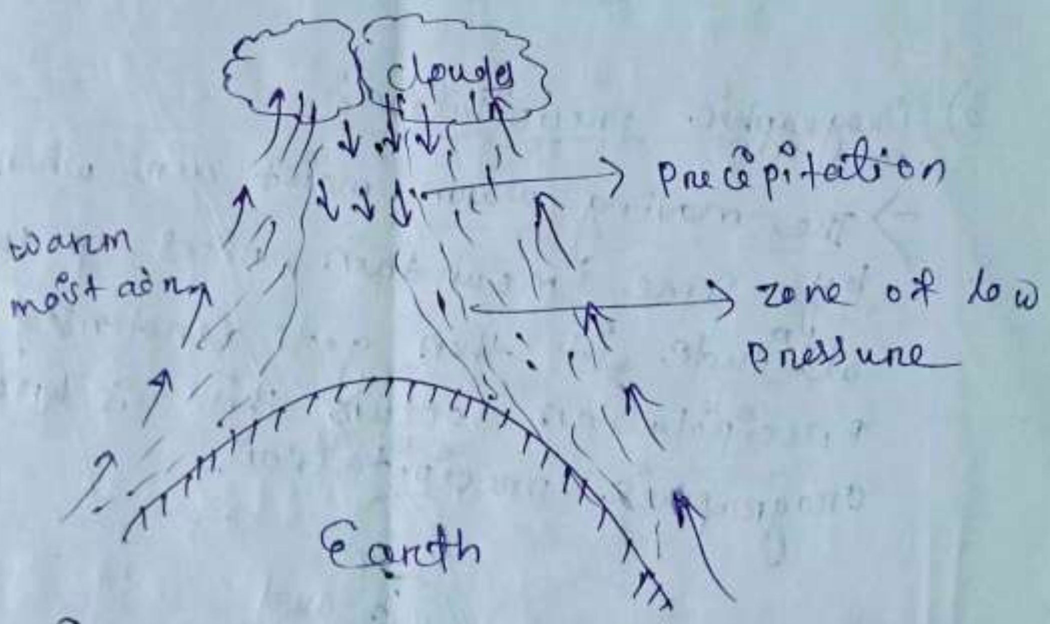
-> When the moving warm moist air mass is ~~ops~~ abstructed by the zone of cold air mass the warm moist air rises up (as it is lighter than cold air mass) to higher altitude where it gets condensed & heavy rainfall occurs. This is known as frontal precipitation.



(Frontal precipitation)

(b) Non-frontal

-> When the warm moist air mass rushes to the zone of low pressure from the surrounding air a pocket is form & the warm moist air rises up like a chimney towards higher altitude & this air mass gets condensed & heavy rainfall occur.
This is known as non-frontal precipitation



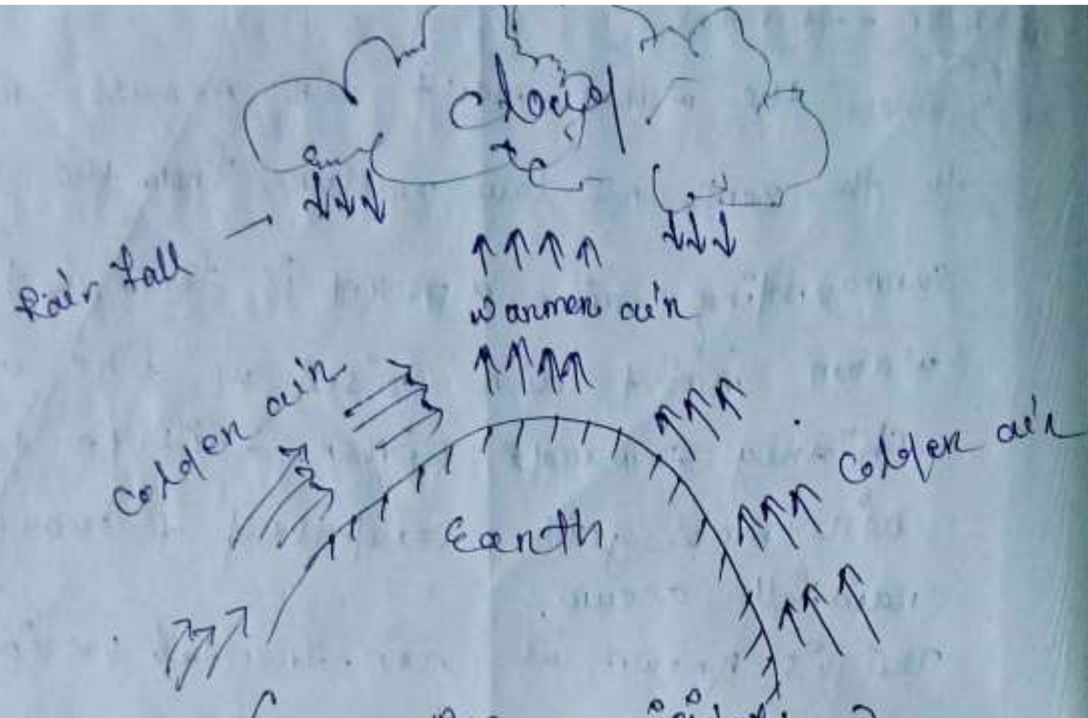
(Non-frontal precipitation)

2) Convective precipitation :-

-> In tropical country when a particular hot-day the ground surface gets heated un equally, the warm air is lifted to high altitude & the cooler air takes its place with high velocity thus the warm moist air mass is condensed at high altitude causing heavy rainfall. This i...

rainfall.

