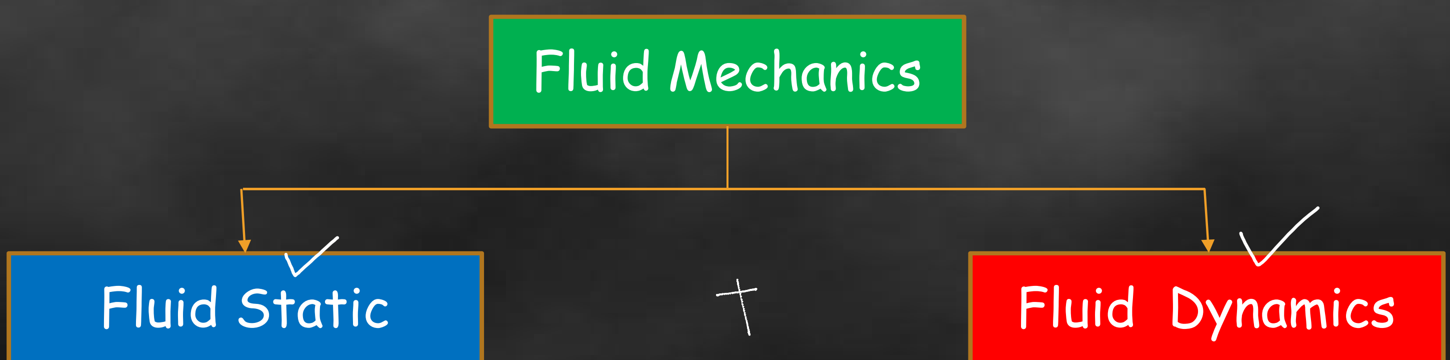
Subject: **Fluid Mechanics and Hydraulic machine**

