

2-) measuring "

3-) Cutting "

4-) Holding "

5-) striking "

F P E

Important points:-

- Fluid cannot resist shear force under static condition.
- Fluid deforms continuously under the action of shear force.
- Fluid can never regain its original shape, when the shear force is applied.
- Fluids are called as zero memory substance
- Liquid and gases are example of fluids.

$$1 \text{ m}^3 = 1000 \text{ l}$$

$$1 \text{ m}^3 = 264.172 \text{ gallons}$$

$$1 \text{ l} = 0.264 \text{ gallons}$$

$$1 \text{ TMC} = 28316.8 \text{ m}^3$$

$$1 \text{ TMC} = 2881 \text{ crore litres}$$

$$1 \text{ TMC} = 6.22 \times 10^9 \text{ imperial gallons}$$

FPE

Fluid - A fluid is a substance which is capable of flowing and deforming under the action of shear, no matter how small force may be.

In solids, deformation almost constant with time but in fluids deformation changes with time so in fluids rate of deformation is more important than deformation.

classification of fluid

1) Ideal fluid

- incompressible, no viscosity, ~~no~~ No surface tension, steady flow, irrotational flow
- Imaginary fluid
- Ex - not available in nature

2) Real fluid

- compressible, having viscosity, surface tension
- Present in nature are real
- Ex - water, air, oil, petrol, alcohol, Benzene etc.

3) Newtonian fluid

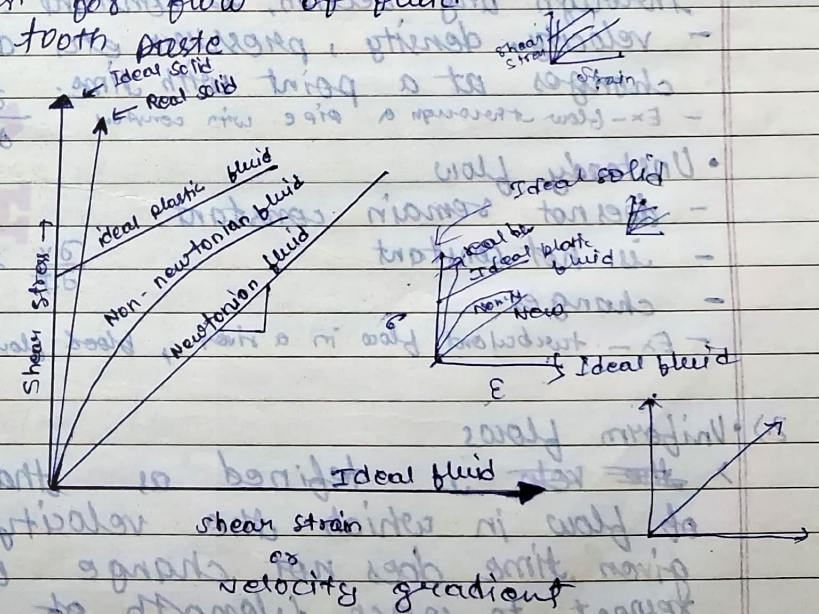
- type of real fluid, shear stress & shear strain
- follows ~~law~~ newton's law of viscosity
- Ex - water, air, alcohol, Benzene etc.
- viscosity remains constant

4) Non-newtonian fluid

- type of real fluid, shear stress & shear strain
- viscosity of fluid changes
- doesn't follow newton's law of viscosity
- Ex - motor oil, Blood, shampoo, food sauces, paints etc.

5) Ideal plastic fluid

- shear stress is more than yield value
- shear stress & shear strain
- we need to provide some yield stress for flow of fluid.
- Ex - tooth paste



N.V.V.S

Types of fluid flow

- steady and unsteady
- uniform and non-uniform
- laminar and turbulent
- compressible and incompressible
- rotational and irrotational

1) Steady flow

- all conditions at any point in a stream remain constant with respect to time.
- the quantity of liquid flowing/sec through any section, is constant
- velocity, density, pressure etc. does not change at a point with time.
- Ex - flow through a pipe with constant

$$\frac{\partial v}{\partial t} = 0$$

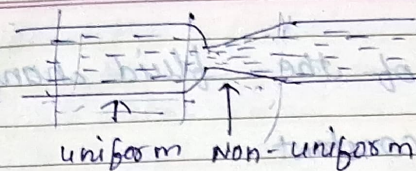
• Unsteady flow

- does not remain constant
- is not constant
- changes
- Ex - turbulent flow in a river, blood flow in arteries

$$\frac{\partial v}{\partial t} \neq 0$$

2) Uniform flows

- > ~~the~~ ~~rate~~ is defined as that type of flow in which the velocity at any given time does not change with respect to space (length of direction of flow)



• Non-uniform flows

- the velocity at any given time change with respect to space (-)

3) Laminar flows

- the fluid particles move along well defined path or stream line & all the streamlines are straight and ||.

Reynolds no helps to predict the flow pattern of fluid

$$Re = \frac{\rho V L}{\mu}$$

ρ ← density
 V ← velocity
 L ← length
 μ ← dynamic viscosity

$$Re < 2000$$

• Turbulent flows

- > fluid particles move in random motion or zig-zag way
- > High losses occurs in this

$$Re > 4000$$

4) Compressible flows

- flow density of the fluid changes point to point.
- density is not constant

• Incompressible flows

- flow density = constant

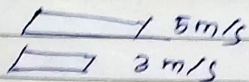
5) Rotational flows

- > In this flow, fluid particles rotates about their own axis while moving along the stream line.

• Irrational flows

- > does not rotates

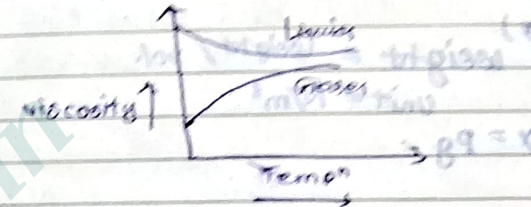
☆ Viscosity - It is the property of fluid which offers resistance to one layer of fluid by another layer



thickness of fluid & viscosity

Newton's law of viscosity = $\frac{\text{shear stress}}{\text{shear strain}}$

viscosity of the fluid is independent of rate of deformation.
eg:- water, air.



Properties of fluid

(P) Density = $\frac{\text{mass}}{\text{Vol.}}$ kg/m³

• Viscosity = A measure of a fluid's resistance to flow (internal friction).

Unit = pascal-second (Pa.s) or poise (P)

(1 Pa.s = 10 poise)

• Tempⁿ = measure of the thermal energy of the fluid.

Unit = kelvin (K), celsius (°C), or fahrenheit (°F)

• Pressure = force / area

Unit = Pascal (Pa) = N/m²

• Specific volume = vol. / mass

= $\frac{1}{\text{density}}$

Unit = $\frac{\text{m}^3}{\text{kg}}$

$$\frac{2 + \frac{1}{2} + 1}{2 + \frac{1}{2} + 1}$$

$$0.9 = \frac{S}{1000} \times 1000$$

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Page _____

(S.G.)

- specific gravity = Specific weight of given fluid (relative density) " " of standard fluid (water = 1000 kg/m³)
— No unit

- Specific ^(γ) weight = weight / vol.
Unit = N/m³
 $\gamma = \rho g$

- Surface tension: Force / unit length
tendency of liquid surfaces at rest to shrink into the minimum surface area possible.

$$\gamma = \frac{F}{L}$$

$$N/m$$

- flow rate: vol. of fluid / unit time
unit = m³/s, L/s or gallons/min (GPM)

(Numericals)

Unit and conversion

- 1) Cubic meter (m³) = volume
1 m³ = 1000 L

- 2) Litres (L):

$$1 \text{ liter} = 1000 \text{ mL}$$

$$" = 0.001 \text{ m}^3$$

- 3) Gallons:

$$1 \text{ gallon} = 3.78541 \text{ L}$$

- 4) TMC (Thousand million cubic feet):
— used in water resource management, mostly in India
1 TMC = 10⁹ cubic feet (ft³)
1 TMC = 28.3168 million m³

2.)

Pascal law

It states that pressure applied to an enclosed fluid will be transmitted without a change in magnitude to every point of the fluid and to the walls of the container.

$$P = F/A$$

$$= N/m^2$$

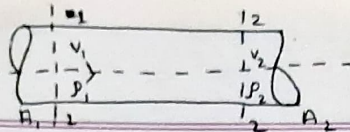
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Eq. of continuity

It is a fundamental principle of fluid dynamics that expresses the conservation of mass in a flowing fluid. It states that, for an incompressible fluid (density ρ is constant), the mass flow rate remain constant along a streamline.

$$A_1 V_1 = A_2 V_2$$

where, • A_1 and A_2 are the cross-sectional areas of the flow at two points (1 and 2).
• V_1 and V_2 are the fluid velocities at those two points.



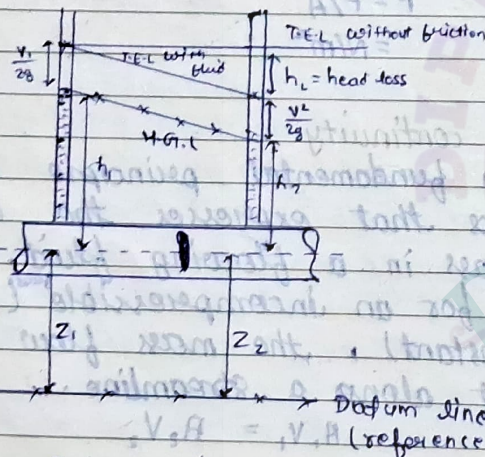
- cross-sectional area A
- velocity of fluid V

In simple words, If no fluid is added or removed from the pipe in any length then the mass passing across diffⁿ sections shall be same.

compressible $\rho_1 A_1 V_1 = \rho_2 A_2 V_2$
 incompressible $A_1 V_1 = A_2 V_2$

$\dot{m}_1 = \dot{m}_2$
 ↑
 mass flow rate
 $\dot{m} = \rho \times A \times V$

concept of total energy



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

$h_1 = \frac{P_1}{\rho g}$
 $h_2 = \frac{P_2}{\rho g}$

Fluid has 3 form of energy
 pressure, potential and kinetic energy

$P_1 > P_2$
 $h_1 > h_2$

$H.G.L = Z_1 + h_1$
 $T.E.L = Z_1 + h_1 + K.E$
 $K.E = \frac{V^2}{2g}$

$\therefore T.E.L = Z_1 + h_1 + \frac{V_1^2}{2g}$

Concept of total Energy:-

In fluids, total energy refers to the sum of diffⁿ forms of energy possessed by the fluid at a given point / unit mass or per unit vol. of a fluid.

These forms of energy can be divided into three primary components:-

1) Kinetic energy (K.E):- The energy possessed by liquid particle by virtue of its velocity or motion. This is the energy due to the motion of the fluid. $K.E = \frac{1}{2} m v^2$

2) Potential Energy (P.E):- The energy possessed by a liquid particle by virtue of its position. This is the energy due to the position of the fluid in a gravitational field. $P.E = mgh$

3) Pressure energy (P.E):- The energy possessed by a liquid particle by virtue

of its existing pressure. This is the energy due to the fluid's pressure.

$$\text{Pre. } E = \frac{P}{\rho} \quad F/A$$

Appli.

