Hind Photostat & Book Store

CIVIL, MECHANICAL - ENGINEERING

UNACADEMY

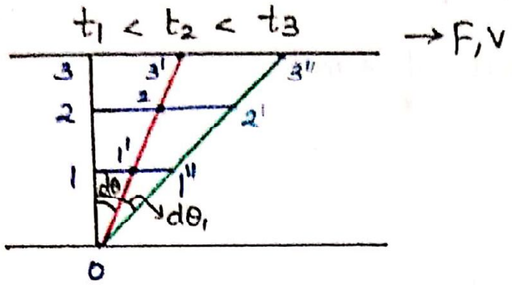
Fluid Mechanics

Written By-kulkarni Sir

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

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/m³. It dimensional formula is ML^{-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. $\Rightarrow \rho$ → $T\uparrow (V\uparrow) \Rightarrow \rho\downarrow$; → $P\uparrow (V\downarrow) \Rightarrow \rho\uparrow$

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

It is the ratio of weight of fluid to its volume. Its unit is (N/m³). It dimensional formula is $ML^{-2}T^{-2}$.

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

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

w → ρ → T, P ; w → g → (varies with location)

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

* 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. $[M^0L^0T^0]$.

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

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

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

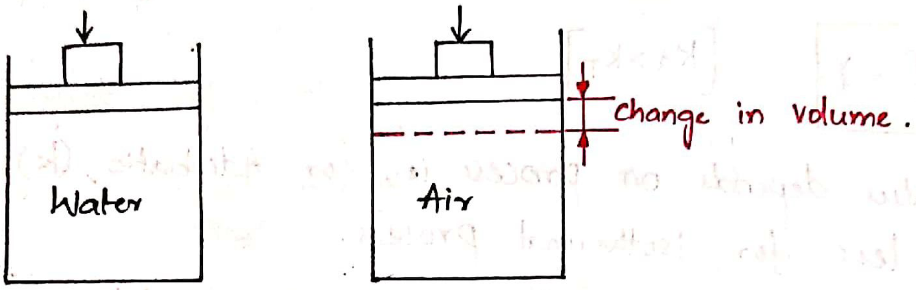
* $S_{water} = 1$.

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., $\beta = 1/K$.

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

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

$$\therefore K = \frac{dP}{-\frac{dV}{V}} = \frac{dP}{d\rho/\rho} = \rho\frac{dP}{d\rho}$$

$$\beta = 1/K = \frac{1}{\rho}\frac{d\rho}{dP} \qquad \therefore \boxed{\beta = \frac{1}{\rho}\cdot\frac{d\rho}{dP}}$$

If $d\rho = 0 \Rightarrow \rho = \text{Constant}$
$\Downarrow$
$\beta = 0 \rightarrow$ 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):-

$PV^\gamma = C$ $\Rightarrow P = C_1 \rho^\gamma$ $\beta = 1/K$

$P\left(\frac{m}{\rho}\right)^\gamma = C$ $\Rightarrow \frac{dP}{d\rho} = C_1 \cdot \gamma \cdot \rho^{\gamma-1}$ $\beta_a = \frac{1}{\gamma P}$

$\frac{P}{\rho^\gamma} = \frac{C}{m^\gamma} = \text{Const.}$ $K = \rho \frac{dP}{d\rho} = \rho \cdot C_1 \cdot \gamma \cdot \rho^{\gamma-1}$

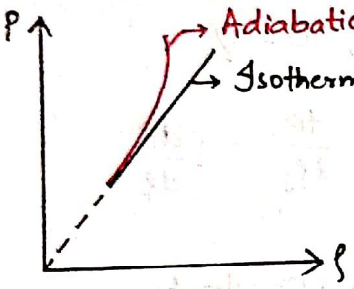
$K = \gamma C_1 \rho^\gamma$

$\frac{P}{\rho^\gamma} = C_1$ $\therefore \boxed{K_a = \gamma P}$

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

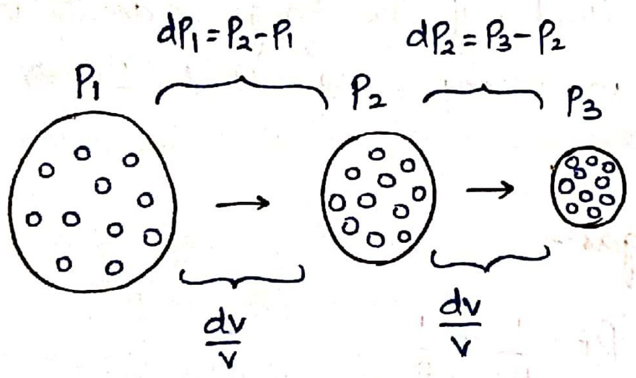
$\therefore \boxed{\frac{K_a}{K_T} = \frac{\gamma P}{P} = \gamma}$ $[K_a > K_T]$

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



$P' = \rho' R \textcircled{T} \rightarrow c.$

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.



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

$K_1 = \frac{dP_1}{-\frac{dv}{v}}$; $K_2 = \frac{dP_2}{-\frac{dv}{v}}$

(5) Viscosity

adjacent

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

$\frac{d\theta}{dt}$ = rat

Now, for

A

μ repre

adjacent

Newto

directl

deform