LECTURES NOTES ON Hydraulic and Irrigation Engineering

Prepared By: Miss Saibali Mishra PTGF(Civil)

Department of Civil Engineering

Government Polytechnic, Sonepur

- ✓ Properties of fluid
- ✓ Fluid Pressure and its measurements
- ✓ Hydrostatics
- ✓ Fluid Flow
- ✓ Flow through pipe
- ✓ Hydraulic pumps

Syllabus: 1.1 Definitions and Units of Density, Specific weight, specific gravity, specific volume 5 1.2 Definitions and Units of Dynamic viscosity, kinematic viscosity, surface tension, Capillary phenomenon

Fluid Definition:

A fluid is a substance which is capable of flowing or a substance which deforms continuously when subjected to external shearing force. Characteristics:

• It has no definite shape of its own but will take the shape of the container in which it is stored.

• A small amount of shear force will cause a deformation.

Classification:

A fluid can be classified as follows:

• Liquid

• Gas Liquid: It is a fluid which possesses a definite volume and assumed as incompressible GAS: It possesses no definite volume and is compressible. Fluids are broadly classified into two types

. • Ideal fluids

• Real fluids

Ideal fluid: An ideal fluid is one which has no viscosity and surface tension and is incompressible actually no ideal fluid exists.

Real fluids: A real fluid is one which has viscosity, surface tension and compressibility in addition to the density

PROPERTIES OF FLUIDS:

1. density or mass density : (rho)
   Density of a fluid is defined as the ratio of the mass of a fluid to its vacuum. It is denoted by y
   The density of liquids are considered as constant while that of gases changes with pressure & temperature variations.
   Mathematically

$$\rho = \frac{mass}{volume}$$

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

2. **Specific weight or weight density((W):**

Specific weight of a fluid is defined as the ratio between the weights of a fluid to its valume. It is denoted by W.

$$\text{Mathematically W} = \frac{weight\ of\ fluid}{volume\ of\ fluid}$$

$$= mg/v$$

$$W = \rho g$$

3. **Specific volume:**

Specific volume of a fluid is defined as the volume of a fluid occupied by a unit mass or volume per unit mass of a fluid is called specific volume.

Mathematically

$$\text{Specific volume} = \frac{\text{Volume of fluid}}{\text{Mass of fluid}} = \frac{1}{\frac{\text{Mass of fluid}}{\text{Volume}}} = \frac{1}{\rho}$$

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

---

4. **Specific gravity:**

Specific gravity is defined as the ratio of the weight density of a fluid to the density or when density standard fluid.

For liquids the standard fluid is water.

For gases the standard fluid is air.

It is denoted by the symbol S

Simple Problems:

Problem: - 1

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

Solution. Given :

$$\text{Volume} = 1 \text{ litre} = \frac{1}{1000} \text{m}^3 \quad \left(\because 1 \text{ litre} = \frac{1}{1000} \text{m}^3 \text{ or } 1 \text{ litre} = 1000 \text{ cm}^3\right)$$

$$\text{Weight} = 7 \text{ N}$$

(*i*) Specific weight (w) $= \dfrac{\text{Weight}}{\text{Volume}} = \dfrac{7\text{N}}{\left(\frac{1}{1000}\right)\text{m}^3} = \mathbf{7000\ N/m^3.\ Ans.}$

(*ii*) Density (ρ) $= \dfrac{w}{g} = \dfrac{7000}{9.81} \text{ kg/m}^3 = \mathbf{713.5\ kg/m^3.\ Ans.}$

(*iii*) Specific gravity $= \dfrac{\text{Density of liquid}}{\text{Density of water}} = \dfrac{713.5}{1000} \quad \{\because \text{Density of water} = 1000 \text{ kg/m}^3\}$

$= \mathbf{0.7135.\ Ans.}$

Problem: - 2

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

Solution. Given : Volume = 1 litre = $1 \times 1000\ \text{cm}^3 = \frac{1000}{10^6}\ \text{m}^3 = 0.001\ \text{m}^3$

Sp. gravity $S = 0.7$

(*i*) *Density* (ρ)

Using equation (1.1.A),

Density (ρ) $= S \times 1000\ \text{kg/m}^3 = 0.7 \times 1000 = \mathbf{700\ kg/m^3}$. **Ans.**

(*ii*) *Specific weight* (*w*)

Using equation (1.1), $w = \rho \times g = 700 \times 9.81\ \text{N/m}^3 = \mathbf{6867\ N/m^3}$. **Ans.**