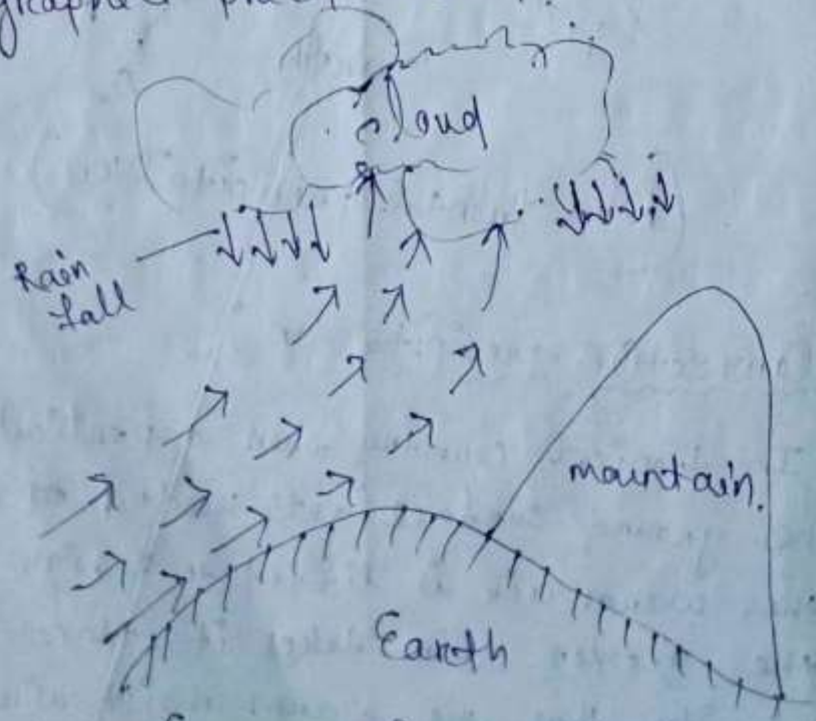
-> in wate...



(convective precipitation)

3) Orographic precipitation:-

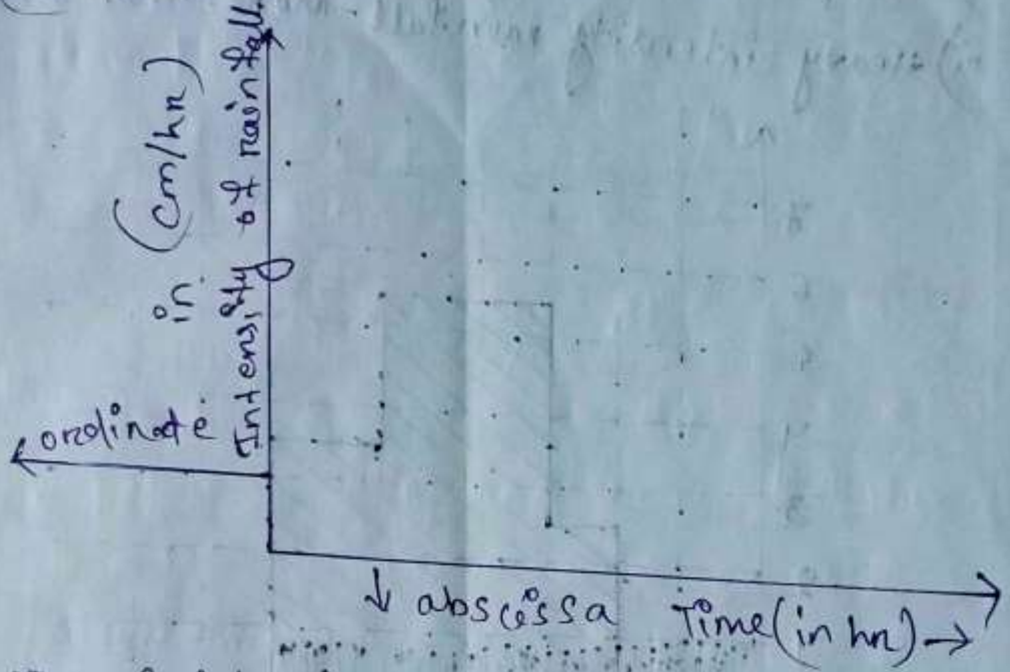
-> The moving warm moist air when obstructed by some mountain, rises up to high altitude it then gets condensed & precipitation occur this is known as orographic precipitation.



(orographic precipitation)

Hyetograph :- The graphical representation of rainfall & run off is known as hyetograph.