Chapter : **Fluid and their Properties**

Topic : **Fluid and Their Properties**

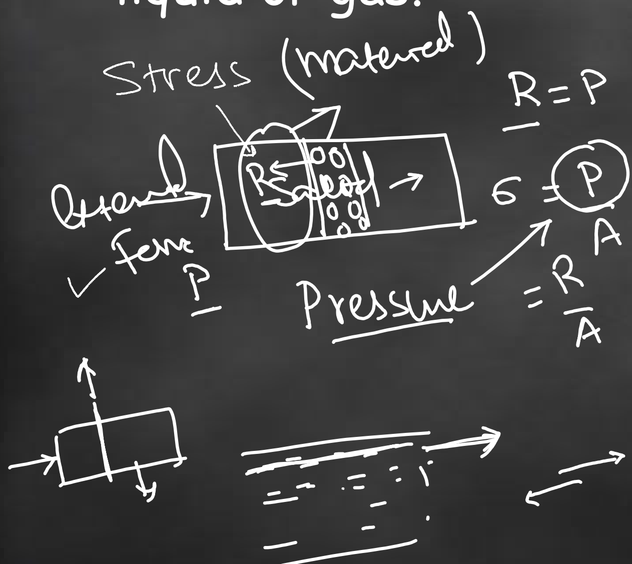
Introduction of Fluid

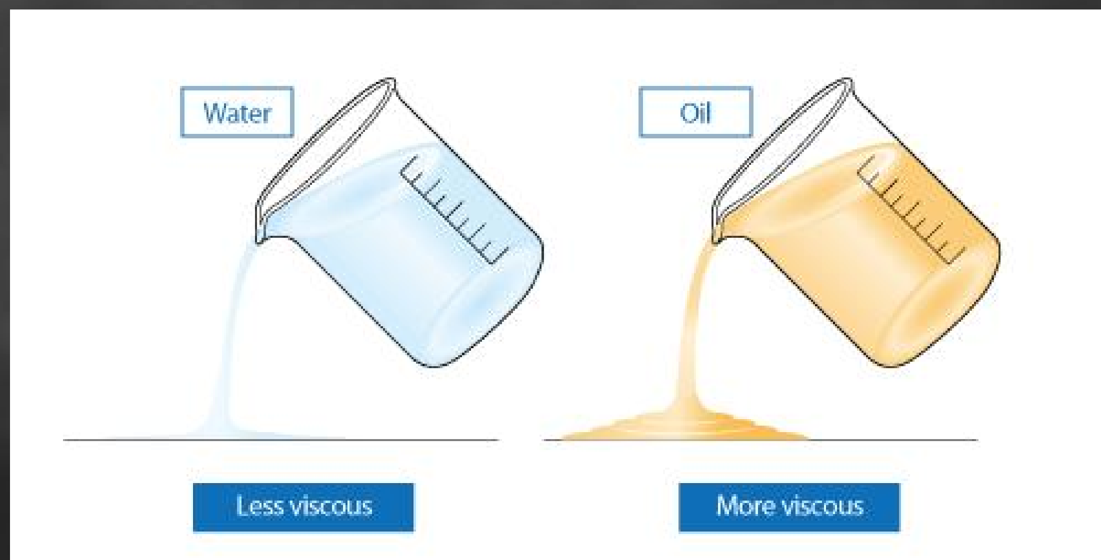
- Fluid mechanics is a study of the behavior of fluids, either at rest (fluid statics) or in motion (fluid dynamics).
- The analysis is based on the fundamental laws of mechanics, which relate continuity of mass and energy with force and momentum.
- An understanding of the properties and behavior of fluids at rest and in motion is of great importance in engineering.



Definition of Fluid

- Fluid can be defined as a substance which can deform continuously when being subjected to shear stress at any magnitude. In other words, it can flow continuously as a result of shearing action. This includes any liquid or gas.





Density

Density of a fluid,

Definition: mass per unit volume,

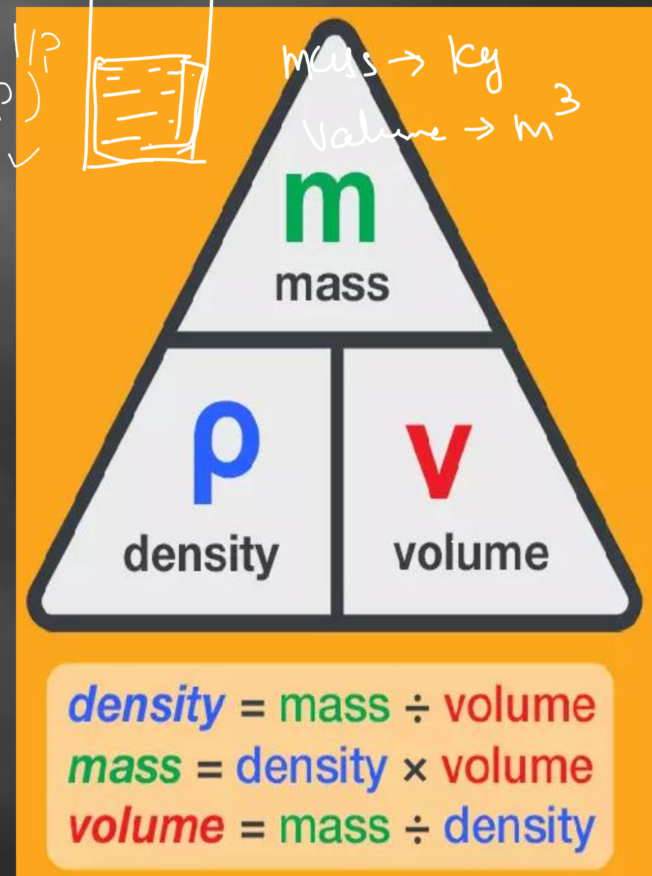
- slightly affected by changes in *temperature* and *pressure*.

ρ = mass/volume = m/V

Units: kg/m^3 or g/cm^3

Typical values:

Water = 1000 kg/m^3; Air = 1.23 kg/m^3



Specific weight or Weight Density

Specific weight of a fluid, ¥

- Definition: weight of the fluid per unit volume

- Arising from the existence of a gravitational force
- The relationship γ and g can be found using the following:

Since $\rho = m/V$

therefore $\gamma = \rho g$

Units: N/m^3

Typical values:

Water = 9814 N/m^3; Air = 12.07 N/m^3

Specific gravity or Relative Density

The specific gravity (or relative density) can be defined in two ways:

Definition 1:

A ratio of the density of a substance to the density of water at standard temperature (4°C) and atmospheric pressure, or

Definition 2:

A ratio of the specific weight of a substance to the specific weight of water at standard temperature (4°C) and atmospheric pressure.

