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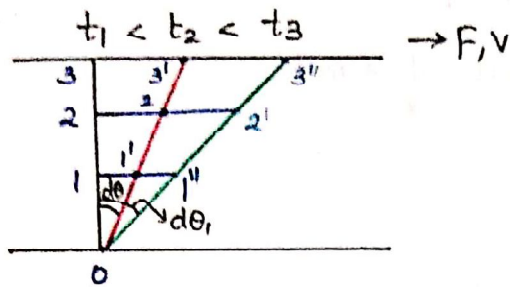
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Definition of fluid:

A fluid is a substance which is capable of flowing or deforming under the action of shear force [however small the force may be]. Ex:- Liquids, Gases, Vapour etc.



Differences between Solids and Fluids:-

In case of solids, under the action of shear force, there is a deformation which does not change with time. Therefore, in solids deformation ($d\theta$) is important.

In case of fluids, under the action of shear force, there is a deformation which constantly change with time. Therefore, in fluids the rate of deformation ($d\theta/dt$) is important.

On the removal of force, solid tries to regain its original shape whereas fluids will never regain its original shape after the removal of shear force.

Note:- When there is a shear force, the fluid flows and when there is no shear force, the fluid remains stationary i.e., on a static fluid the shear force is zero.

PROPERTIES OF FLUIDS:

1) Density (or) Mass Density (ρ):-

It is the ratio of mass of fluid to its volume. Its unit is kg/m^3 . Its dimensional formula is $M L^{-3}$.

* Density represents the heaviness of fluid.

$$\rho_{H_2O} = 1000 \text{ kg/m}^3.$$

$$\rho_{Air} = 1.2 \text{ kg/m}^3$$

$$\rho_{Hg} = 13600 \text{ kg/m}^3.$$

Density depends on temp. and pressure. \Rightarrow $\rho \begin{cases} \nearrow T \uparrow (V \uparrow) \Rightarrow \rho \downarrow \\ \searrow P \uparrow (V \downarrow) \Rightarrow \rho \uparrow \end{cases}$

2) Specific Weight (or) Weight density (w):-

It is the ratio of weight of fluid to its volume. Its unit is (N/m^3) . Its dimensional formula is $M L^{-2} T^{-2}$.

$$w = \frac{\text{Wt. of fluid } \left(\frac{N}{m^3}\right)}{\text{Volume}} ; w = mg \Rightarrow w = \frac{mg}{\text{Vol}} = \rho g.$$

$$\therefore \boxed{w = \rho g}$$

$$w_{H_2O} = 1000 \times 9.81 \Rightarrow 9810 \text{ N/m}^3.$$

$w \begin{cases} \nearrow \rho \begin{cases} \nearrow T \\ \searrow P \end{cases} \\ \searrow g \rightarrow (\text{varies with location}) \end{cases}$

* Though Density is an absolute quantity; Specific weight is not because Specific weight varies from location to location.

(3) Specific Gravity (S):-

It is the ratio of density of fluid to density of standard fluid.

In case of liquids, the standard fluid is Water at 4°C whereas in case of gases, the standard fluid is either Hydrogen or Air at a given temp. and pressure. It is dimensionless (or) unitless. $[M^0 L^0 T^0]$.

$$\boxed{S = \frac{\rho_{\text{fluid}}}{\rho_{\text{std. fluid}}} = \frac{\rho_f \cdot g}{\rho_{\text{std. f.}} \cdot g} = \frac{w_f}{w_{\text{std. f.}}}}$$

* Though all specific gravities are relative densities, All Relative densities need not be Specific gravities.

$$\boxed{S = \frac{w_{\text{fluid}}}{w_{\text{std. fluid}}}}$$

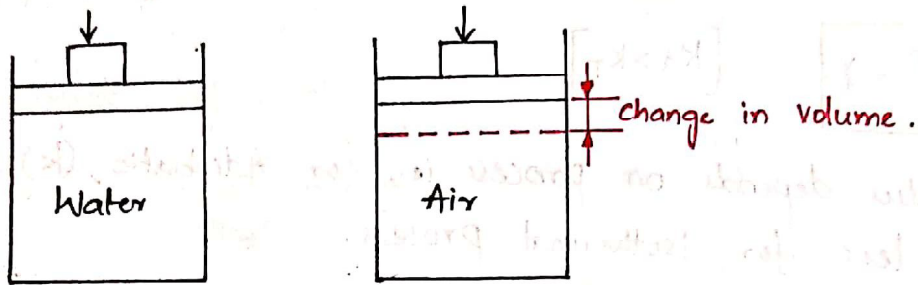
* $S_{\text{water}} = 1$.

If the specific gravity of liquid is less than 1; it is lighter than water.
 If the specific gravity of liquid is more than 1; it is heavier than water.

(4) Compressibility (β):-

Compressibility is variation of volume (or) density on a given mass of fluid w.r.t. pressure.

Liquids are generally treated as incompressible and gases are compressible fluids.