(*iii*) *Weight (W)*

We know that specific weight $= \frac{\text{Weight}}{\text{Volume}}$

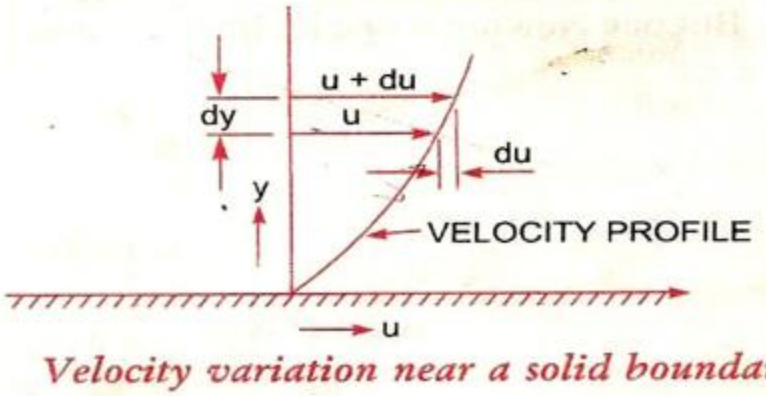
$$w = \frac{W}{0.001} \text{ or } 6867 = \frac{W}{0.001}$$

$\therefore$ $W = 6867 \times 0.001 = \mathbf{6.867\ N}$. **Ans.**

Viscosity:

Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.

Let two layers of a fluid at a distance dy apart, move one over the other at different velocities u and u + du.



Velocity variation near a solid boundary.

.

Mathematically $$\tau \; \alpha \; \frac{du}{dy}$$

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

Kinematic Viscocity:

It is defined as the ratio between the dynamic viscosity and density of fluid.

It is denoted by ϑ.

Mathematically

$$\nu = \frac{\text{Viscosity}}{\text{Density}} = \frac{\mu}{\rho} \qquad \text{...(1.4)}$$

The units of kinematic viscosity is obtained as

$$\nu = \frac{\text{Units of } \mu}{\text{Units of } \rho} = \frac{\text{Force} \times \text{Time}}{(\text{Length})^2 \times \frac{\text{Mass}}{(\text{Length})^3}} = \frac{\text{Force} \times \text{Time}}{\frac{\text{Mass}}{\text{Length}}}$$

$$= \frac{\text{Mass} \times \frac{\text{Length}}{(\text{Time})^2} \times \text{Time}}{\left(\frac{\text{Mass}}{\text{Length}}\right)} \qquad \left\{ \begin{aligned} \because \text{ Force} &= \text{Mass} \times \text{Acc.} \\ &= \text{Mass} \times \frac{\text{Length}}{\text{Time}^2} \end{aligned} \right\}$$

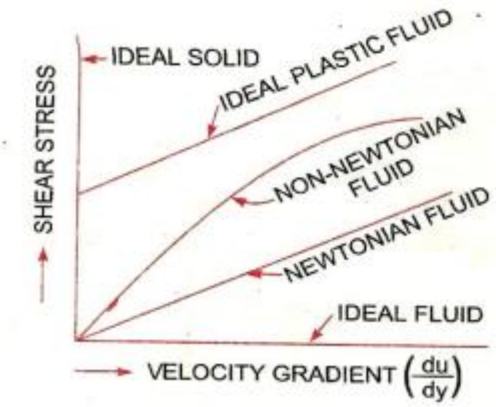
$$= \frac{(\text{Length})^2}{\text{Time}}.$$

Newton's law of viscosity:

It states that the shear stress on a fluid element layer is directly proportional to the rate of shear stear strain. The constant of proportionality is called the co-efficient of viscosity.

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

Fluids which obey the above equation or law are known as Newtonian fluids & the fluids which do not obey the law are called Non-Newtonian fluids.



Chapter-2

Syllabus: 2.1 Definitions and units of fluid pressure, pressure intensity and pressure head 2.2 Concept of atmospheric pressure, gauge pressure, vacuum pressure and absolute pressure 2.3 Pressure measuring instruments Manometers: Simple and differential Bourdon tube pressure gauge (Simple Numerical)

Pressure of a Fluid:

When a fluid is contained in a vessel, it exerts force at all points on the sides & bottoms of the container. The force exerted per unit area is called pressure.

If P = Pressure at any point

F = Total force uniformly distributed over an area

A = unit area

P = F/A

Pressure head of a liquid:

A liquid is subjected to pressure due to pressure due to its own weight, this pressure increases as the depth of the liquid increases.

Let a bottomless cylinder stand in the liquid

Let w = specific weight of the liquid.

H = height of the liquid in the cylinder.