-> The graph is prepared with intensity of rainfall (in cm/hr) on ordinate and time (in hours) as abscissa.



-> The infiltration capacity curve is down on this graph to show the amount of loss (shown by dotted portion).

-> The upper portion indicates the effective rainfall (shows by hatched line).

-> The centroid of the effective rainfall is ascertained of the graph for determination of total turn off at any specified period.

Intensity of rainfall :- It is defined as the rate at which rainfall occurs & expressed as cm/hr or mm/hr.

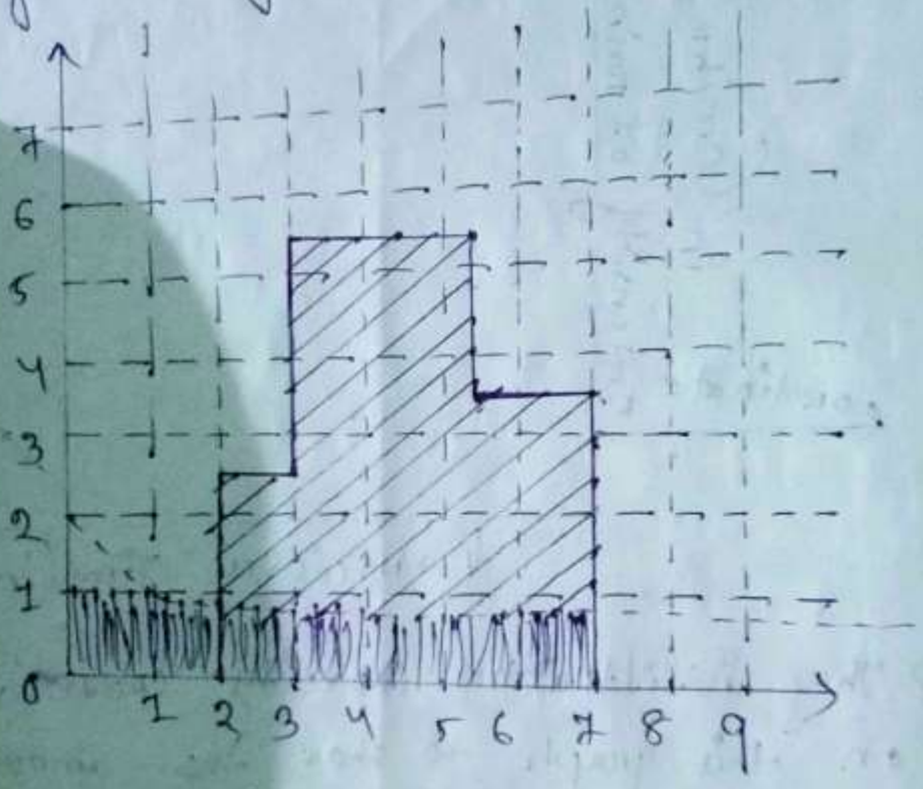
$i = \frac{P}{t} = \frac{\text{depth of rainfall}}{\text{duration of rainfall}} = \frac{\text{amount of rainfall}}{\text{duration}}$

→ It is of three types.

i) Light intensity rainfall = 2.5 mm/hr.

ii) Moderate intensity rainfall - 2.5 - 7.5 mm/hr

iii) Heavy intensity rainfall - More than 7.5 mm/hr.



Measurement of rainfall :-

The instrument which is used to measure the amount of rainfall is known as raingauge.

→ The principle of raingauge is that the amount of rainfall in a small area will present the amount of rainfall in a large area provided the metrological characteristics of both small & large area are similar.

Types of Raingauge :-

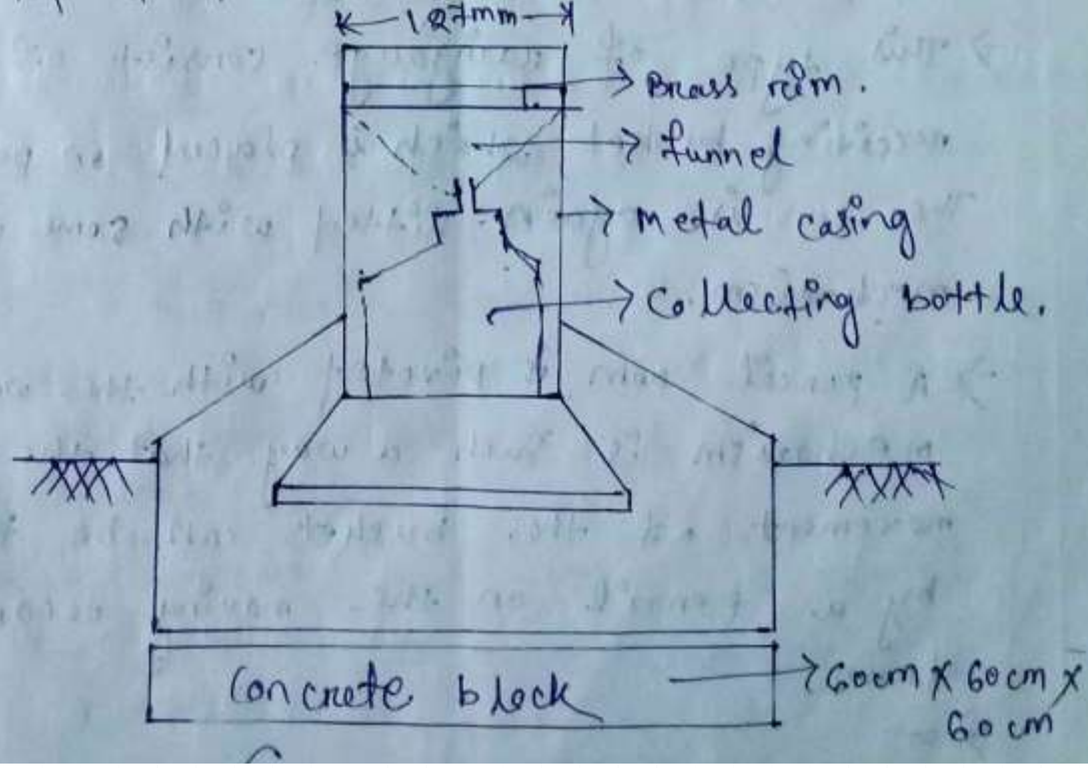
1) Non-recording type raingauge (Non-Automatic)
2) Recording type raingauge (Automatic)
-> a) weighing bucket raingauge
-> b) Tipping bucket raingauge.
-> c) Float type raingauge.