Bernoulli's equation and its application

It is a principle of fluid dynamics that describes the behaviour of flowing fluid. It is derived from the conservation of mechanical energy for the flowing fluid which states that the total mechanical energy (pressure energy, kinetic energy and potential energy) along the streamline remains constant, assuming the fluid is incompressible, and there are no friction losses (i.e., it's an ideal fluid).

$$P + K.E + P.E$$

$$\textcircled{1} \quad P + \frac{1}{2} \rho v^2 + \rho g h = \text{constant} \quad \frac{P}{\rho g} + \frac{v^2}{2g} = Z = \text{constant}$$

P = fluid pressure

ρ = " density

v = " velocity

g = gravitational

accelⁿ.

Z/h = height from reference point

$$\textcircled{11} \quad P_1 + \frac{\rho}{2} v_1^2 + \rho g h_1 = P_2 + \frac{\rho}{2} v_2^2 + \rho g h_2$$

$$P.E \propto \frac{1}{K.E} \quad \text{velocity} \propto \frac{1}{\text{Pressure}}$$

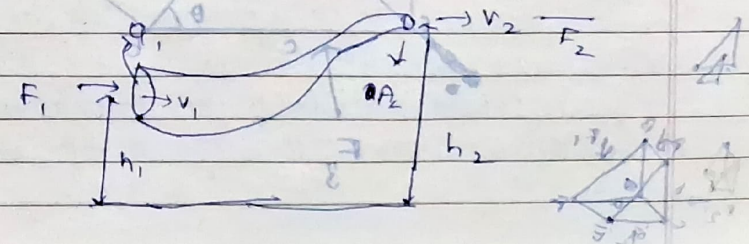
$$\textcircled{111} \quad P_1 - P_2 = \frac{\rho}{2} (v_2^2 - v_1^2) \quad \left| \begin{array}{l} \frac{P_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + Z_2 \end{array} \right.$$

ρ = Pressure density

Limitations of Bernoulli's equation

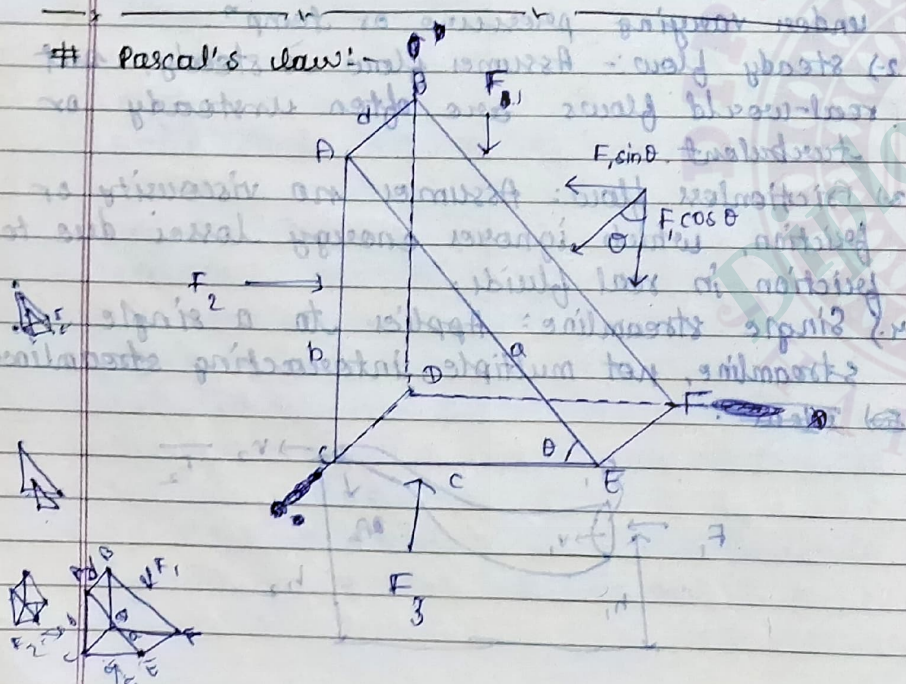
- 1) Incompressible fluids - Assumes the fluid is incompressible, which is not true for gas under varying pressure or tempⁿ.
- 2) steady flow: - Assumes flow is steady, but real-world flows are often unsteady or turbulent.
- 3) Frictionless flow: Assumes no viscosity or friction, which ignores energy losses due to friction in real fluids.
- 4) Single streamline: Applies to a single streamline, not multiple interacting streamlines.

Ideal



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Page _____

- ### # Pascal's law:-



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Also,

$$\sin \theta = \frac{b}{a}$$

$$\cos \theta = \frac{c}{a}$$

$\therefore$ The prism is in equilibrium
 $\therefore$ The net force on the prism will be 0

$$F_1 \sin \theta = F_2$$

$$F_1 \cos \theta = F_3$$

$$P_1 a d \times \frac{b}{a} = P_2 b d \quad (i)$$

$$P_1 a d \times \frac{c}{a} = P_3 c d \quad (ii)$$

Considering width $(d) = 1$

Putting $d=1$ in (i) & (ii)

$$P_1 a \times \frac{b}{a} = P_2 b \times 1$$

$$\Rightarrow P_1 = P_2 \quad (iii)$$

$$P_1 a \times 1 \times \frac{c}{a} = P_3 c \times 1$$

$$P_1 = P_3 \quad (iv)$$

From (iii) & (iv)

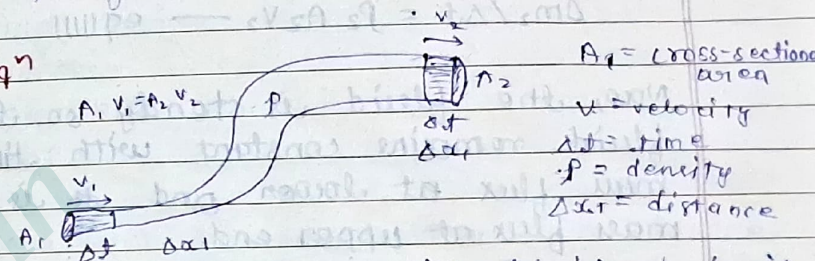
$$P_1 = P_2 = P_3$$

Assumptions

- 1) The fluid is incompressible, at rest (static), homogeneous, enclosed.
- 2) External forces like gravity are either negligible or accounted for.

3) Press. is transmitted equally in all directions within the fluid.

continuity eqⁿ



Now, consider the pipe with fluid of density (ρ) flows for a short interval of time in the pipe, and assume that short interval of time as Δt . In this time Δt , the fluid will cover a distance Δx_1 with a speed or velocity v_1 at the lower end of the pipe to the upper end of pipe v_2 .

The dist. covered by fluid in Δt will be
 $\Delta x_1 = v_1 \Delta t$

Now, the vol. of fluid at lower end of pipe

$$V = A_1 \Delta x_1 = A_1 v_1 \Delta t$$

We know that mass $(m) = \text{Density } (\rho) \times \text{vol. } (V)$,
 so the mass of liquid in Δx_1 will

$$\Delta m_1 = \rho A_1 v_1 \Delta t \quad \text{--- eq (i)}$$

Now, the mass flux (the mass of the fluid/unit time passing through any cross-sectional area) for lower end with area A_1 will be

$$\Delta m_1 / \Delta t = \rho A_1 v_1 \quad \text{--- eq (ii)}$$

And similarly, the mass flux for upper end with area A_2 will be
 $\Delta m_2 / \Delta t = \rho_2 A_2 V_2$ — eq(III)

Now, the fluid is steady so the P of fluid remains constant with time and mass flux at lower end is equal to mass flux at upper end.

$$Eq(II) = Eq(III)$$

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2 \text{ — Eq(IV)}$$

$$\rho A V = \text{const.}$$

This proves the principle of conservation of mass. For steady flow, the P remains constant

$$\rho_1 = \rho_2$$

Thus,

$$A_1 V_1 = A_2 V_2$$

$$A V = \text{constant} = \rho A V = \rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$A_1 V_1 = A_2 V_2$$

$$A_1 V_1 = A_2 V_2$$

Appli. of Bernoulli's eqⁿ:-
 Bernoulli's eqⁿ is applied in the following measuring devices

- 1) venturimeter
- 2) orifice meter
- 3) pitot tube

1) Venturimeter:- A venturimeter is a device used for measuring the rate of a flow of a fluid flowing through a pipe. It is based on the principle of Bernoulli's eqⁿ.

Principle:-

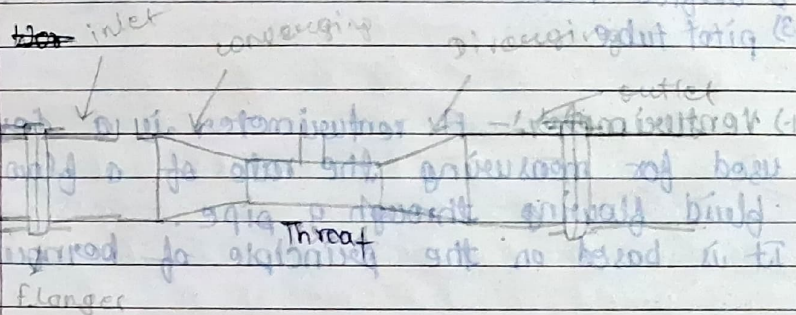
The venturimeter operates on the principle of Bernoulli's eqⁿ, which states in a steady, incompressible flow, the sum of the pressure energy, kinetic energy and potential energy per unit vol. or mass is constant.

Construction:-

A venturimeter consists of three parts are following:-

- i) converging section:- A gradually narrowing section of the pipe where the pipe fluid velocity increases and pressure decreases.
- ii) Throat:- The narrowest section of the venturimeter where the velocity is maximum and pressure is minimum.

iii) Diverging section:- A gradually expanding section where the fluid slows down and pressure recovers to avoid energy losses.



Works on the principle of continuity eqⁿ and Bernoulli's Theorem.

Working:- The fluid enters the venturimeter through the converging section. As the cross-sectional area decreases, the velocity of the fluid increases, causing a drop in pressure at the throat due to Bernoulli's principle. Then the fluid passes through the throat, where the velocity is at its maximum and the pressure is at its minimum.

In the diverging section, the fluid slows down and pressure partially recovers. The pressure difference between the inlet and throat is measured and the flow rate is calculated using the continuity equation and Bernoulli's eqⁿ.

$$P_1 - P_2 = \frac{\rho}{2} (v_1^2 - v_2^2) \quad Q_{act} = C_d \times \frac{Q_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$$

C_d = Co-efficient of venturimeter and value less than 1.

② Orifice meter or orifice plate:-

It is a device used for measuring the rate of flow of a fluid passing through a pipe. It works on the same principle as that of venturimeter. It is cheaper than venturimeter but does not give accurate discharge values as given by venturimeter because of more loss of energy during flow.

Principle:- It is based on the principle of Bernoulli's eqⁿ.

Construction:-

It consists of a flat circular plate which has a circular sharp edged hole

called as orifice and the diameter of orifice is $1/2$ to $3/4$ that of diameter of pipe.

It consists of four parts are below-

(i) Inlet section:- The name inlet section means the fluid will enter into the orifice meter through inlet section.

(ii) Orifice plate:- The orifice plate is situated both the inlet and outlet. It is thin size having one hole from that the water will pass.

(iii) Flow conditioner:- The flow conditioner is used to increase the linear flow in the inlet section of the meter tube.

(iv) Outlet section:- In the outlet section, the pressure of the fluid is being discharged and determined.

pressure diffⁿ betⁿ sections (i) and (ii) is measured.

$$\text{Actual discharge, } Q_{\text{act}} = \frac{C_d a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$$

where a_1 = cross-sectional area of pipe $= \frac{\pi}{4} d^2$
 a_2 = area of circular hole $= \frac{\pi}{4} d^2$
 C_d = Co-efficient of discharge for orifice meter.

