Module-I

FLUID STATICS

Mechanics: Deals with action of forces on bodies at rest or in motion.

State of rest and Motion: They are relative and depend on the frame of reference. If the position with reference to frame of reference is fixed with time, then the body is said to be in a state of rest. Otherwise, it is said to be in a state of motion.

Scalar and heater quantities: Quantities which require only magnitude to represent them are called scalar quantities. Quantities which acquire magnitudes and direction to represent them are called vector quantities.

Eg: Mass, time internal, Distance traveled _ Scalars

Weight, Displacement, Velocity _ Vectors

Velocity and Speed: Rate of displacement is called velocity and Rate and distance travelled is called Speed.

Unit: m/s

Acceleration: Rate of change of velocity is called acceleration. Negative acceleration is called retardation.

Momentum: The capacity of a body to impart motion to other bodies is called momentum.

The momentum of a moving body is measured by the product of mass and velocity the moving body

Momentum = Mass x Velocity

Unit: Kgm/s

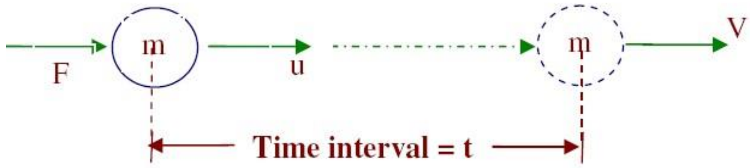
Newton's first law of motion: Every body continues to be in its state of rest or uniform motion unless compelled by an external agency.

Inertia: It is the inherent property the body to retain its state of rest or uniform motion.

Force: It is an external agency which overcomes or tends to overcome the inertia of a body.

Newton's second law of motion: The rate of change of momentum of a body is directly proportional to the magnitudes of the applied force and takes place in the direction of the applied force.

Measurement of force:



Change in momentum in time ‘t’ = mv – mu

$$\text{Rate of change of momentum} = \frac{mv - mu}{t}$$

$$F \,\alpha\, \frac{mv - mu}{t}$$

$$F \,\alpha\, m\left(\frac{v - u}{t}\right)$$

$$F \,\alpha\, ma$$

$$F = K\ ma$$

If F = 1 When m = 1 and u = 1

Then K = 1

F = ma.

Unit: Newton (N)

Mass: Measure of amount of matter contained by the body it is a scalar quantity. Unit: Kg.

Weight: Gravitational force on the body. It is a vector quantity.

F = ma

W = mg

Unit: Newton (N) g = 9.81 m/s^2

Volume: Measure of space occupied by the body.

Unit: m3

m3 = 1000 liters

Work: Work done = Force x Displacement _ Linear motion.

Work done = Torque x Angular displacement _ Rotatory motion.

Unit: Nm or J

Energy: Capacity of doing work is called energy.

Unit: Nm or J

Potential energy = mgh

Kinetic energy = ½ mv^2

Power: Rate of doing work is called Power.

$$\text{Power:} = \frac{\text{Force x displacement}}{\text{time}}$$

$$= \text{Force x Velocity} \rightarrow \text{Linear Motion.}$$

$$P = \frac{2\Pi N T}{60} \rightarrow \text{Rotatory Motion.}$$

Matter: Anything which possesses mass and requires space to occupy is called matter.

States of matter:

Matter can exist in the following states

Solid state.

Solid state: In case of solids intermolecular force is very large and hence molecules

are not free to move. Solids exhibit definite shape and volume. Solids undergo certain amount of deformation and then attain state of equilibrium when subjected to tensile, compressive and shear

Fluid State: Liquids and gases together are called fluids. In case of liquids

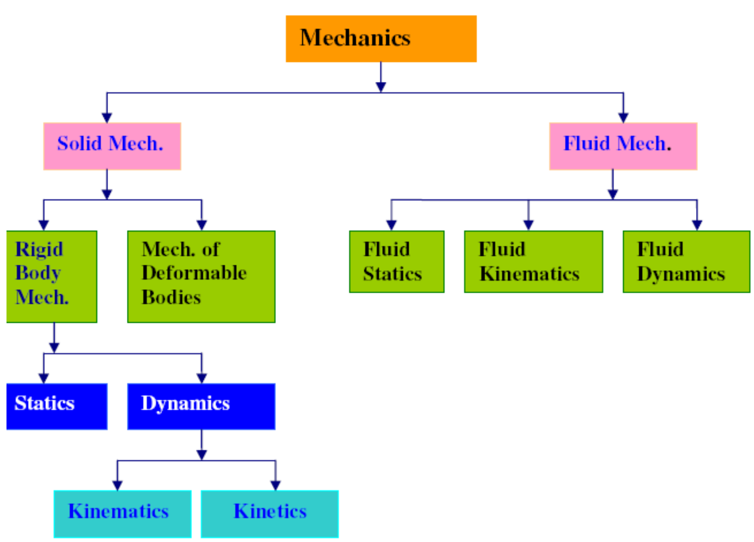
Intermolecular force is comparatively small. Therefore liquids exhibit definite volume. But they assume the shape of the container

Liquids offer very little resistance against tensile force. Liquids offer maximum resistance against compressive forces. Therefore, liquids are also called incompressible fluids. Liquids undergo continuous or prolonged angular deformation or shear strain when subjected to tangential force or shear force. This property of the liquid is called flow of liquid. Any substance which exhibits the property of flow is called fluid. Therefore liquids are considered as fluids.