Mathematically; it is the reciprocal of Bulk Modulus i.e., $\beta = 1/k$.

$$\rho = \frac{m}{V} \Rightarrow m = \rho V = C$$

$$\Rightarrow \rho dv + V d\rho = 0 \Rightarrow -\frac{dv}{v} = \frac{d\rho}{\rho}$$

$$\therefore k = \frac{dp}{-\frac{dv}{v}} = \frac{dp}{\frac{d\rho}{\rho}} = \rho \frac{dp}{d\rho}$$

$$\beta = 1/k = \frac{1}{\rho} \frac{d\rho}{dp} \quad \therefore \boxed{\beta = \frac{1}{\rho} \cdot \frac{d\rho}{dp}} \quad \text{If } d\rho = 0 \Rightarrow \rho = \text{Constant}$$

$$\downarrow$$

$$\beta = 0 \rightarrow \text{Incompressible.}$$

A fluid is said to be incompressible fluid; if the change in density is zero with respect to pressure i.e., for an incompressible fluid; Density remains constant.

Isothermal Compressibility of an Ideal gas:-

$$PV = mRT$$

$$P = \frac{m}{V} RT$$

$$P = \rho RT$$

$$\frac{dp}{d\rho} = RT$$

$$k = \rho \frac{dp}{d\rho}$$

$$k = \rho RT$$

$$\boxed{k_T = P}$$

$$\therefore \beta_T = \frac{1}{k_T} = \frac{1}{P}$$

$$\boxed{\beta_T = \frac{1}{P}}$$

Adiabatic Bulk Modulus (K_a):-

$$PV^\gamma = c$$

$$\Rightarrow P = C_1 \rho^\gamma$$

$$\beta = \frac{1}{\rho k}$$

$$P \left(\frac{m}{V} \right)^\gamma = c$$

$$\Rightarrow \frac{dP}{d\rho} = \gamma \cdot C_1 \cdot \rho^{\gamma-1}$$

$$\beta_a = \frac{1}{\gamma P}$$

$$\frac{P}{\rho^\gamma} = \frac{c}{m^\gamma} = \text{Const.}$$

$$k = \rho \frac{dP}{d\rho} = \rho \cdot \gamma \cdot C_1 \cdot \rho^{\gamma-1}$$

$$k = \gamma C_1 \rho^\gamma$$

* Here; $PV^\gamma = c$ is used for Rev. Adiabatic \Rightarrow Isentropic
 $\therefore K_a = K_s = \gamma P$

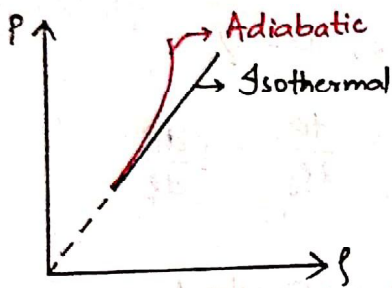
$$\frac{P}{\rho^\gamma} = C_1$$

$$\therefore K_a = \gamma P$$

$$\therefore \frac{K_a}{K_T} = \frac{\gamma P}{P} = \gamma$$

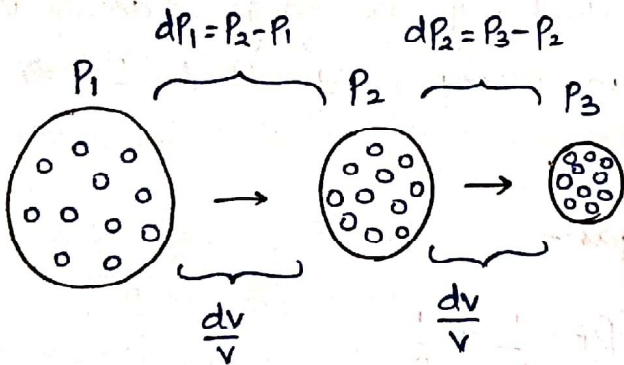
$$[K_a > K_T]$$

\rightarrow Bulk Modulus depends on process i.e., for Adiabatic; (k) is more and it is less for isothermal process.



$$P = \rho R T = c$$

The Adiabatic Bulk Modulus is greater than Isothermal Bulk Modulus because in adiabatic; there is no heat transfer. Therefore during Compression the temp. increases; resulting in higher molecular activity which offers more resistance for further Compression and hence Adiabatic Bulk Modulus is more.



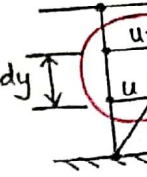
$$k_1 = \frac{dP_1}{-\frac{dv}{v}}$$

$$; k_2 = \frac{dP_2}{-\frac{dv}{v}}$$

With increase in Pressure; the Bulk modulus increase, this is because at high pressure molecules offer greater resistance for further Compression.

(5) Viscosity :

adjacent la



$$\frac{du}{dy} = \text{velo}$$

$$\frac{d\theta}{dt} = \text{rot}$$



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