Unit: dimensionless.

$$SG = \frac{\rho_s}{\rho_w} = \frac{\gamma_s}{\gamma_w}$$

gas

$$Sp.\,grav = \frac{\rho_{gas}}{\rho_a} \quad \frac{kg/m^3}{kg/m^3}$$

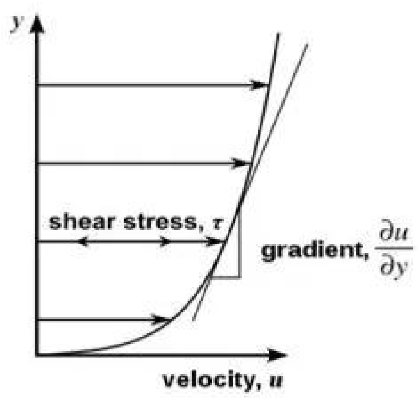
$$Sp.\,gravity = \frac{\rho_F}{\rho_w}$$

Viscosity (Dynamic viscosity)

- Viscosity, μ, is the property of a fluid, due to cohesion and interaction between molecules, which offers resistance to shear deformation.

- Different fluids deform at different rates under the same shear stress. The ease with which a fluid pours is an indication of its viscosity. Fluid with a high viscosity such as syrup deforms more slowly than fluid with a low viscosity such as water. The viscosity is also known as dynamic viscosity.