In case of gases intermolecular force is very small. Therefore the molecules are free to move along any direction. Therefore gases will occupy or assume the shape as well as the volume of the container.

Gases offer little resistance against compressive forces. Therefore gases are called compressible fluids. When subjected to shear force gases undergo continuous or prolonged angular deformation or shear strain. This property of gas is called flow of gases. Any substance which exhibits the property of flow is called fluid. Therefore gases are also considered as fluids.

Branches of Mechanics:



I. Fluid Statics deals with action of forces on fluids at rest or in equilibrium.

II. Fluid Kinematics deals with geometry of motion of fluids without considering the cause of motion

Properties of fluids:

1. Mass density or Specific mass (ρ):

Mass density or specific mass is the mass per unit volume of the fluid.

$$\rho = \frac{Mass}{Volume}$$

$$\rho = \frac{M}{V} \text{ or } \frac{dM}{dV}$$

2. Weight density or Specific weight (ϒ):

Weight density or Specific weight of a fluid is the weight per unit volume.

Unit: kg/m3 or kgm3

With the increase in temperature volume of fluid increases and hence mass density decreases.

In case of fluids as the pressure increases volume decreases and hence mass density increase

3. Specific gravity or Relative density (S):

It is the ratio of specific weight of the fluid to the specific weight of a standard fluid.

$$S = \frac{\gamma \text{ of fluid}}{\gamma \text{ of standard fluid}}$$

Unit: It is a dimensionless quantity and has no unit.

In case of liquids water at 4^0C is considered as standard liquid.

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γ (specific weight) of water at 4^{o}C (standard liquid) is 9.81 $\frac{kN}{m^3}$ or 9.81 x 10^3 $\frac{kN}{m^3}$

Note: We have

1. $S = \frac{\gamma}{\gamma_{standard}}$

$\therefore \quad \gamma = S \times \gamma_{standard}$

2. $S = \frac{\gamma}{\gamma_{standard}}$

$S = \frac{\rho \times g}{\rho_{standard} \times g}$

$S = \frac{\rho}{\rho_{standard}}$

Specific gravity or relative density of a fluid can also be defined as the ratio of mass density of the fluid to mass density of the standard fluid. Mass density of standard water is 1000 kg/m3.

4. Specific volume (∀): It is the volume per unit mass of the fluid.

$$\therefore \quad \forall = \frac{Volume}{mass}$$

$$\forall = \frac{V}{M} \; or \; \frac{dV}{dM}$$

Unit: m3/kg

As the temperature increases volume increases and hence specific volume increases. As the pressure increases volume decreases and hence specific volume decreases.

Effect of temperature on surface tension of liquids:

In case of liquids, surface tension decreases with increase in temperature. Pressure has no or very little effect on surface tension of liquids.

Problems:

1. What is the pressure inside the droplet of water 0.05 mm in diameter at 20^0C if the pressure outside the droplet is 103 kPa Take σ = 0.0736 N/m at 20^0C.

$$p = \frac{4\sigma}{D}$$

$$= \frac{4x0.0736}{0.05x10^{-3}}$$

$$p = 5.888x10^{+3} N/m^2$$

$$p = p_{inside} - p_{outside}$$

$$p_{inside} = (5.888 + 103)10^3$$

$$p_{inside} = 108.88x10^3 Pa$$

$$p_{inside} = ?$$

$$D = 0.05x10^{-3} m$$

$$p_{outside} = 103kPa$$

$$= 103x10^3 N/m^2$$

$$\sigma = 0.0736 N/m$$

2. liquid bubble 2cm in radius has an internal pressure of 13Pa. Calculate the surface tension of liquid film.

$$p = \frac{8\sigma}{D}$$

$$\sigma = \frac{13x4x10^{-2}}{8}$$

$$\sigma = 0.065 N/m$$

$$R = 2cm$$

$$D = 4cm$$

$$= 4x10^{-2} m$$

$$p = 13Pa(N/m^2)$$

Compressibility:

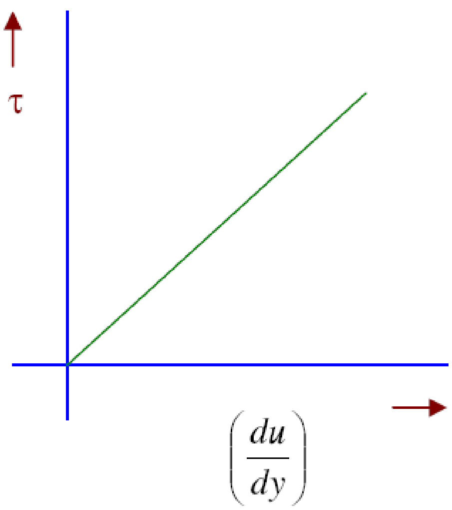
It is the property by virtue of which there will be change in volume of fluid due to change in pressure.