1) Non-recording type raingauge :-

-> Symon's raingauge is a non-recording type raingauge which is most commonly used. It consist of metal casing of diameter 127mm, which is set on concrete foundation.

-> A glass bottle of capacity about 100mm of rainfall is placed within the casing.

-> A funnel with brass rim is placed on the top of the bottle.



(Symon's Raingauge)

-> The rainfall is recorded at every 24 hrs. In case of heavy rainfall the measurement should be taken 2-3 times daily, so that bottle does not over flow.

-> To measure the
is taken off & the collected water is measured.

2) Recording type raingauge :-

-> In this type of raingauge the amount of rainfall is automatically recorded on a graph paper by some mechanical device & noportion is required for ~~measuremen~~ measuring the amount of rainfall from the container.

(a) Weighing bucket raingauge :-

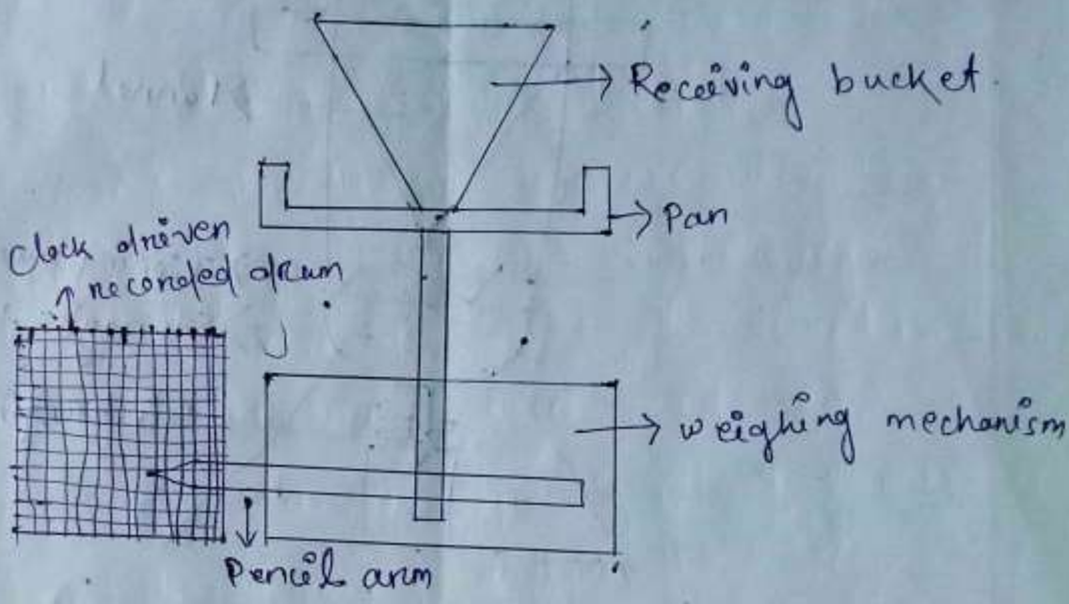
-> This type of raingauge consist of a receiving bucket which is placed on pan. The pan is again fitted with some weighing mechanism.

-> A pencil arm is pivoted with the weighing mechanism is such a way that the movement of the bucket can be tressed by a pencil on the moving recording drum.

->

the water is collected in the bucket the increasing weight of water is transmitted through the pencil which traces a curve on the recording drum.

-> The raingauge produces a graph of cumulative rainfall vs time.



(Weighing bucket raingauge)

b) Tipping bucket raingauge :-

-> It consist of a circular collector of diameter 80 cm in which the rain water is initially collected.