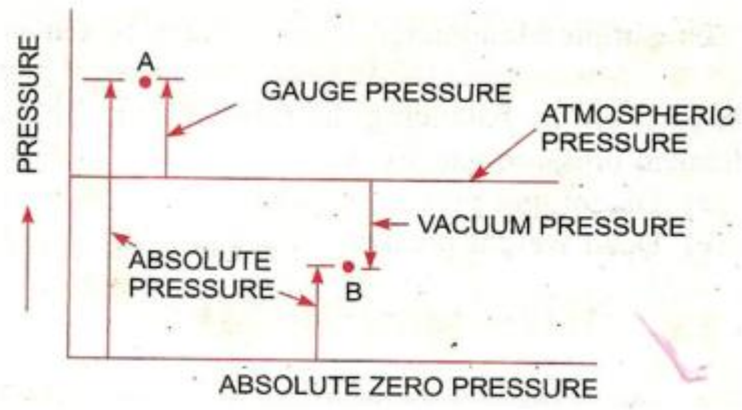
A = Area of the cylinder.

$$P = \frac{F}{A} = \frac{weight\ of\ the\ liquid\ in\ the\ cylinder}{Area\ of\ the\ cylinder}$$

$$= \frac{W \times A\,h}{A}$$

$$= Wh$$

$$= \rho gh$$



Atmospheric Pressure:

The atmospheric air exerts a normal pressure upon all surfaces with which It is in contact & known as atmospheric pressure.

Absolute pressure:

It is defined as the pressure which is measured with reference to absolute vacuum pressure or absolute zero pressure.

Gauge pressure:

It is defined as the pressure which is measured with the help of a pressure measuring instrument in which the atmospheric pressure is taken as datum. The atmospheric pressure on the scale is marked as zero.

Vacuum pressure:

It is defined as the pressure below the atmospheric pressure.

Mathematically:

Absolute pressure = Atmospheric pressure + gauge pressure

Or $P_{abs} = P_{atm} + P_{gauge}$

Pressure Measuring Instruments:

The pressure of a fluid is measured by the following devices :

1. **Manometers**
2. **Mechanical Gauges.**

Manometers:

Manometers are defined as the device used for measuring the pressure at a point in a fluid by balancing the collomn of fluid by the same another column of the fluid. They are classified as:

(a) **Simple manometers.**
(b) **Differential Manometers.**

Chapter-3

Syllabus: 3.1 Definition of hydrostatic pressure 3.2 Total pressure and centre of pressure on immersed bodies (Simple Numericals) 3.3 Archimedis' principle, concept of buoyancy, metacentre and metacentric height 3.4Concept of floatation

Hydrostatics:

Hydrostatics means the study of pressure exerted by thye liquid at rest & the direction of such a pressure is always right angle to the surface on which it acts.

Total pressure and center of pressure:

Total pressure

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

Center of pressure:

Center of pressure is defined as the point of application of the total pressure on the surface.

There are four cases of submerged surfaces on which the total pressure force and center of pressure is to be determined. The submerged surfaces may be:

1. **Vertical plane surface**
2. **Horizontal plane surface**
3. **Inclined plane surface**
4. **Curved surface.**

Vertical plane surface submerged in liquid

Consider a plane vertical surface of arbitrary shape immersed in a liquid as shown in figure

Let A = total area of the surface

H = distanced of C.G. of the area from free surface of liquid

G = center of gravity ofplane surface

P = center of pressure

h* = distance of center of pressure from free surface of liquid.

Total pressure(F):

The total pressure on the surface may be determined by dividing the entire surface into a number of small parallel strips. The force on surface is then calculated by integrating the force on small strip.

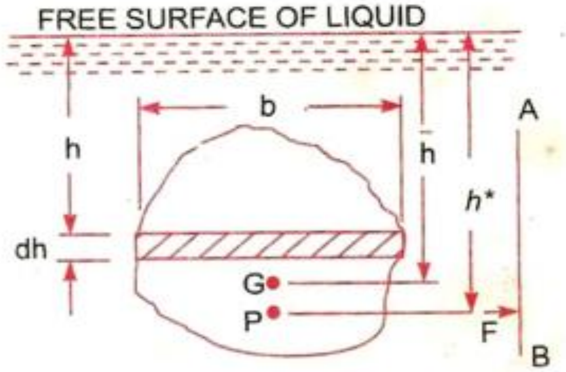
Consider a strip of thickness dh & width b at a depth of h form free surface of liquid.