→ It is simple in construction and hence cost of replacement is cheaper as compared to a venturimeter.
→ It requires less space to install.

(3) Pitot tube:- It is a device 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 a point becomes zero, there is increase in the pressure due to the conversion of kinetic energy into pressure energy.

The pitot tube consists of a glass tube, bent at right angle.

The lower end which is bent through 90° is directed in the up-stream direction and the liquid rises up in the tube due to the conversion of kinetic energy into pressure.

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

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

Actual velocity is given by:-

$$V_{act} = C_v \sqrt{2gh}$$

h = rise of liquid in the tube above the free surface.

where, C_v = co-efficient of pitot tube.
∴ velocity at any point $V = C_v \sqrt{2gh}$.

① Explain Discharge through rectangular Notch - Numerical.

② Explain Discharge through V-Notch - Numerical.

③ Explain flow through pipe - major and minor losses.

* Notch:- A notch is a device used for measuring the rate of flow of a liquid through a small channel or a tank.

It may be defined as an opening in the side of a tank or a small channel in such a way that the liquid surface in the tank or channel is below the top edge of the opening. The bottom end of the notch is generally made sharp.

* Weir:- A weir is a concrete or masonry structure, placed in an open channel over which the flow occurs.

It is generally in the form of vertical wall with a sharp edge at the top.

The notch is of small size while the weir is of bigger size.

The notch is generally made of metallic plate while weir is made of concrete or masonry structure.

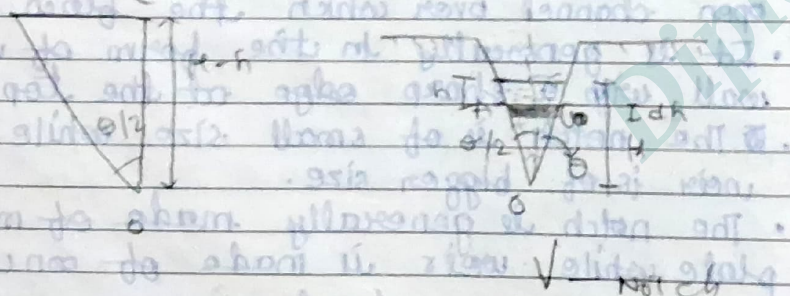
* Nappe or vein:- The sheet of water flowing through a notch or over a weir.

* Crest or sill:- The bottom edge of a notch or a top of a weir over which the water flows.

Rectangular notch - It is a common type of weir used to measure the flow rate of liquids. It consists of a vertical opening with a rectangular shape, often placed in a channel or tank.

- Easy to construct and maintain.
- Provides reliable flow rate readings.
- Suitable for various flow rates and liquid types.
- Used in Hydrology, industrial process, research and development.
- Sharp and Broad - created R.N.

* Discharge through Rectangular notch:-



The expression for discharge over a notch and weir is the same.

Consider, a rectangular notch provided in a channel carrying water.

Let, H = Head of water over the crest
 L = length of the notch.

Consider, An elementary horizontal strip of water of thickness dh and length L at a depth h from the free surface of water.

Area of strip = $L \times dh$

Theoretical velocity of water flowing through strip = $\sqrt{2gh}$

The discharge dQ through strip is
 $dQ = cd \times \text{Area of strip} \times \text{Theoretical velocity}$
 $= cd \times L \times dh \times \sqrt{2gh}$

where,

cd = co-efficient of discharge

The total discharge for whole notch is -

$$Q = \int_0^H cd \cdot L \cdot \sqrt{2gh} \cdot dh$$

$$= cd \times L \times \sqrt{2g} \cdot \int_0^H h^{1/2} dh$$

$$dQ = C_d \times L \times \sqrt{2g} \left[\frac{h^{3/2}}{3/2} \right]_0^H$$

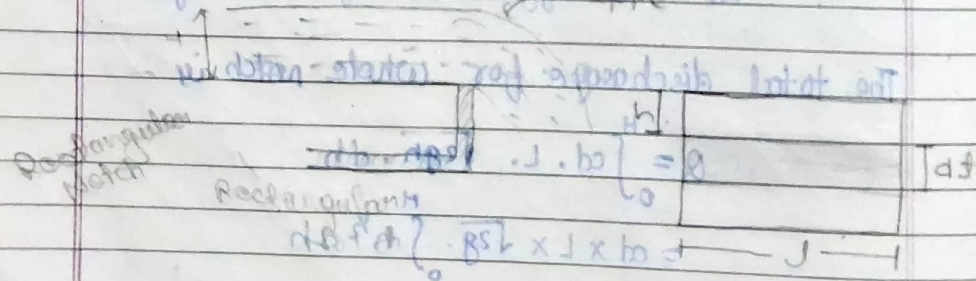
$$Q = \frac{2}{3} C_d \times L \times \sqrt{2g} (H)^{3/2}$$

$$Q = \frac{2}{3} C_d \times L \times \sqrt{2g} (H)^{3/2} \rightarrow \text{Discharge through rectangular notch}$$

Triangular notch (V-notch) —

A Δ notch is a type of hydraulic structure used to measure the flow rate of fluids, typically water, by creating a Δ -shaped opening in a weir or dam. The notch is designed to allow a specific vol. of fluid to flow through it, and the flow rate is calculated based on the water level above the notch and the notch's geometric dim.

* Discharge through V-notch (Triangular notch): —



$$Q = \frac{2}{3} C_d \times L \times \sqrt{2g} (H)^{3/2}$$

The expression for the discharge over a V-notch and weir is the same.

Let,

H = head of water above the V-notch

$\theta = \angle$ of the notch

consider,

A horizontal strip of water thickness ' dh ' at a depth of h from the free surface of water.

Then, In $\triangle ACD$

$$\tan \frac{\theta}{2} = \frac{AC}{DC} = \frac{AC}{(H-h)}$$

$$AC = (H-h) \tan \frac{\theta}{2}$$

$$\text{width of the strip} = AB = 2AC = 2(H-h) \tan \frac{\theta}{2}$$

So,

$$\text{Area of strip} = 2(H-h) \tan \frac{\theta}{2} \times dh$$

The theoretical velocity of water through strip = $\sqrt{2gh}$

$\therefore$ Discharge through the strip

$$dQ = C_d \times \text{area of strip} \times \text{velocity}$$

$$= C_d \times 2(H-h) \tan \frac{\theta}{2} \times dh \times \sqrt{2gh}$$

Total discharge,

$$Q = \int_0^H 2 C_d (H-h) \tan \frac{\theta}{2} \times \sqrt{2g} \times dh$$

$$= 2 C_d \tan \frac{\theta}{2} \times \sqrt{2g} \int_0^H (H-h) h^{1/2} dh$$

$$\begin{aligned}
 &= 2cd \times \tan \theta/2 \times \sqrt{2g} \int_0^H (Hh^{1/2} - h^{3/2}) dh \\
 &= 2cd \times \tan \theta/2 \times \sqrt{2g} \left[\frac{Hh^{3/2}}{3/2} - \frac{h^{5/2}}{5/2} \right]_0^H \\
 &= 2cd \times \tan \theta/2 \times \sqrt{2g} \left[\frac{H \cdot H^{3/2}}{3/2} - \frac{H^{5/2}}{5/2} \right] \\
 &= 2cd \times \tan \theta/2 \times \sqrt{2g} \left[\frac{2}{3} H^{5/2} - \frac{2}{5} H^{5/2} \right] \\
 &= \frac{8}{15} cd \times \tan \frac{\theta}{2} \times \sqrt{2g} \times H^{5/2}
 \end{aligned}$$

$$Q = \frac{8}{15} cd \times \tan \frac{\theta}{2} \times \sqrt{2g} \times [H]^{5/2} \rightarrow \text{discharge through V-notch}$$

For a right-angled V-notch, if $cd = 0.6$

$$\tan \theta = 1$$

Then Discharge,

$$Q = \frac{8}{15} \times 0.6 \times 1 \times \sqrt{2 \times 9.8} \times H^{5/2}$$

$$Q = 1.417 H^{5/2}$$

Explain flow through pipes:-

Major and minor losses when a fluid is flowing through a pipe. The fluid experiences some resistance due to which some of the energy of fluid is lost. This loss of energy is classified as

$$\begin{aligned}
 \square \text{ notch } Q &= \frac{8}{15} cd \times L \times \sqrt{2g} \times (H)^{5/2} \\
 \sqrt{\text{notch}} Q &= \frac{8}{15} (cd) \times \tan \frac{\theta}{2} \times \sqrt{2g} \times (H)^{5/2}
 \end{aligned}$$

Sumit
Kumar
Thakur

Energy losses

1) Major energy losses

• This is due to friction

• It is calculated by:-

i) Darcy-Weisbach formula

ii) Chezy's formula

2) Minor energy losses

• This is due to:-

i) Sudden expansion of pipe

ii) Sudden contraction of "

iii) Bend in pipe

iv) Pipe fitting etc

v) An obstruction in pipe

Major energy losses:- Major losses occur due to the friction between the fluid and the pipe wall over the length of the pipe. and it is calculated by the following formula:-

(a) Darcy - Weisbach formula:- The loss of head (or energy) in pipe due to friction is calculated from Darcy-Weisbach equation

$$h_f = \frac{4fLV^2}{d \times 2g}$$

where, h_f = loss of head due to friction

f = co-efficient of friction which is function of Reynolds no. (Re)

= $\frac{64}{Re}$ for $Re < 2000$ (laminar or viscous flow)

$= 0.079 \text{ for } Re \text{ varying from } 4000 \text{ to } 10^5$

L = length of pipe
 V = mean velocity of flow
 ϕ = Diameter of pipe

⑤ Chezy's formula for loss of head due to friction in pipe:-

Frictional resistance

$$h_f = \frac{F'}{P} \times \frac{P}{A} \times L \times V^2 \quad \text{--- (1)}$$

where,

h_f = loss of head due to friction

P = wetted perimeter of pipe

A = Area of cross-section of pipe

L = length of pipe

V = mean velocity of flow

The ratio of A to P is called hydraulic mean depth or hydraulic radius and is denoted by m .

$\therefore$ Hydraulic mean depth (m) = $\frac{A}{P} = \frac{\pi/4 d^2}{\pi d} = \frac{d}{4}$

$m = \frac{A}{P}$, So, $\frac{P}{A} = \frac{1}{m}$

Substituting the value of P/A in eqn (1)

$$h_f = \frac{F'}{P} \times \frac{1}{m} \times L \times V^2$$

$$V^2 = h_f \times \frac{P}{F'} \times m \times \frac{1}{L} = \frac{P}{F'} \times m \times \frac{h_f}{L}$$

$$V = \sqrt{\frac{P}{F'} \times m \times \frac{h_f}{L}}$$

$$V = \sqrt{\frac{P}{F'} \times m \times \frac{h_f}{L}} \quad \text{--- (11)}$$

Let,

$\sqrt{\frac{P}{F'}} = C$, where C is a constant known as Chezy's constant

$\frac{h_f}{L} = i$, where i is loss of head per unit of pipe.

Substituting the value of $\sqrt{\frac{P}{F'}}$ and $\frac{h_f}{L}$ in eqn (11)

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

--- Chezy's formula.

The value of m for pipe is always equal to $d/4$.