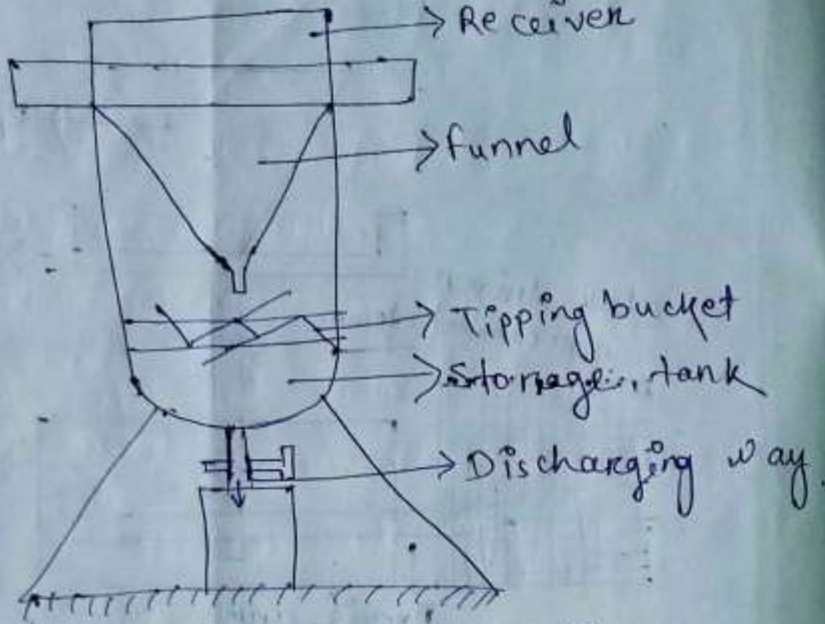
-> The rainwater is then passes through a funnel fitted to the circular collector & gets collected in two compartment tipping bucket pivoted below the funnel.

-> When 0.25mm rain water is collected in one bucket then it tips & discharges the water to the storage tank.

-> At the same time the other bucket comes below the funnel & rain water goes on collecting in it & then

-> In this way a circular motion is generated by the buckets which is transmitted to a pencil (which traces a wave like curve) on the sheet mounted on a revolving drum.

-> The total rainfall may be ascertained from the graph.



(Tipping bucket raingauge.)

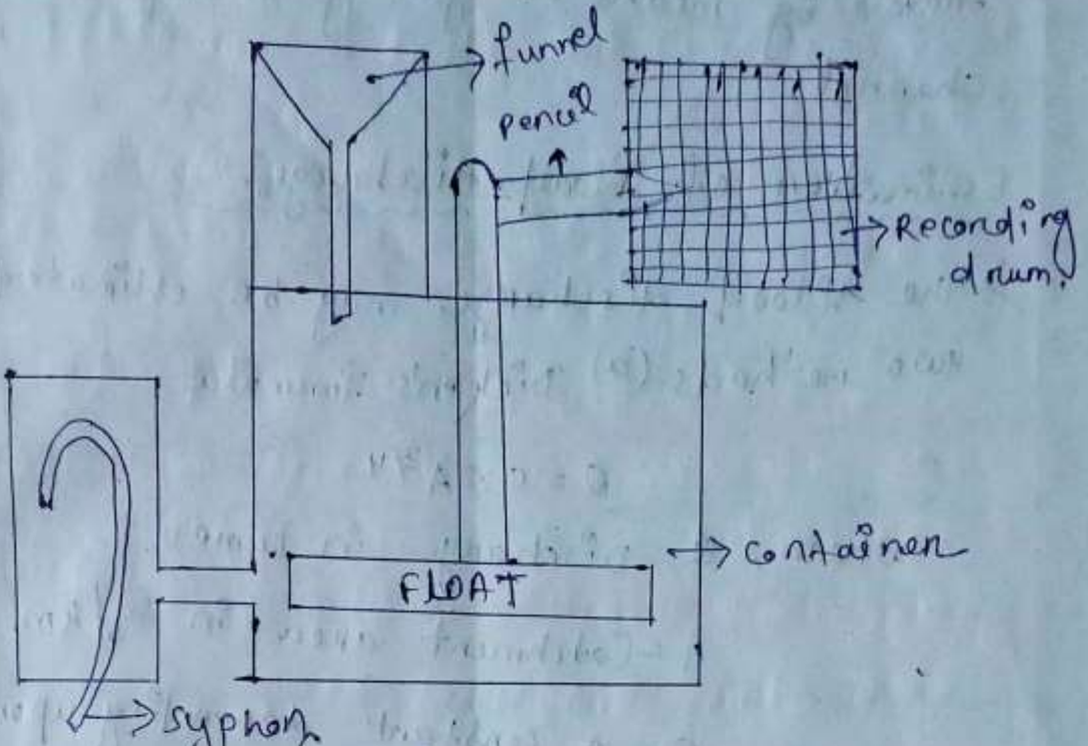
-> In this type of raingauge a funnel is provided at one end of rectangular container & rotating recording drum is provided at the another end.

-> The rain water enters the container through the funnel.

-> A float is provided with the container which rises up as the rainwater gets collected there.