  Units: $N.s/m^2$ or kg/m/s



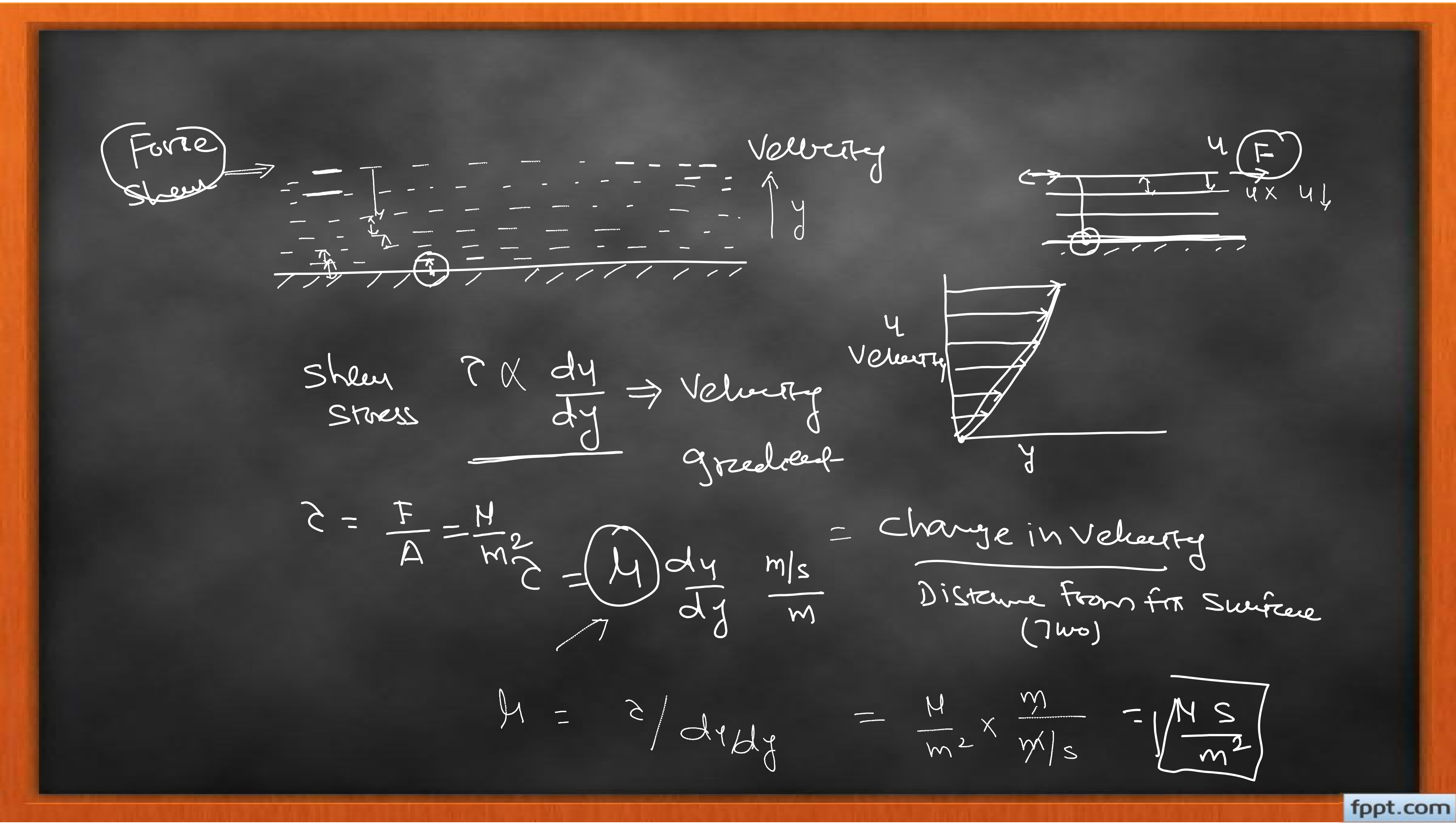
Viscosity, $\tau = \mu \frac{du}{dy}$

Where,

μ = Dynamic viscosity

τ = Shear stress= F/A

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



Force Shear
Velocity
y
u
F
u x u
u
Velocity
y
Shear stress τ ∝ du/dy ⇒ Velocity gradient
τ = F/A = N/m²
τ = μ du/dy
m/s / m
= Change in Velocity / Distance from fix surface (Two)
μ = τ / du/dy = N/m² × m / m/s = N S / m²

Newtonian and Non-Newtonian Fluid

Fluid --obey--> Newton's law of viscosity --refer--> Newtonian fluids

Example:
- Air
- Water
- Oil
- Gasoline
- Alcohol
- Kerosene
- Benzene
- Glycerin

Newton's' law of viscosity is given by;

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

τ = shear stress
μ = viscosity of fluid
du/dy = shear rate, rate of strain or velocity gradient

- The viscosity μ is a function only of the condition of the fluid, particularly its temperature.

Newtonian and Non-Newtonian Fluid

Fluid --- Do not obey ---> Newton's law of viscosity --- refer ---> Non- Newtonian fluids

- The viscosity of the non-Newtonian fluid is dependent on the *velocity gradient* as well as the *condition of the fluid*.

Newtonian Fluids

- a linear relationship between shear stress and the velocity gradient (rate of shear),
- the slope is constant
- the viscosity is constant