(Head) ② Minor Energy losses:-

The loss of head or energy due to friction in a pipe is known as major loss while the loss of energy due to change of velocity of fluid in magnitude or direction is

The minor loss of energy, included following cases:-

- i) loss of energy due to sudden enlargement
- ii) " " " due to sudden contraction
- iii) " at the entrance of a pipe.
- iv) " at the exit of a pipe.
- v) " due to obstruction in a pipe
- vi) " due to bend in the pipe.
- vii) " in various pipe fittings.

- In case of long pipe the above losses are small as compared with the loss due to friction
- In case of a short pipe, these losses are comparable with the loss of head due to friction.

① loss of head due to sudden enlargement

Let,

P_1 = Pressure intensity at section 1-1

V_1 = velocity of flow at section 1-1

A_1 = Area of pipe at section 1-1

Similarly,

P_2, V_2 and A_2 are pressure, velocity and area at section 2-2

- Due to sudden change of diameter of the pipe from D_1 to D_2 , the liquid flowing from the smaller pipe is not able to follow the abrupt change of the boundary.
- Then the flow separates from the boundary and turbulent eddies are formed.
- The loss of head or energy takes place due to the formation of these eddies.

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

where, h_e = loss of head due to sudden enlargement

② loss of head due to sudden contraction:-

The liquid flows from large pipe to a smaller pipe and the area of flow goes on decreasing and becomes minimum at a section c-c. This section c-c is called Vena-contracta.

After section c-c, a sudden enlargement of the pipe takes place.

The loss of head due to sudden contraction is actually due to sudden enlargement from vena-contracta to smaller pipe.

$$h_c = K \frac{V_2^2}{2g} \quad \text{where } K = \left(\frac{1}{C_c} - 1 \right)^2$$

if $C_c = 0.62$

$$K = \left(\frac{1}{0.62} - 1 \right)^2 = 0.375$$

then,

$$h_c = K \frac{V_2^2}{2g} = 0.375 \frac{V_2^2}{2g}$$

If the value of C_c is not given

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

② Loss of energy at the entrance to pipe.

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

where, V = velocity of liquid in pipe

h_i = loss of head at entrance

④ Loss of energy at the exit from a pipe.

$$h_o = \frac{V^2}{2g} \quad \text{where } h_o = \text{loss of head at the exit}$$

V = velocity at outlet of pipe

⑤ Loss of energy due to obstruction in pipe

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

⑥ Loss of energy in bends.

$$h_b = K \frac{V^2}{2g}$$

h_b = loss of head due to bends

V = velocity of flow

K = co-efficient of bend

⑦ Loss of energy in various pipe fittings

$$h_f = K \frac{V^2}{2g}$$

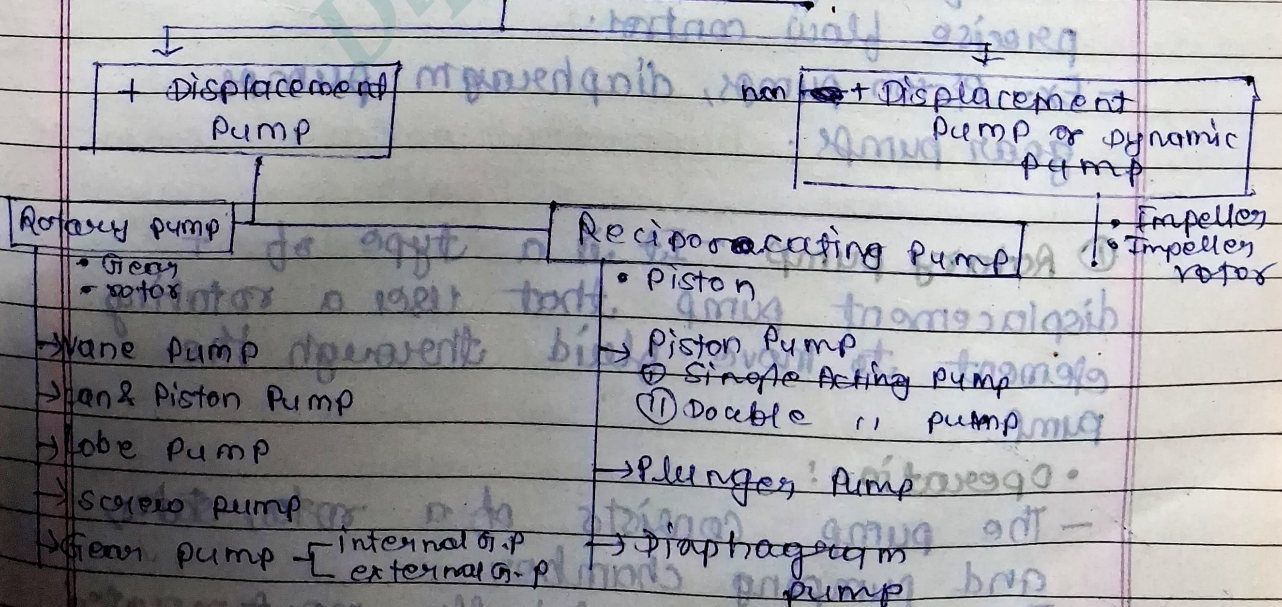
where, V = velocity of flow

K = co-efficient of pipe fitting

- 1# Classification of pumps:-
- 2# Explain the working principle of centrifugal pump and its Application.
- 3# Explain the working principle of monoblock and its Application.

• **Pump:-** A pump is a mechanical device used to move liquids, gases, or slurries from one location to another. It typically works by applying mechanical energy to the fluid to increase its pressure or velocity. Pumps are essential in various appli. such as in water supply systems, oil pipelines, HVAC systems, medical devices, and more.

Classification of pumps



Dynamic Pump

special effect pump

(i) Jet pump

(ii) Electromagnetic pump

- Centrifugal pump

(i) Axial flow pump

(ii) Submersible pump

(iii) Radial flow pump

(iv) Mixed flow pump

A) + Displacement Pumps:

- Move a fixed amount of fluid with each cycle, - Provide a high-pressure output.
- Flow is constant, • regardless of pressure.
- Best for high-viscosity fluids and precise flow control.
- Ex- Piston pumps, diaphragm pumps, gear pumps.

(i) Rotary pump - It is a type of + displacement pump that uses a rotating element to move fluid through the pump.

• Operation:

- The pump consists of a rotor, stator, and pumping chamber.
- The rotor is eccentrically mounted

and rotates inside the stator.

- As the rotor rotates, it creates a vacuum in the pumping chamber.
- Fluid enters the pumping chamber through the inlet.
- The rotor pushes the fluid through the outlet.

• Types

- 1) Gear Pump: Uses interlocking gears to move fluid.
- 2) Lobe Pump: Uses rotating lobes to move fluid.
- 3) Screw Pump
- 4) Vane Pump

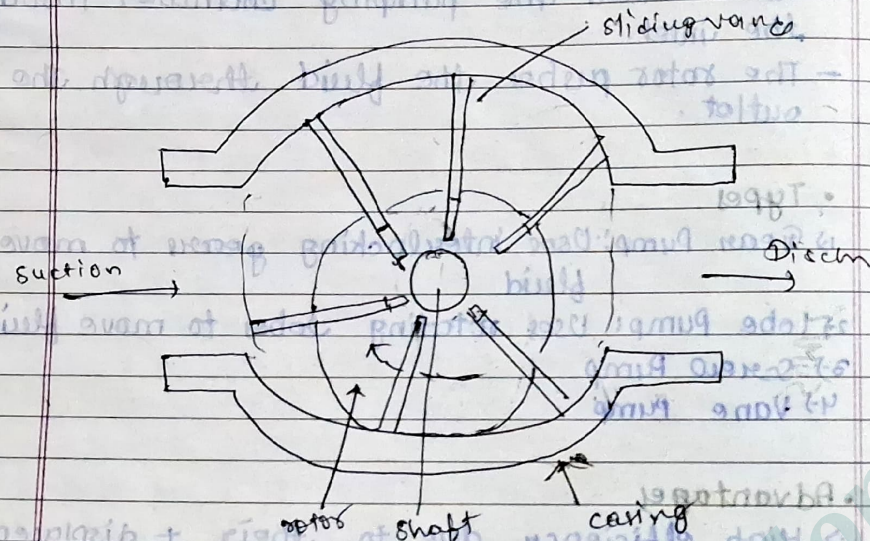
• Advantages

- > High efficiency due to their + displacement design.
- > low pulsation: - provide a smooth flow with low pulsation.
- > High pressure: - can handle high pressure.

• Applications:

- 1) Rotary pumps are used in chemical processing plants to handle corrosive and abrasive fluids.
- 2) ... used in food processing plants to handle viscous and non-viscous fluids.
- 3) ... used in pharmaceuticals.

plants to handle high-pressure fluids.
It is used in oil and gas applications to handle crude oil and other petroleum products.



② Reciprocating Pump - It is a type of displacement pump that uses a piston or plunger to move fluid through the pump.

• Operation

- The pump consists of a piston or plunger, cylinder and valves.
- The piston or plunger moves back and forth in the cylinder, creating a suction and discharge stroke.

- During the suction stroke, the piston or plunger moves away from the valve, creating a vacuum that draws fluid into the cylinder.
- During the discharge stroke, the piston or plunger moves towards the valve, pushing the fluid out of the cylinder.

• Types

- 1) Single-Acting Pump: Fluid is pumped only during one stroke (either suction or discharge).
- 2) Double-Acting Pump: Both suction and discharge strokes.
- 3) Diaphragm Pump: Uses a flexible diaphragm instead of a piston or plunger.

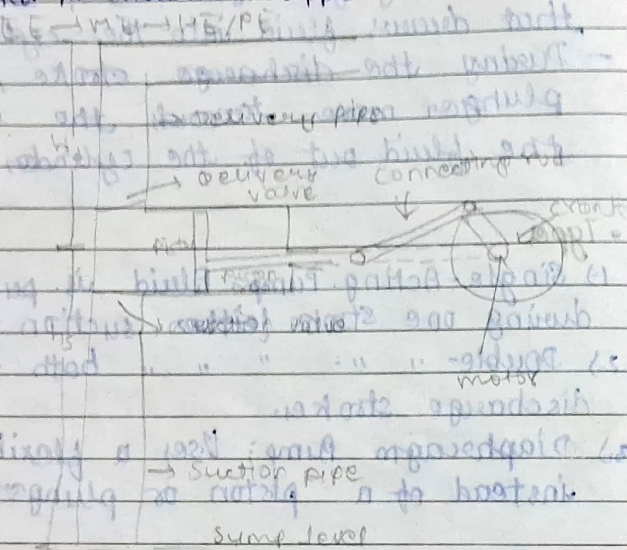
• Advantages:

- can handle high pressure.
- can provide high flow rates.
- are efficient, especially for low-flow, high-pressure applications.
- have a compact design.

• Applications:

- for industrial processes, such as manufacturing oil and gas, and chemical processing.
- used in water supply systems to provide drinking water and irrigation.
- used in power plants to provide cooling.

water and other fluids -
are used in marine appli.



⑩ ^{not standard term so use} + Displacement pump or dynamic pump
also known as a non-positive displacement pump, is a type of pump that uses a rotating impeller to increase the velocity of a fluid, which in turn increases the pressure of the fluid.

⑪ Special effect pump

• Jet Pump - It is a type of pump that uses the principle of fluid dynamics to create a pressure diffⁿ, which drives the fluid

flow. It consists of a nozzle, a venturi, and a diffuser.

• Electromagnetic Pump - It is a type of pump that uses electromagnetic forces to move fluids. It consists of a coil, a magnetic field, and a fluid channel.