-> The float consist of a rod. which contains a ~~pencil~~ pencil arm for recording the amount of rainfall on the graph papper dropped

→ It consist of a syphon which start functioning when the float rises to some definite height & the container goes on emptying gradually.



(float type Raingauge)

Catchment area:-

→ A hydrological catchment is defined as the area of land point (usually the sea).

→ A hydrological catchment can very widely in size & other characteristics such as slope, geology, land use & may content different combination of fresh water bodies (surface water & ground water) & costal water.

Run off:- Run off or surface run off in hydrology is defined as the quantity of water discharged in surface streams.

-> Run off includes the waters that travel over the land surface & also interflow that is the water that infiltration the soil surface & travels by means of gravity towards a stream channel.

Estimation of flood discharge:-

-> The flood discharge may be estimated by two methods (a) Dicken's formula

$$Q = C \times A^{3/4}$$

where, Q = Discharge in cumec.

A = Catchment area in sq/km.

C = A constant depending upon the factors affecting flood discharge.

= 11.5 is considered.

b) Ryve's formula

$$Q = C \times A^{2/3}$$

where, Q = Discharge in cumec.

A = Catchment area is sq km.

C = Average value considered as 6.8.

Hydrograph:-

-> The hydrograph is a graphical representation of the discharge of river (in cumec) against the time (in hr/days).

-> In rainy season at the biging of the rainfall there is only base flow (

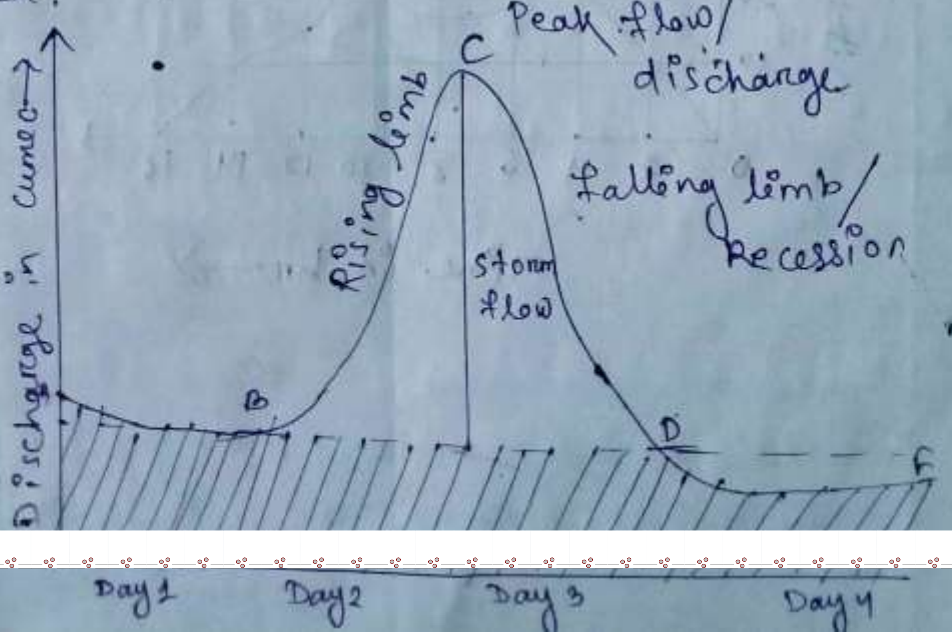
-> After some period when the some lossel (like evaporation & infiltration) are fulfilled, the surface run off ~~stat stapt~~ start & hence the discharge of river goes increasing. Hence, the limb of the curve rises which is called rising limb (shown by the line BC).

-> The line reachest to the peak value at C.

-> Again when the rain stops the flow in the river decreases & the limb of the curve declines. This limb is known as the ~~rescession~~ recession limb (shown by the line CD).

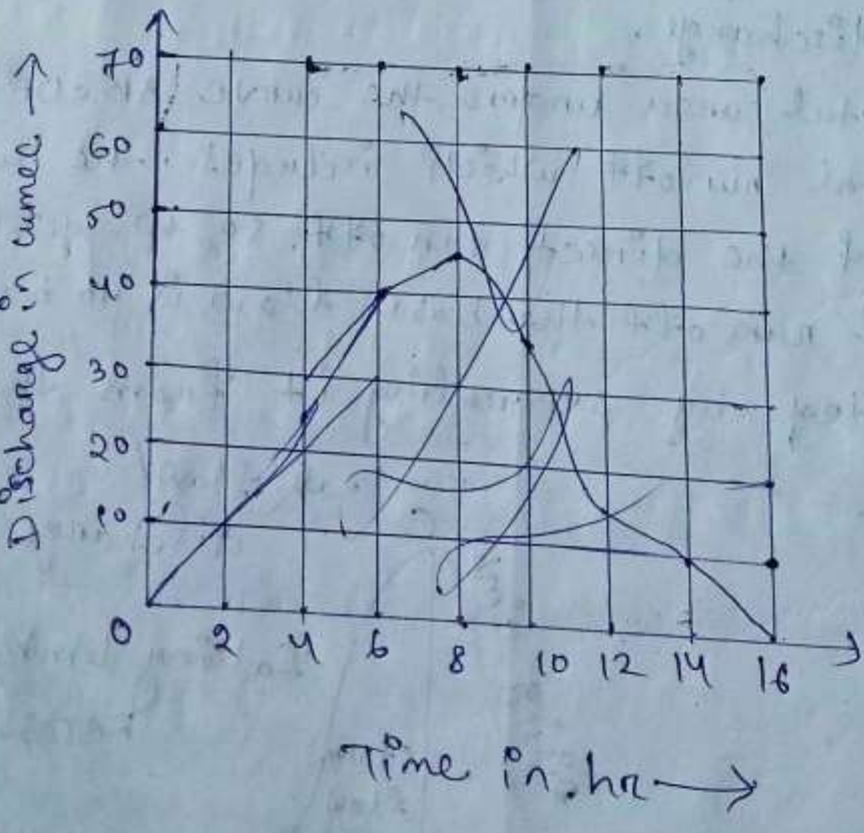
-> The discharge at the point 'C' indicate the max^m discharge.