Rheological classification of fluids: (Rheology _ Study of stress – strain behavior).

1. **Newtonian fluids:** A fluid which obeys Newton's law of viscosity i.e., t = μ. *du/dy* is called Newtonian fluid. In such fluids shear stress varies directly as shear strain.

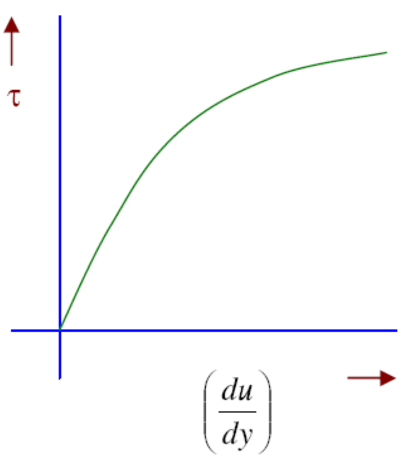
In this case the stress strain curve is a stress line passing through origin the slope of the line gives dynamic viscosity of the fluid.

Eg: Water, Kerosene.



3. **Non- Newtonian fluid:** A fluid which does not obey Newton's law of viscosity is called non-Newton fluid. For such fluids,

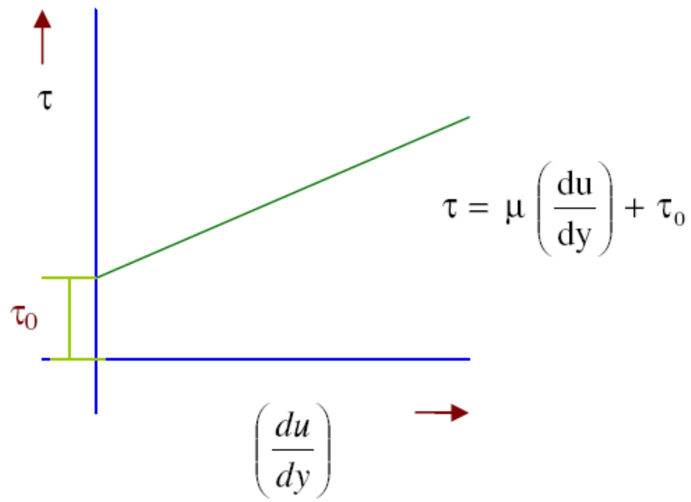
$$\tau = \mu . \left(\frac{du}{dy}\right)^n$$



3. Ideal Plastic fluids:

In this case the strain starts after certain initial stress (t0) and then the stress strain relationship will be linear. t0 is called initial yield stress. Sometimes they are also called Bingham's Plastics.

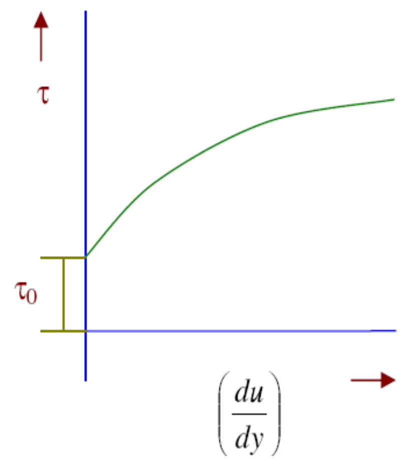
Eg: Industrial sludge.



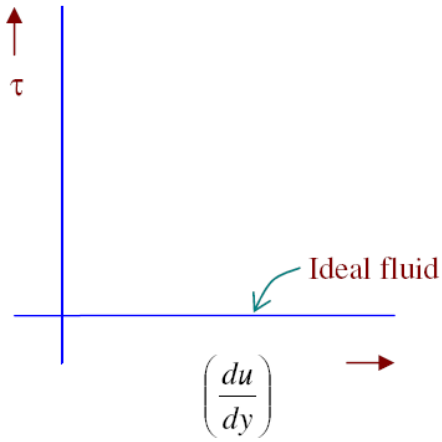
4. Thixotropic fluids:

These require certain amount of yield stress to initiate shear strain. After wards stress-strain relationship will be non – linear.

Eg; Printers ink.



Ideal fluid: Any fluid for which viscosity is assumed to be zero is called Ideal fluid. For ideal fluid t = 0 for all values of du/dy



5. Real fluid :

Any fluid which posses certain viscosity is called real fluid. It can be Newtonian or non – Newtonian, thixotropic or ideal plastic.