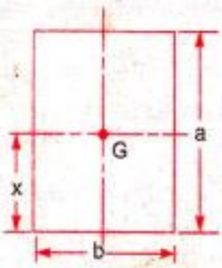
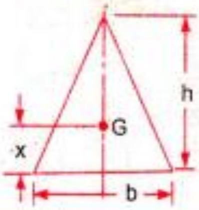
Pressure intensity on the strip

$$p = \rho g h$$

<u>Centre of the pressure:(</u> h*)

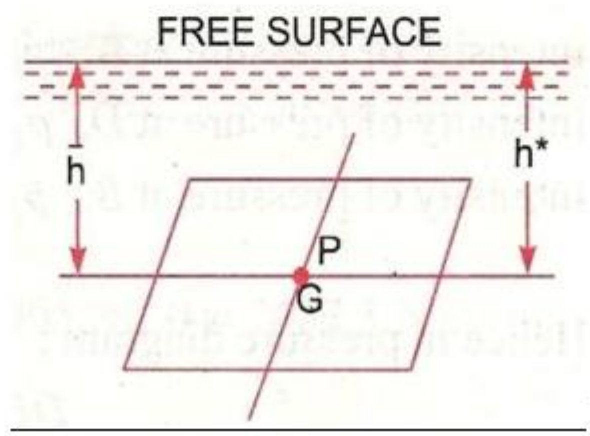
Centre of pressure is calculated by using the principle of moments which states that the moment of resultant force about an axis is equal to the sum of moments of the components about the same axis.



Plane surface	C.G. from the base	Area	Moment of inertia about an axis passing through C.G. and parallel to base (I_G)	Moment of inertia about base (I_0)
1. Rectangle 	$x = \frac{d}{2}$	bd	$\frac{bd^3}{12}$	$\frac{bd^3}{3}$
2. Triangle 	$x = \frac{h}{3}$	$\frac{bh}{2}$	$\frac{bh^3}{36}$	$\frac{bh^3}{12}$

Horizontal plane surface submerged in liquid:

Consider a plane horizontal surface immersed in a static fluid as every point of the surface is at the same depth from the free surface of the liquid, the pressure intensity will be equal on the entire surface.



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

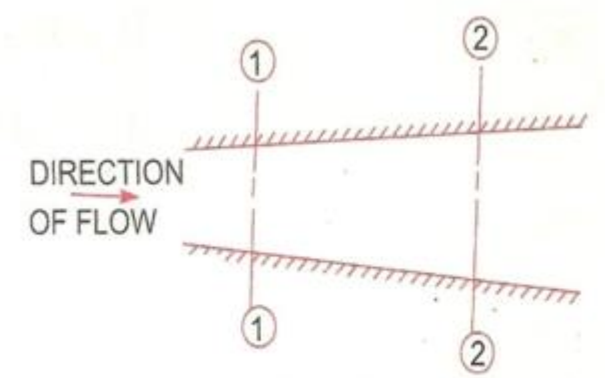
TYPES OF FLOW:-

The fluid flow is classified as follows:

- **STEADY AND UNSTEADY FLOW**
- **UNIFORM AND NON- UNIFORM FLOWS**
- **LAMINAR AND TURBULANT FLOWS**
- **COMPRESSIBLE AND INCOMPRESSIBLE FLOWS**
- **ROTATIONAL AND IRROTATIONAL FLOWS**
- **ONE, TWO, THREE DIMENSIONAL FLOW**

EQUATION OF CONTINUITY:-

It is based on the principle of conservation of mass. For a fluid flowing through the pipe at all the cross-section, the quantity of fluid per second is constant.



Fluid flowing through a pipe.

$$A_1 V_1 = A_2 V_2$$

Application of Bernoulli's equation:

Bernoulli's equation is applied in all problems of incompressible fluid flow where energy consideration are involved.
It is also applied to following measuring devices

1. **Venturimeter**
2. **Orifice meter**
3. **Pitot tube**

Venturimeter:

A venturimeter is a device used for measuring the rate of a flow of a fluid flowing through a pipe it consists of three parts.

I. **Short converging part**
II. **Throat**
III. **Diverging part**

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 flow at a point becomes zero, the pressure there is increased due to conversion of the kinetic energy into pressure energy.

The pitot-tube consists of a glass tube, bent an right angles

Consider two points 1 and 2 at te same level. Such a ay that 2 is at he inlet of pitot tube and one is the far away from the tube

Let P_1 = pressure at point 1

V_1 = velocity of fluid at point 1

P_2 = pressure at 2

V_2 = velocity of fluid at point 2

H = Depth of tube in the liquid

h = Rise of the liquid in the tube above the free surface

Different Arrangement of Pitot tubes