$$\tau = \mu \frac{du}{dy} + 0$$

$$y = mx + c$$

Non-Newtonian fluids

- slope of the curves for non-Newtonian fluids varies

Types of Fluids

$$\tau = \mu \left(\frac{du}{dy}\right)^{n} + C$$

$y = mx^{n} + c$

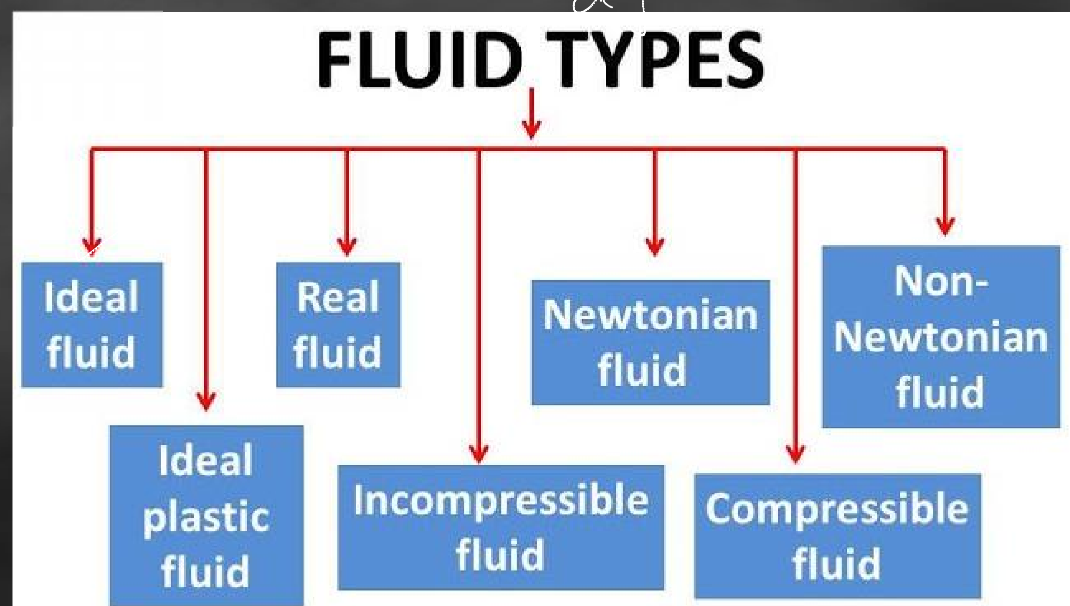
$n = 1$

$y \rightarrow x$

$c \neq 0 \quad n \neq 1 \quad \Rightarrow \quad \tau = \mu \frac{dy}{dy}$ ✓

Types of fluid based on two value

1. Value of n ✓
2. Value of C ✓



Types of Fluids

1. Newtonian Fluids:

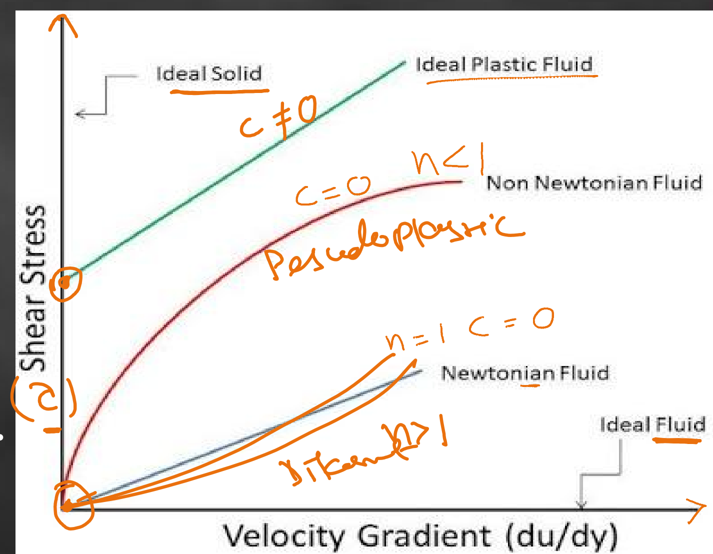
- Value of $n = 1$ and $C = 0$ in equation then the fluid is known as Newtonian fluid

2. Non-Newtonian Fluids:

- Value of $n > 1$ or $n < 1$ and $C = 0$ in equation then the fluid is known as Non-Newtonian fluid

- $N < 1$ -------

Pseudo plastic: most non-Newtonian fluids fall under this group. Viscosity decreases with increasing velocity gradient,
e.g. colloidal substances like clay, milk, and cement.



Types of Fluids

- N > 1 -----

Dilatants: viscosity decreases with increasing velocity gradient, e.g. quicksand.

3. Idea Fluid

If $\tau = 0$ in the equation then the fluid is known as Ideal Fluid.

4. Ideal Solid

If $du/dy = 0$ in the equation then substance is Known as Ideal Solid.

5. Ideal Plastic Fluid

If $n = 1$ and $C > 0$ then the fluid is known as Ideal Plastic fluid.