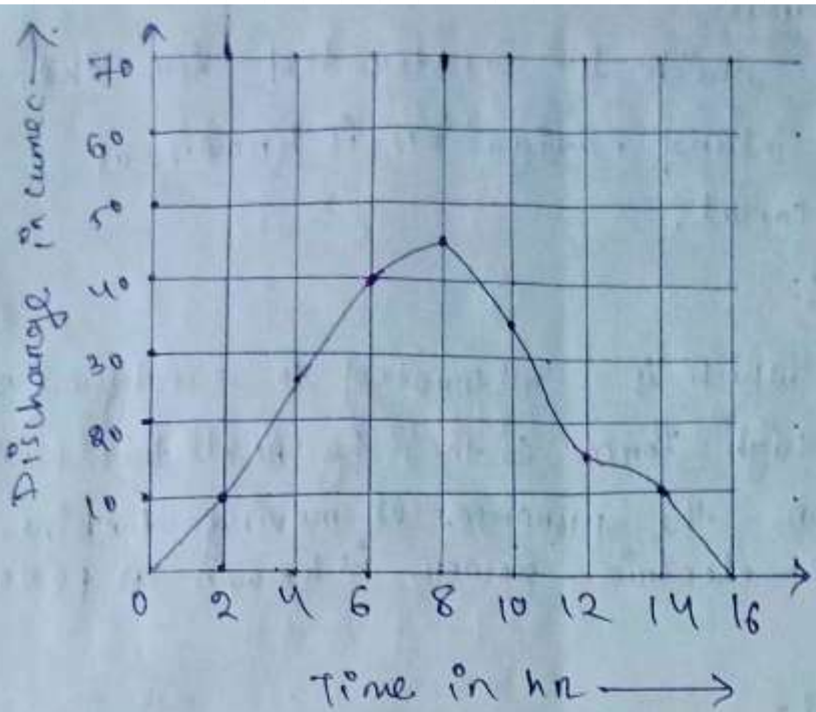
-> The total area under the curve ABCDE indicates the total run off which includes the base flow & the direct run off. So, to get the actual run off the base flow is to be deducted by separating it from the total area.



Unit hydrograph :-

- A unit hydrograph may be defined as a hydrograph which is obtained from 1cm of effective rainfall (that is run off) per unit duration
- Here effective rainfall means the rainfall excess i.e - Run off which directly flows to the river or stream.
- The unit duration is the period during which the effective rainfall is assume to be uniformly distributed.
- The unit duration may be considered as 1hrs, 2hrs, 3hrs, 4hrs, etc.





Chapter-04 FLOW IRRIGATION

-> The irrigation system in which the water flows under gravity from the source to agricultural land is known as flow irrigation.

Perennial irrigation:-

-> In this ~~system~~ irrigation water is available through out the year, Hydrolic structures are necessary across the river for rising the water level.

Types of canal:-

1) Based on the purpose :-

-> Based on the purpose of service the canals are of four types.

(a) **Irrigation canal:-**

-> The canal which is constructed to carry out water from the source to the agricultural land for the ~~purf~~ purpose of irrigation is

b) Navigation canal :-

-> The canal which is constructed for the purpose of inland navigation is known as navigation canal,

c) Power Canal :-

-> The canal which is constructed to supply water with very high force to the hydro electric power station for the purpose of moving turbine to generate electric power is known as power canal.

d) Feeder canal :-

-> The canal which is constructed to feed another canal or river for the purpose of irrigation or navigation is known as feeder canal.

2) Based on the nature of supply :-

-> Based on the nature of supply the canal are 2 types,

a) Inundation canal :- The canal which is excavated from the banks of the inundation river to carry the water to agricultural land in rainy season only is known as inundation canal.

b) Perennial canal :- The canal which can supply water to the agricultural land throughout the year is known as perennial canal.