⑫ Centrifugal pump - It is a type of pump that uses a rotating impeller to increase the pressure of a fluid. It is one of the most common types of pumps used in various industries.

• Operation

- The pump consists of a rotating impeller, a casing, and an inlet and outlet.
- The impeller is connected to a shaft that is driven by a motor or engine.
- As the impeller rotates, it creates a low-pressure area at the inlet.
- Fluid enters the pump through the inlet and is accelerated by the impeller.
- The fluid is then discharged through the outlet at a higher pressure.

• Components:

- 1) Impeller: The rotating component that increases the pressure of the fluid.
- 2) Casing: The stationary component that houses the impeller and directs the fluid flow.
- 3) Shaft: The rod that connects the impeller to the motor or engine.
- 4) Bearing: The component that supports the shaft and allows it to rotate smoothly.

• Types

- 1) Radial Flow Pump: The impeller is designed to produce a radial flow pattern.
- 2) Axial flow pump: The impeller is designed to produce an axial flow pattern.
- 3) Mixed flow pump: The impeller is designed to produce a combination of radial and axial flow patterns.

• Advantages:

- 1) High flow rates: can handle high flow rates.
- 2) High efficiency
- 3) Low maintenance: have fewer moving parts, making them easier to maintain.
- 4) Compact design.

• Applications:

- 1) Water Supply Systems: to distribute water.
- 2) Industrial processes: such as chemical processing and oil refining.
- 3) Power plants: to circulate cooling water and other fluids.
- 4) Irrigation Systems: to distribute water to crops.

• Diagram

The diagram illustrates the internal components and flow of a centrifugal pump. It shows the impeller mounted on a horizontal shaft, which is supported by bearings. The impeller is connected to the shaft by a coupling. The fluid enters the pump through an inlet pipe at the bottom, moves into the center of the impeller, and is then thrown outwards by the rotating blades. The fluid exits the pump through an outlet pipe at the top. The diagram also shows the casing, which houses the impeller and directs the flow of the fluid. The flow is indicated by arrows, showing the path from the inlet to the impeller and then outwards to the outlet.

A. centrifugal pump works on the principle of centrifugal force to transport fluids. It converts mech. energy and then into ps. energy of the fluid.
from a motor into K.E

• Working principle of centrifugal pump

The working principle of a centrifugal pump is based on converting mechanical energy into fluid energy using the centrifugal force.

How it works:

- 1) Fluid entry (Suction) - Fluid enters the pump through the suction pipe & reaches the eye (center) of the rotating impeller.

- 2) Rotation of Impeller: The pump has a rotating impeller powered by an electric motor or engine. When the impeller rotates, it imparts kinetic energy to the fluid inside the pump casing.

- 3) Fluid Enters the pump: The fluid enters the pump through the suction side, typically through the eye of the impeller.

- 4) Fluid Accel: As the impeller blades rotate, they push the fluid outward (radially) from the center (eye) of the impeller to the outer edges. This causes the fluid to gain velocity and kinetic energy.

- 5) Conversion of kinetic to pressure energy: The high-velocity fluid flows into the volute or diffuser, where the flow area increases, causing the velocity to drop and converting kinetic energy into pressure energy.

- 6) Fluid Discharge: The fluid, now under high pressure, exits the pump through the discharge pipe and is delivered to

the required location.

2) #) Explain the working principle of monoblock and its application

A monoblock pump is a type of centrifugal pump where the motor and pump are integrated into a single unit. It works on the principle of centrifugal force, which is generated by a rotating impeller.

Process -

- 1) Suction: Liquid is drawn into the pump's suction inlet.

- 2) Impeller Rotation: The impeller, connected to the motor shaft, rotates at high speed.

- 3) C.F: As the impeller spins, it imparts kinetic energy to the liquid. The liquid is thrown outward due to C.F.

- 4) Volute casing: The liquid is directed into the volute casing, a spiral-shaped chamber.

- 5) Pressure conversion: In volute casing, the K.E of the liq. is gradually converted into P.E.

- 6) Discharge: The pressurized liquid is then discharged through the pump's outlet.

Appli

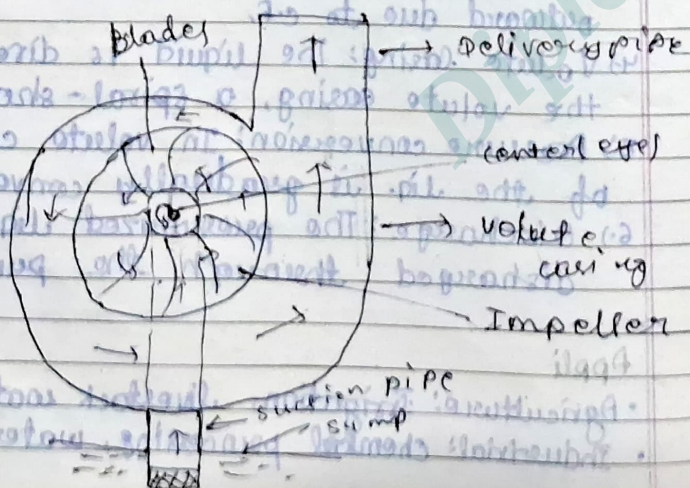
- Agriculture: Irrigation, livestock watering and spraying
- Industrial: chemical processing, water supply and

wastewater treatment

- Domestic: Water supply for homes and buildings.
- Construction: Dewatering, concrete mixing and gravel pumping
- Marine: Bilge pumping and fire fighting.

Key Advantages

- 1) Compact Design: Save space and reduce installation costs.
- 2) High Efficiency: Efficient energy conversion, leading to lower operating costs.
- 3) Ease of Maintenance: Simple design and easy access to components.
- 4) Versatility: Available in various sizes and conf. configurations to suit diff. needs.
- 5) Reliability: Durable construction and robust components ensure long service life.



Monoblock Pump

Design: 1) ~~is~~ Motor and pump are integrated into a single unit.

Structure: Compact and simple design.

Function: Uses centrifugal force to move fluids.

Appl: Typically used in smaller appl. (domestic, irrigation, small industries).

Maint: Easier maint. but requires replacing the entire unit if the motor fails.

Cost: cost-effective for smaller systems.

Centrifugal Pump

Motor and pump can be separate, connected by a coupling.

Varies in size and complexity.

Uses c.f. to transfer fluid (wide range of design and conf.).

Used in a variety of industries (water treatment, chemical, HVAC, etc.).

More complex maint. due to separate comp.

Generally more expensive especially for larger or industrial system.

- 1) determine co-efficient of friction by using Chezy's and Darcy's formulae.
- 2) Design a pipe for a given no. of inhabitants.
- 3) Design a pipe for a given discharge.

∴ Chezy's formula:

$$V = C \sqrt{m i}$$

The chezy's formula is used to calculate the velocity of flow in an open channel, such as a river or a stream. It is derived by Darcy-Weisbach eqⁿ for fluid flow in pipe.

V = velocity of flow (m/s)

C = chezy coefficient

m = Hydraulic mean depth

i = Hydraulic slope

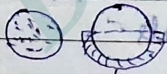
To find the value of " m "

$$m = \frac{\text{Area of pipe}}{\text{wetted perimeter}}$$

Wetted Perimeter

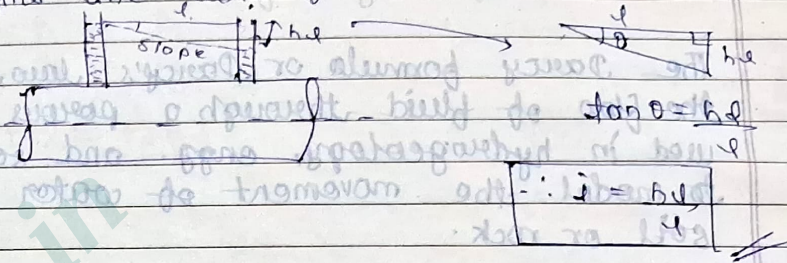
$$= \int d \cdot \frac{\pi d}{4}$$

$$m = \frac{d}{4}$$



wet area

To find the value of " i "



∴ final formula

$$V = C \sqrt{m i}$$

$$V = C \sqrt{\frac{d}{4} \times \frac{h}{l}}$$

$$\Rightarrow V^2 = C^2 \times \left(\frac{d}{4} \times \frac{h}{l} \right) \quad (\text{squaring both side})$$

$$\Rightarrow \frac{V^2}{C^2} \times \frac{4}{d} = \frac{h}{l}$$

$$\Rightarrow h l = \frac{4 d V^2}{C^2}$$

Used to calculate flow velocity in open channel, helping design efficient drainage systems, manage man flood, assess erosion risks, and predict sediment transport.

∴ Darcy's formula:-

The Darcy formula or Darcy's law, describes the flow of fluid through a porous medium, used in hydrogeology, engg. and soil science to model the movement of water through soil or rock.

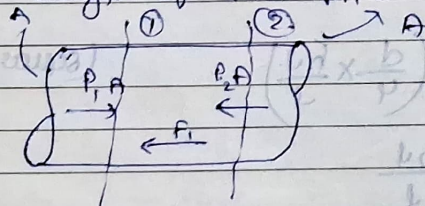
Let,

P_1 = pressure intensity inlet (1-1)

P_2 = " " " inlet (2-2)

A = cross-section area of pipe

L = length of the pipe



We know that:

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

↑
friction loss

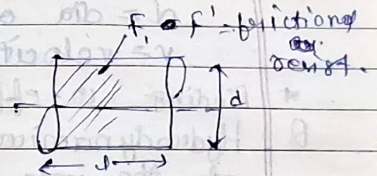
$Z_1 = Z_2$ (datum head)

$V_1 = V_2$ (due to area is constant)

$$\therefore \frac{P_1}{\rho g} = \frac{P_2}{\rho g} + h_f$$

$$h_f = \frac{P_1}{\rho g} - \frac{P_2}{\rho g}$$

$$(P_1 - P_2) = \rho g h_f$$



Frictional force = friction resistance / wetted area $\times V^2$

$$F_1 = F' \times \pi d L \times V^2 \quad \left[\begin{array}{l} \text{circumferential} \\ \text{area} = 2\pi r L \end{array} \right]$$

$$F_1 = F' \times P \times L \times V^2$$

$$\Sigma F_x = 0$$

$$P_1 A - P_2 A - F_1 = 0$$

$$(P_1 - P_2) A = F_1$$

$$\Rightarrow \rho g h_f \times A = F_1$$

$$\Rightarrow \rho g h_f \times A = F' \times P \times L \times V^2 \quad \left[\because P_1 = F' \times P \times L \times V^2 \right]$$

$$\Rightarrow h_f = \frac{F' \times P \times L \times V^2}{\rho g A}$$

$$= \frac{F'}{\rho g} \times \frac{P}{A} \times L \times V^2$$

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

Parameters of circle

$$\text{Darcy coefficient} \quad \frac{F'}{\rho} = \frac{f}{2}$$

$$h_f = \frac{F'}{2g} \times \frac{4}{d} \times L \times V^2$$

head loss

F = coefficient of friction

L = length of pipe

d = dia of pipe

v = velocity of pipe

* Finding co-efficient of friction in pipe

Q. Hydrodynamically smooth pipe carries water at the rate of $0.3 \text{ m}^3/\text{s}$ at 20°C . Density of water is 1000 kg/m^3 . Kinematic viscosity $\nu = 10^{-6} \text{ m}^2/\text{s}$ with a head loss of 3 m in 100 m length of pipe. Determine the pipe dia use $F = 0.0032 + 0.221/Re$, eqⁿ for F , where

$$h = \frac{F \times L \times v^2}{2gd}$$

$$\text{and } Re = \frac{\rho v D}{\mu}$$

(Re) se-rend

solⁿ:-

$$Q = 0.3 \text{ m}^3/\text{s}$$

$$\rho = 1000 \text{ kg/m}^3$$

$$\nu = 10^{-6} \text{ m}^2/\text{s}$$

$$h_f = 3 \text{ m}$$

$$L = 100 \text{ m}$$

$$\text{Friction } (F) = 0.0032 + \frac{0.221}{(Re)^{0.237}}$$

$$Re = \frac{\rho v d}{\mu} = \frac{v d}{\nu} = v d \times 10^6 \quad \left[\nu = \frac{\mu}{\rho} \right]$$

$$\therefore h_f = \frac{F L v^2}{2gd}$$

$$3 = \frac{F \times 100 \times v^2}{2 \times 9.81 \times d}$$

$$\therefore F = 0.5886 d / v^2$$

$$\therefore Q = A \times v \rightarrow \text{velocity}$$

$$0.3 = \frac{\pi d^2}{4} \times v \quad \text{or } d^2 v = \frac{4 \times 0.3}{\pi}$$

$$v = \frac{0.382}{d^2}$$

$$\text{Also, } F = 0.0032 + \frac{0.221}{(Re)^{0.237}}$$

$$\therefore \frac{0.5886 d}{v^2} = 0.0032 + \frac{0.221}{(Re)^{0.237}}$$

$$\frac{0.5886 d}{\left(\frac{0.382}{d^2}\right)^2} = 0.0032 + \frac{0.221}{(v d \times 10^6)^{0.237}}$$

$$\therefore \frac{0.5886 \times d^5}{(0.382)^2} = 0.0032 + \frac{0.221}{\left(\frac{0.382}{d^2} \times d \times 10^6\right)^{0.237}}$$

$$4.003 \times d^5 = 0.0032 + 0.0105 \times d^{0.287}$$

$$4.003 d^5 = 0.0105 d^{0.287} + 0.0032 = 0$$

① $d = 1 \text{ m}$

Let, $4.033 \times 10^{-5} - 0.0105 \times 10^{-5} - 0.032 = 4.0193$

$Re \text{ (Renold No.)} = \frac{Vd}{\mu}$

Water is flowing through a pipe of dia 200 mm with a velocity of 3m/s. Find the head loss due to friction for a length of 5m.

$f = 0.02 + \frac{0.09}{Re^{0.2}}$, $K \cdot E_{\text{velo}} = 0.01 \text{ strokes } (\frac{\mu}{m})$

Solⁿ:- Given,

$d = 200 \text{ mm}$

$v = 3 \text{ m/s}$

$l = 5 \text{ m}$

Friction $= 0.02 + \frac{0.09}{(Re)^{0.2}}$

We use Darcy formula,

$h_f = \frac{4f l v^2}{2g d}$

To convert Stokes into metre of velocity.

$\mu = 0.01 \times 10^{-4} \text{ m}^2/\text{s}$

$\therefore Re = \frac{Vd}{\mu} = \frac{3 \times 0.2}{0.01 \times 10^{-4}} = 6 \times 10^5 > 4000$

$\therefore f = 0.02 + \frac{0.09}{6 \times 10^5} = 0.02166$

$\therefore h_f = \frac{4f l v^2}{2g d} = \frac{4 \times 0.02166 \times 5 \times 3^2}{2 \times 9.81 \times 0.2} = 0.39 \text{ m of water.}$

N. imp.

Design a pipe for a given no. of Inhabitants.

1) Estimate water demand:

- Assume 100-150 litres / person / day.
- Total daily demand = inhabitants $\times$ water demand/person

2) Calculate flow rate

- Convert daily demand to flow rate:

Flow rate (l/s) = $\frac{\text{Total daily demand (litres)}}{86400 \text{ seconds}}$

3) choose pipe size

- Estimate the pipe dia based on flow rate (commonly 25-50 mm for residential use).

4) consider Material & Pressure:

- Use materials like PVC or HDPE and ensure the pressure rating is adequate (around 2-5 bar).

5) Plan for growth:

- Account for future population increase (20-30% more capacity).

Example:
Suppose we have a residential area with 500 inhabitants.

- 1) Estimate water demand:
- Assume each person uses 150 litres of water/day.
 - Total water demand/day:

$$\text{TWD (l/day)} = 500 \text{ inhabitants} \times 150 \text{ l/person/day} \\ = 750 \times 10^3 \text{ l/day}$$

2) Calculate flow rate:

- Convert daily demand to flow rate (litres/sec):
 $\text{Flow rate (l/s)} = \frac{75000 \text{ l/day}}{86400 \text{ sec/day}} \approx 0.868 \text{ l/s}$

3) Choose pipe size:

- Based on the flow rate (0.868 l/s), we can estimate the pipe size. For residential use with this flow rate, a 32mm or 40mm dia pipe would be appropriate.

4) Consider Material & Pressure:

- Let's use PVC pipes commonly used in residential systems with a pressure rating of 2-5 bar.

5) Plan for Growth:

- To account for future population growth, we add a 25% increase in capacity:

$$\text{Adjusted flow rate} = 0.868 \text{ l/s} \times 1.25 = 1.085 \text{ l/s}$$

- This would suggest using a slightly larger pipe (e.g., 40mm or 50mm) to ensure it can handle the increase load.

Example:

For 500 inhabitants using 150 l/day.

- Total daily demand: 75,000 l
- Flow rate: 0.868 l/s
- Pipe size: 32mm or 40mm
- Material: PVC with 2-5 bar pressure rating
- Future growth: Plan for a 25% increase (up to 1.085 l/s)

N.T.M

#

Design a pipe for a given discharge:

1) Given data:

- Flow rate (discharge) Q in litres/second (l/s)
- Pipe material and pressure (usually related to pipe type, e.g., PVC, HDPE).
- Length of the pipe.
- Desired velocity of water in the pipe (typically 1-3 m/s for most water distribution systems).

2) Calculate flow rate (discharge)

- Flow rate Q (l/s)

3) Estimate the pipe size (dia) using the flow velocity:

$$Q = A \times V$$

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

$$d = \sqrt{\frac{4Q}{\pi V}}$$

4) select a pipe material:

PVC, HDPE and steel

Check for pressure loss and add safety factor using Darcy-Weisbach

Plan for future growth

consider increasing the pipe size by 20-30%

to handle potential future increase in flow demand

Final Pipe Design:

• Flow rate: 10 l/s

• Pipe dia: 95mm

• Material: PVC

• Flow velocity: 2m/s

CH-5

N.tra

select a suitable pump for a given appl:

To select a suitable pump:

1) Identify requirements:

- Flow rate: How much liquid needs to be moved?
- Head/pressure: How high or at what pressure does the liquid need to be pumped?
- Fluid type: what fluid is being pumped (e.g., water, oil, slurry)?
- Viscosity: Is the fluid thick or thin?

2) Choose Pump Type:

- Centrifugal pump: for low-viscosity fluids and high flow.
- Displacement pump: for high-viscosity or precise flow control (e.g., diaphragm, gear, piston pumps).

3) Consider Other factors:

- Efficiency, maintenance: choose based on energy use and service needs.
- Power source: Electric, pneumatic, or other options.
- Environment: Ensure safety standards (e.g., for hazardous fluids).

4) Ex - for pumping clean water at high flow, a centrifugal pump is a good choice.

submersible pump.

Working principle

A submersible pump is a type of pump designed to be fully submerged in the liquid it is pumping. The key principle behind its operation is simple: it uses a sealed motor to push fluid from a lower point to a higher point, typically from a well or underwater reservoir to the surface.

Key Components:

- 1) Pump motor: The motor is completely enclosed and submersible. It drives the pump's impeller, which moves the water.
- 2) Impeller: A rotating component that creates pressure to push the liquid upwards.
- 3) Discharge Port: The outlet where the water is expelled.
- 4) Casing: The casing surrounds the motor and impeller to protect them and prevent leakage.
- 5) Suction: Water enters the pump through the intake port, where the impeller draws it in.
- 6) Power cable: Provides electrical energy to the motor, typically armored for protection against damage while submerged.

Working Process:

- 1) Submersion: The pump is placed below the water surface, typically at the bottom of a well or reservoir.
- 2) Motor Activation: When powered on, the motor begins to turn the impeller inside the pump.
- 3) Water intake: The impeller spins, creating low pressure at the intake and drawing water into the pump.
- 4) Water compression and movement: As the impeller continues to spin, it increases the pressure of the water and pushes it up the discharge pipe.
- 5) Water Discharge: The water exits the pump through the discharge port and is delivered to the surface or to a higher point (e.g., a tank or irrigation system).

Applⁿ

- 1) Water wells: drinking water or irrigation.
- 2) Sewage and wastewater systems: to move sewage or wastewater for treatment.
- 3) Dewatering: to remove water from flooded areas, const. sites, mines, or basements.
- 4) Flood control: to pump out excess water from stormwater systems.
- 5) Aquariums and fountains: to circulate water in aquariums or fountains.

1) Explain the working principle of submersible pump and its application.

b) Agricultural irrigation: used to lift water from wells or rivers for irrigation in agricultural applⁿ.

7) Oil and gas industry: used to move liquids in mining operations.

8) Marine and fish farm: used to move water in fish farms.

9) Industrial Applⁿ:

Advantages:

High efficiency, durable, space-saving,

Disadvantages:

Complex maintenance, power consumption, risk of overheating.

Classification of Hydraulic Turbines.
Turbines can be classified in various ways based on diff^r factors.

1) Based on energy at the inlet:

a) Impulse Turbines:

- Energy type: use only K.E of water.
- Working: Water is directed at high speed toward the turbine blades (buckets) via nozzles. The force of the high-velocity water hitting the blades causes the turbine to rotate.
- Ex - Pelton wheel, Turgo Turbine.

b) Reaction Turbines:

- Energy Type: use both kinetic E_k and P.E. (due to pressure changes at the inlet).
- Working: Water flows over the blades, and both the change in v.t and p. of water provide the T_n needed to turn the blades.
- Ex - Francis Turbine, Kaplan Turbine.

2) Based on Head at Inlet (Hydraulic Head):

Hydraulic Head refers to the height or pressure at the inlet that drives the water's flow through the turbine.

a) High-Head Turbines:

- Head range: Generally designed for high-head appl^s.

where water falls from a significant height (usually greater than 300 m).

- Prop. - ~~has~~ higher p. and smaller flow rate.
- Ex - Pelton wheel, Turgo turbine.

b) Medium - H.T.

- H.A = suitable for medium-head appⁿ (usually betⁿ 50m and 300m)
- Prop. - Can be either impulse or reaction turbines, designed to handle moderate p. and flow
- Ex - Francis Turbine, Pelton wheel

c) Low-Head Turbine

- H.A = for LH appⁿ (usually less than 50m).
- Prop. - Typically reaction turbines, designed for large flow rates with lower p.
- Ex - Kaplan T., Propeller T.

3) Based on Direction of flow through the runner:
The dir. in which water flows through the turbine runner (the rotating part of the turbine) determines the classification of the turbine.

a) Axial flow Turbines.

- Flow Dir. - In this T., water flows || to the axis of rotation of the runner i.e., along the

shaft).