3) Based on discharge :-

-> According to discharge capacity the canals are :-

a) Main canal :- The large canal which is taken directly from the diversion head work or from the storage to supply water to the network of the small canal is known as main canal.

b) Branch canal :- The branch canal are taken from either side of the main canal at suitable points so that the whole command area can be covered by the networks.

c) Distributory channel :- These channels are taken from the branch canals to supply water to different sectors.

d) Field channel :- These channels are taken from the outlets of the distributory channel by the cultivation to supply water to their own lands.

4) Based on alignment :-

-> Depending upon the alignment the canal are following types.

a) Ridge or water shed canal :-

The canal which is aligned along the ridge line is known as ridge canal. These canals usually take off from the contour canal.

b) Contour canal :- The canal which is aligned approximately parallel to the contour lines is known as contour canal.

c) Side slope canal :-

The canal which is aligned approximately at right angle to the contour lines is known as side slope canal.

Canal section :-

Terms related to canal section:-

(1) Canal bank
(2) Berm
(3) Hydraulic gradient
(4) Counter beam
(5) Free board
(6) Side slope
(7) service road & inspection road
(8) Dowel or Dowla
(9) Borrow pit
(10) Spoil bank
(11) Land width.

1) Canal bank :-

-> The canal bank is necessary to retained water in the canal to the full supply level.

-> According to different side conditions the bank of the canals are of two types.

i) Canal bank of cutting :-

-> The bank are constructed from the both side of the canal to provide only a inspection road.

-> The side slope will 1.5 : 1 or 2 : 1 according to the nature of the soil.

ii) Canal bank in full banking :-

-> Both canal bank are constructed above the ground level. the height of the bank will be high & the section will be large due to hydraulic gradient.

2) Berm :- The distance between toe of the bank & the top edge of the cutting is called berm.

-> The berm is provided following reasons.

i) To protect the bank from erosion.

ii) To provide a space for widening the canal section in future if necessary.

iii) To protect the bank from sliding down towards the canal section.

-> When water is retained by the canal bank the seepage occurs through the body of the bank.

-> Due to the resistance of soil the saturation line forms a slopping line which may pass through ~~country~~ contry side of the bank.

-> The slopping line is known as hydraulic gradient.

Soil	Hydraulic Gradient
clayey soil	1 : 4
Sandy soil	1 : 6
Alluvial soil	1 : 5

4) Free Board :-

-> It is the distance between the full supply level & top of the bank.

-> The amount of free board varies from 0.6m to 0.75m.

-> It is provided for the following reasons :-

i) To keep a sufficient margin so that the Canal water does not over top the bank.

ii) To keep the saturation gradient much below the top of the bank.

5) Dowel :-

-> The protective small embankment which is Provided on the Canal side of the service road for safety of the vehicles playing on it is known as Dowel or dowla.

-> The top width is generally 0.5m & the height of above the road level is about 0.3m.

6) Service road :-

-> The road is provided on the top of the Canal bank for inspection & maintainance work is known a service road or inspection road.

-> For main canal the service roads are provided on both sides of the bank but for branch canal the road is provided on one side of the bank only.

-> The width of the service road for main canal varies from 3-4 m.

7) Counter berm :-

-> When the water is retained by a canal bank the hydraulic gradient line passes through the body of the bank, the gradient should not intercept the outer side of the bank.

-> It should pass through the base & a minimum cover of 0.5m should always be maintained. It may occur that the hydraulic gradient line of the bank in that case a projection is provided on the banks to obtain minimum cover. This projection is known as counter berm.

8) Borrow pits :-

-> When the canal is constructed in partially cutting & partially banking the excavated earth may not be sufficient for forming the required bank.

-> In such case the extra earth required for the construction of banks is taken from some pits which are known as borrow pits.

-> The borrowpit may be inside or outside of the canal. The maximum should be 1m.

d) Spoil bank :-

-> When the canal is constructed in full cutting the excavated earth may be much sufficient for forming the bank.

-> In such case the extra earth is deposited in the form of small bank which is known as spoil bank.

-> The spoil banks are provided on one side or both side of the canal bank depending upon the quantity of extra earth & available space.

iv) Side slope :-

-> The side slope of the canal bank & canal section depends upon the angle of repose of the soil existing on site, so to determine the side slope of different sections the soil sample should be collected from the site & should be tested in the soil testing laboratory

Type of soil	Side slope in cutting	side slop in banking
Clayey soil	1:1	1 1/2 : 1
Alluvial soil	1:1	2:1
Sandy soil loam	1 1/2 :1	2:1

ii) Land width :-

-> The total land width required for construction of canal depends upon the nature of site condition. Such as fully in cutting of fully in banking or partially in cutting or partially in banking.

-> To determine the total width the following dimension should be added.

i) Top width of the canal
ii) Twice the berm width
iii) Twice the bottom width of bank
iv) A margin of 1m from the heel of the bank on both side.
v) Twice of the width of the external borrowpit if any required.
vi) A margin of 0.5m from the outer edge of borrowpit on both sides if external borrowpit becomes necessary.

Balancing depth :-

-> If the quantity of excavated earth can be fully utilised when making the bank on both side ~~then th~~ then that canal section is known as economical section.

-> The depth of cutting for the ideal condition is known as balancing depth.