- Prop. - have blades that resemble propellers, and the water flows in a straight line through the runner.

- Ex - Kaplan Turbine, Propeller T.

b) Radial flow T.

- F.D: water flows radially toward the center of the turbine from the outer edges, then exits along the axis.
- Prop. Ex - Pelton wheel, Francis Turbine.

c) Mixed flow T.

- F.D: F.D is a combination of axial and radial
- Prop. The water enters the turbine runner at an L, combining both axial and radial flow elements.
- Ex - some variations of Kaplan turbines.

4) Based on Specific Speed of the turbine:
The specific speed (N_s) is a dim. less no. that characterizes the type of turbine based on the flow rate, head and speed.

a) Low specific Speed Turbines ($N_s < 50$):

- Prop. : designed for high-head, low-flow appⁿ operate at slower speeds.
- Ex - Pelton wheel, Turgo turbine.

b) Medium S.S.T ($N_s = 50$ to 250):

- prop. - used for medium head and medium flow appl^s.
- Ex - Francis Turbine.

c) High S.S.T ($N_s > 250$):

- prop. - designed for low head, high flow appl^s. It operates at higher speed.
- Ex - Kaplan T., Propeller Turbine.

$$N_s (\text{specific speed}) = \frac{N \sqrt{Q}}{H^{3/4}}$$

N = speed of the turbine (RPM)

Q = flow rate (m^3/s)

H = Head (in m)

In Summary

Parameter Classification

- 1) Energy at inlet: Impulse, reaction
- 2) Head at inlet: high, medium, low
- 3) D. of flow: Axial, radial, mixed
- 4) Specific speed: low, medium, high

Select a suitable turbine for a given head.

Head based turbine	Head (m)	Discharge	Type
1. low head	2-15 m	high	Kaplan or propeller
2. medium head	16-70 m	high or medium	Kaplan or Francis
3. high head	70-500 m	medium or low	Francis or Pelton
4. very high head	> 500 m	low	Pelton

Explain the Working Principle of Impulse Turbine and its Appl^s.

* Working Principle

An impulse turbine operates by converting the K.E. of a high-velocity fluid jet into M.E.

Here's how it works:

1) Fluid jet creation: Water or steam is forced through a nozzle, creating a high-speed jet of fluid.

2) Jet strikes the Blade: The high-velocity jet of fluid strikes the blade (or bucket) of the turbine. These blades are shaped to capture the energy of the jet.

effectively.

3) Energy Transfer: When the jet hits the blades, the change in the velocity of the fluid (from high to lower speed) exerts a force on the blades, causing them to rotate.

4) Constant Pressure - The pressure of the fluid remains constant as it passes through the turbine, and the energy is only transferred through the change in speed (K.E) of the fluid.

5) Fluid exits the turbine: After striking the blades, the fluid exits the turbine at a much lower velocity, having transferred most of its K.E to the turbine blades.

Impulse turbines convert the K.E from the high-speed fluid jet into mech. rotation of the turbine blades.

Appl.

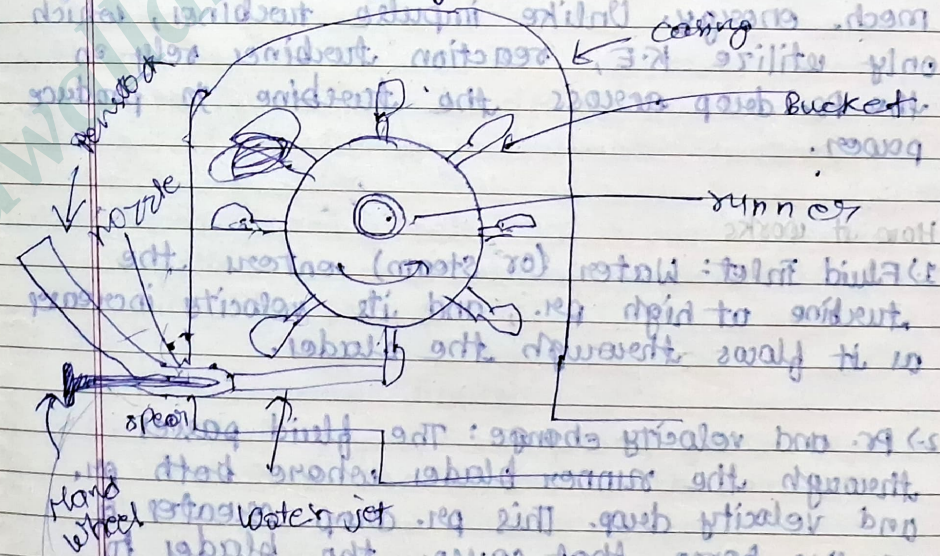
1) High-head hydropower: Used in locations with large vertical drops, like Pelton turbines.

2) Steam and gas power plants: Utilized in turbines where high-p. steam or gas drives mech. power.

3) Micro-Hydro systems: Ideal for small-scale power generation with high head but low flow.

4) Industrial Appl.: Used in chemical plants, refineries, and systems requiring high-pressure fluid.

5) Water Pumping: Applied in irrigation and drainage systems where high-pressure fluid is needed.

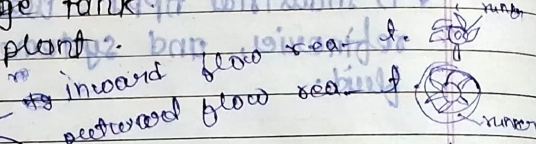


Impulse turbine

- 1) Explain the working principle of reaction turbine and its Appl.
- 2) Explain the Importance of draft tube, Penstock and surge tank.
- 3) Hydroelectric Power plant.

1

Working principle



A reaction turbine operates by converting both the K.E and the P.E of the fluid into mech. energy. Unlike impulse turbines, which only utilize K.E, reaction turbines rely on the P.E drop across the turbine to produce power.

How it works

- 1) Fluid Inlet: Water (or steam) enters the turbine at high pr. and its velocity increases as it flows through the blades.
- 2) Pr. and velocity change: The fluid passes through the runner blades where both pr. and velocity drop. This pr. drop creates a reactive force that causes the blades to rotate.
- 3) Energy conversion: The turbine blades are designed in such a way that they harness the energy from both the pr. drop

(reaction) and the fluid's increasing velocity to produce mech. energy.

- 4) Outflow: The fluid exits the turbine at low pr. and velocity than it entered.

Key point: The rotation of the runner is due to the combined effect of pr. and velocity changes in the fluid.

Applⁿ:

1) Medium and low-head hydropower:

- Used in Francis and Kaplan turbines.

2) Steam power plants:

- Applied in steam turbines to generate power from high-pr. steam.

3) Pumped-storage Plants:

- Used in hydropower plants for energy storage and generation during peak demand.

4) Irrigation and water supply:

Importance

1) Draft tube - large, tapered pipe

- Purpose: Connect the turbine outlet to the tailrace, allowing water to exit the turbine smoothly.

Importance: Pressure Reduction, energy conversion, smooth water flow, improving turbine efficiency, reduced energy loss.

2) Penstock: - large pipe or conduit
Purpose: Carries water from the reservoir to the turbine

1) Draft Tube: - use in reaction not in impulse turbine
① large pipe or conduit, ② directs water from a reservoir or natural source to a turbine, ③ used in hydroelectric power plants, ④ regulates the flow and pressure of water, ⑤ The pr. from the water helps generate power through turbine. ⑥ plays a crucial role in energy generation.

Type: conical type $\eta = 50\% - 80\%$
⑦ Elbow type $\eta = 60\% - 70\%$

used in hydroelectric plants for smooth flow and generation during peak demand.

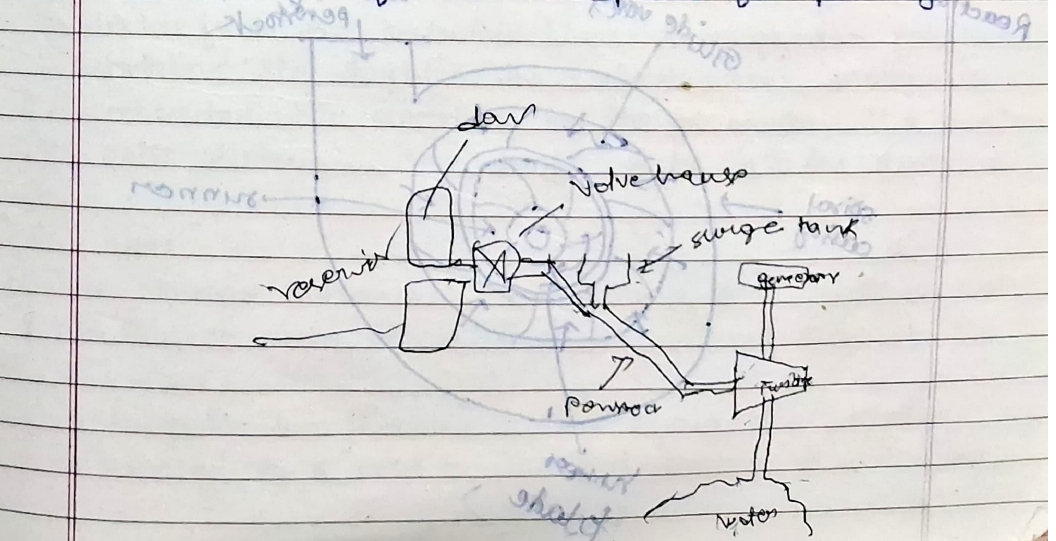
Importance: Draft tube - large tapered pipe, smooth flow, reduces energy loss, improves turbine efficiency, reduced energy loss.

2) Penstock: - large pipe or conduit
It delivers water from a reservoir or lake to the turbine in hydroelectric power plants.

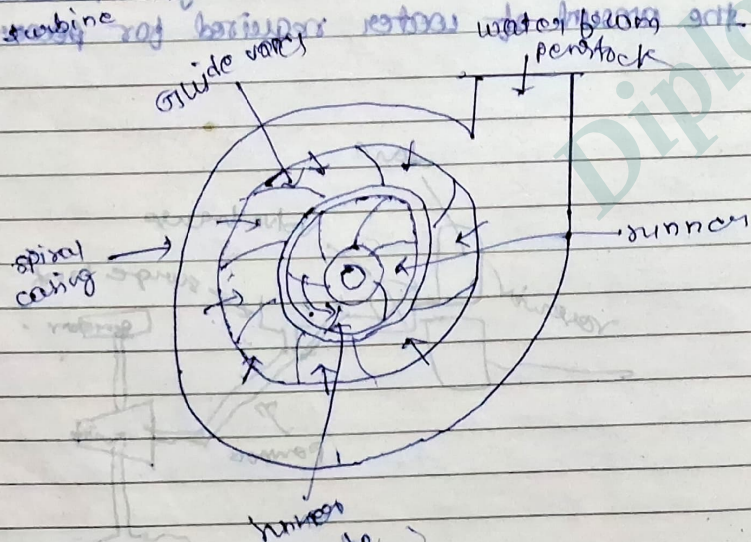
Typically made of steel, reinforced concrete, or sometimes wood, depending on the design and location.

A penstock is a large pipe or conduit that carries water under pressure.

- Designed to withstand high water pressure as it channels water rapidly toward turbine.
- Allows the conversion of P.E from stored water into mech. energy at turbine.
- key role in generating hydroelectric power, making them - used in irrigation systems or water treatment plants.
- The dia. of a penstock can vary, depending on the amount of water required for power generation.



3) Surge Tank:- type of pr. - regulating device used in hydroelectric power plants to manage water pr. in the penstock. (i) It is a small, elevated reservoir or chamber connected to a penstock, designed to absorb sudden change in water pr. (ii) It prevents damage to the penstock and turbines due to water hammer (a pr. surge caused by rapid changes in water flow) and helps maintain steady pr.



Hydraulic power plant (Hydropower plant):
A hydraulic power plant generates electricity by converting the energy of falling or flowing water into mech. and electrical energy.

- Components:
- 1) Dam: Stores water and creates potential energy.
 - 2) Reservoir: Stores water for continuous supply.
 - 3) Penstock: Carries water under pr. to the turbine.
 - 4) Turbine: Converts water's energy into mech. energy.
 - 5) Generator: Converts mech. energy into electrical energy.
 - 6) Draft tube: Carries water from the turbine to the tailrace.
 - 7) Surge tank: Absorbs pr. fluctuations in the penstock.
 - 8) Tailrace: Carries water back to the river or reservoir.

Working Principle:

Water from the reservoir flows through the penstock, rotating the turbine. The turbine's mech. energy is converted into electricity by the generator. The water exits through the draft tube into the tailrace.

Types:

- Storage (reservoir) Plants: Use a dam to store water.
- Run-of-river plants: Use the natural flow of the river.
- Pumped-storage Plants: Store energy by pumping water to a higher elevation during low demand.

Applⁿ:-

- Large-scale electricity generation.
- Backup power in pumped-storage plants.
- Rural electrification.

Hydropower plants offer renewable, reliable, and efficient energy generation.

Turbine is a device that converts fluid

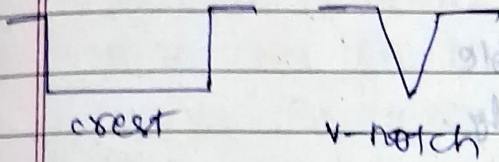
Centrifugal Pump

- 1) Type of rotary pump used
- 2) continuously discharges the fluid
- 3) flow rate decreases which increasing the pressure
- 4) for pumping high viscous fluid
- 5) discharge rate $\propto \frac{1}{\text{viscosity of fluid}}$
- 6) efficiency is low compare to R.P
- 7) have problem of priming
- 8) use impellers to transfer energy to fluid
- 9) light
- 10) gives higher discharge at low heads
- 11) less costly
- 12) less maintenance
- 13) easy to install, less floor space

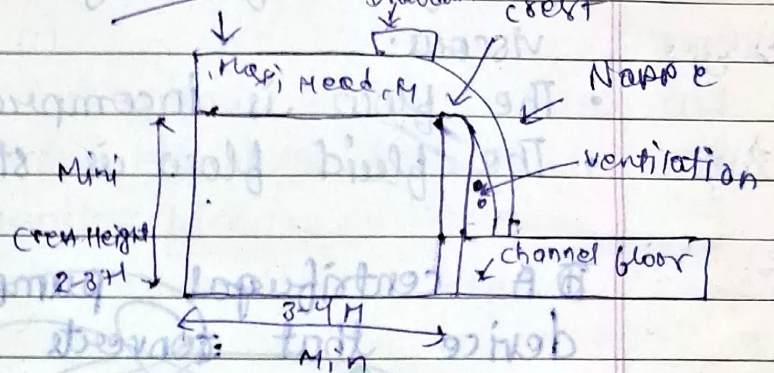
Reciprocating Pump

- 1) type of displacement pump which is forced by piston
- 2) not
- 3) pressure does not effect flow rate
- 4) used for pump low V.F
- 5) does not effect
- 6) ~~eff~~ high
- 7) not
- 8) use piston cylinder device to transfer energy to fluid
- 9) heavy
- 10) higher heads at low discharge
- 11) ~~is~~ more
- 12) higher maintenance
- 13) difficult to install, more floor area

Notch



Head measurement point



Q) What is a Notch?

→ a kind of opening (throughout the width) to the fluid

Notch

- A notch may be defined as the opening provided in the side of the tank or vessel such that the liquid surface in the tank is below the top edge of the opening.

small structure

→ Made of metallic plates.

→ Measure small flow rate.

Weir

→ A weir may be defined as any regular obstruction in an open stream over which the flow takes place.

large structure

→ Made of concrete bricks.

→ Measure large flow rate.

Appelli. name

1) Venturi meter:

- measures fluid rate in pipelines. It is used in water treatment plants, chemical industries, and HVAC systems to monitor flow.

2) Pitot tube:

- Measures fluid velocity. Commonly used in aircraft to measure airspeed and in wind tunnel to study airflow.

3) Orifice meter:

- Measures flow rate by creating a pressure drop. Used in pipelines, oil and gas industries, and chemical processing.

Eqⁿ of continuity

It states that the mass flow rate of a fluid through a pipe of varying cross-section, the product of area of cross-section and the fluid velocity is constant throughout.

Assumption

- The tube is having a single entry and single exit.

Sol. +

$$I = F \times t$$

$$= m \times a \times t$$

$$= \frac{m(v-u) \times t}{t}$$

Initial velocity

$$= 0.25 \text{ (initial velocity)}$$

Appl. of Pascal Law

1) Hydraulic Brake: Force transmission for braking.

2) Hydraulic lifts: lifting heavy loads.

3) Hydraulic Press: Amplifying force for shaping materials.

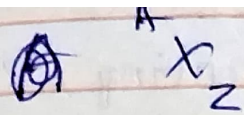
4) Hydraulic Jacks: lifting vehicles.

5) Aircraft/Ship systems: controlling components.

6) Pressurized systems: Even pressure distribution.

7) Medical syringes: forcing fluid through a needle.

8) BP cuffs: Measuring BP.



X = atom

A = mass no.

Z = no. of proton

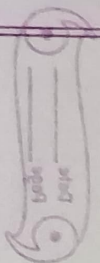
$\text{X}^+ \text{ or } \text{X}^- = \text{ions} = \text{Electrically charged atoms are called ions.}$

loss = X^+

gain = X^-

Appl. of Continuity eqⁿ

- 1) Pipes and fluid flow: Maintain constant flow rate in pipes.
- 2) Venturi effect: Used in carburetors and airplane wings for speed and pressure changes.
- 3) Blood flow: Ensure consistent flow through arteries.
- 4) Water Distribution: Maintain steady water flow in pipelines.
- 5) HVAC Systems: Ensure consistent airflow in ducts.



Feature Impulse Turbine

Working principle: ~~As hydraulic energy is converted into steam jets. into m.e~~

Pressure change: Pr. drop occurs in nozzles.

Blade action: Blade only change the direction of steam

Energy conversion: Energy is primarily from steam velocity

Example: Pelton wheel turbine

Reaction Turbine

Working principle: ~~As hydraulic energy is converted into steam jets. into m.e~~

Pressure change: Pr. drop occurs across blades.

Blade action: Blade experience both Pr. and velocity change

Energy conversion: Energy is extracted from both Pr. and velocity

Example: Francis turbine

① degree of reaction

velocity ratio

pressure ratio

discharge of water

water flow is a

fan shaped

the turbine wheel

operates at high water head

medium & low head

$$= 700 + 90 \times 5.5 + 80$$

$$= 700 + 495 + 80 = 1275 \text{ Nm}$$

$$\bullet B.M_{(A)} = 100 \times 8 + 30 \times 3 \times \left(1 + 2 + 2 + \frac{3}{2}\right) + 40 \times 2 \times \left(1 + \frac{2}{2}\right) + 50$$

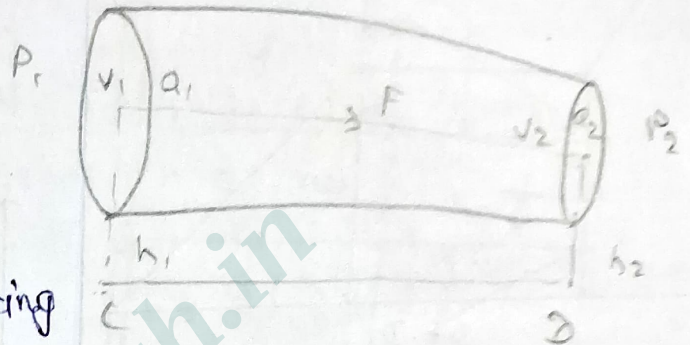
$$= 800 + 90 \times 6.5 + 80 \times 2 + 50 = 800 + 585 + 160 + 50 = 1595 \text{ Nm}$$

Bernoulli's Eqⁿ

Incompressible, Non-viscous,
streamline flow, frictional
free flow

$$K.E + P.E + P = \text{Constant}$$

Consider ^{2 sections at} a pipe with reducing
cross-section area ~~but~~ having



• In given diagram

$$P_1 = P_2 \text{ at sect 1}$$

$$V_1 = \text{velocity at sec 1}$$

$$a_1 = \text{cross-sec area at sec 1}$$

$$P_2 = P_1 \text{ at 2}$$

$$V_2 = v_2 \text{ at 2}$$

$$a_2 = \text{area at 2}$$

We know that

$$K.E = \frac{1}{2} m v^2$$

$$P.E = mgh$$

$$\text{work done} = F \times d$$

Derivation

In given condition a_1 is greater than a_2

$$\text{so } V_2 > V_1$$

$$\bullet \text{ Increase in } K.E = \frac{1}{2} m (V_2)^2 - \frac{1}{2} m (V_1)^2$$

$$\bullet \text{ Increase in } P.E = mgh_1 - mgh_2$$

$$\text{work done} = F \times d$$

$$\text{at C} = \rho_1 \times a_1 \times v_1 \times t$$

$$= \rho_1 \times (a_1 \times v_1 \times t)$$

$$= \rho_1 \times \text{vol.}$$

$$= \rho_1 \times \frac{m}{\rho}$$

Similarly, work done at D

$$= \rho_2 \times \frac{m}{\rho}$$

$$\left[\rho = \frac{m}{\text{vol.}} \right]$$

$$\text{Net work done} = \rho_1 \times \frac{m}{\rho} - \rho_2 \times \frac{m}{\rho}$$

Then, A.T conservation of energy

Increase in K.E = Decrease in P.E + work done

$$\Rightarrow \frac{1}{2} m(v_2)^2 - \frac{1}{2} m(v_1)^2 = mgh_1 - mgh_2 + \rho_1 \times \frac{m}{\rho} - \rho_2 \times \frac{m}{\rho}$$

$$\Rightarrow \frac{(v_2)^2}{2} - \frac{(v_1)^2}{2} = gh_1 + \frac{P_1}{\rho} - \frac{P_2}{\rho}$$

$$\Rightarrow \frac{(v_2)^2}{2} + gh_2 + \frac{P_2}{\rho} = gh_1 + \frac{(v_1)^2}{2} + \frac{P_1}{\rho}$$

$$\Rightarrow \frac{\rho(v_2)^2}{2} + \rho gh_2 + \frac{P_2}{\rho}$$

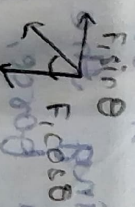
$$= \frac{\rho(v_1)^2}{2} + \rho gh_1 + \frac{P_1}{\rho}$$

$$\therefore \frac{\rho(v_2)^2}{2} + \rho gh_2 + P_2 = \frac{\rho(v_1)^2}{2} + \rho gh_1 + P_1$$

Hence proved.

Pascal Law

F₁



Consider an arbitrary right-angled triangular A in the water with density ρ (p). Let ad, bd and cd be the area of ABF, BCF and CDF respectively.

