

# HindPhotostat



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### MADE EASY CIVIL ENGINEERING Fluid Mechanics BY-KAKKAR SIR

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

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# INTRODUCTION

# ESE Prelims → lot of variation  
(~ 6-8 questions)

# Textbook - (not required)

• R K Bansal

• Modi & Seth

• Cengel & Cimbala

• Made Easy

Theory Book

# Class notes



Workbook



GATE / ESE PYQs



Test Series

(solutions will be provided  
but see them after  
attempting on your own)

# GATE & ESE have almost same syllabus

# Don't take large breaks in between  
the lecture

## # List of Topics

1. Fluid Properties
  2. Pressure & its measurement
  3. Hydrostatic Force on Surfaces
  4. Buoyancy
  5. Fluid Kinematics
  6. Fluid Dynamics
  7. Dimensional Analysis
  8. Pipe Flow
  9. Laminar Flow
  10. Boundary Layer Flow
  11. Flow over Submerged Bodies
  12. Turbulent Flow in Pipe
- } Fluid Statics

## # Subject Division

① Fluid Static  $\rightarrow$  Study of fluid when it is in static condition

② Fluid Kinematics  $\rightarrow$  Study of the motion of fluid without considering the cause of motion i.e. force.

eq<sup>n</sup> used  $\rightarrow \vec{v} = \frac{d\vec{s}}{dt}, \quad \vec{a} = \frac{d\vec{v}}{dt}$

③ Fluid Dynamics  $\rightarrow$  Study of the motion of fluid considering the cause of motion i.e. force

eq<sup>n</sup> used  $\rightarrow \vec{F} = \frac{d}{dt}(m\vec{v})$

# In general, states of matter include -

Solids

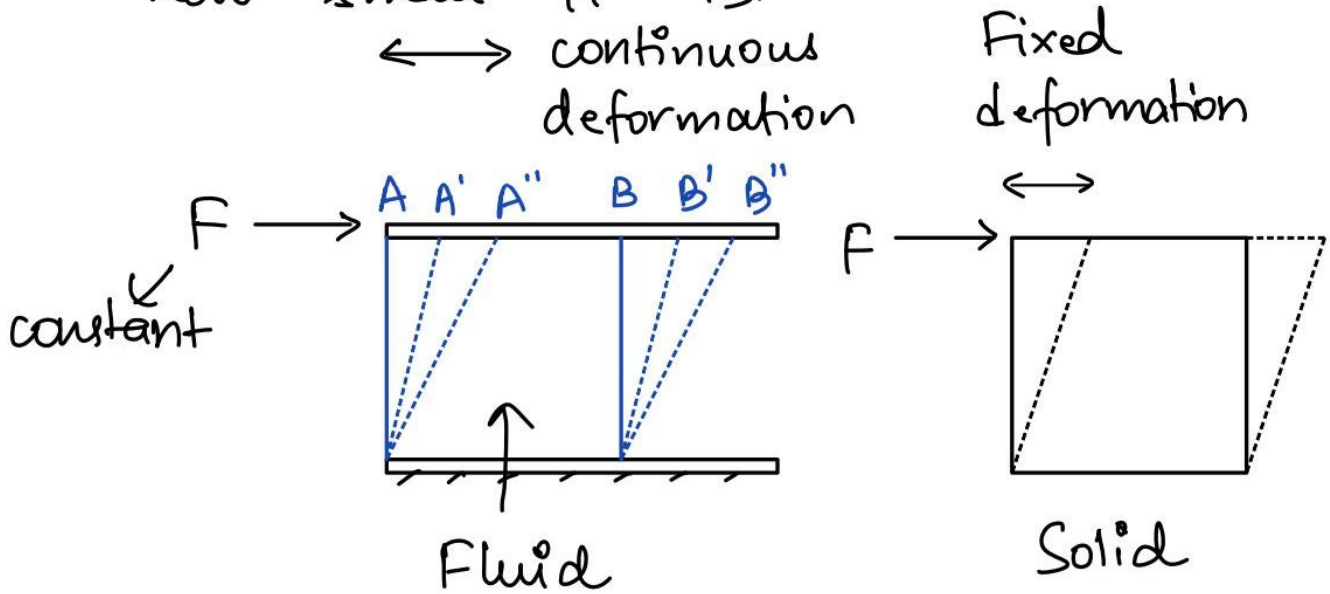
Liquids

Gases

} Fluids

# Fluids

# Fluid is a substance that deforms continuously under the application of tangential / shear force, no matter how small it is.



- In fluids, rate of deformation is important.
- Liquids & gases both have the property of continuous deformation under the application of shear / tangential force. This property is not present in solids. So, both liquids & gases come under the category of fluids.

# Fluid as a Continuum

- In macrosystems, when the inter-molecular distances are negligible as compared to characteristic dimension of the system, we can assume that adjacent to one molecule, there is another molecule without any space or gap. Therefore, the entire fluid mass system can be treated as a continuous distribution of mass, and such continuous mass of fluid is known as a continuum.

- Knudsen Number ( $Kn$ ) =  $\frac{\lambda}{L}$

$\lambda \rightarrow$  mean free path

$L \rightarrow$  characteristic dimension of system

If  $Kn < 0.01$ , then the fluid can be considered as a continuum.

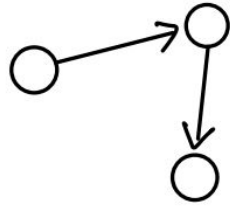
$\left\{ \begin{array}{l} 0.01 < Kn < 0.1 \end{array} \right. \rightarrow$  Slip Flow

$\left\{ \begin{array}{l} 0.1 < Kn < 10 \end{array} \right. \rightarrow$  Transition Flow

$\left\{ \begin{array}{l} Kn > 10 \end{array} \right. \rightarrow$  Free Molecular Flow

not in our study

- Mean Free Path ( $\lambda$ )  $\rightarrow$  Average distance covered by a molecule between collisions



- Fluid properties such as density, etc. can be defined as a continuous function of space variable.
- Continuum is invalid at very low pressure (at high elevations).

## Fluid Properties

### ① Density ( $\rho$ )

- It is defined as mass per unit volume of a fluid substance

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

- units  $\rightarrow$   $\text{kg/m}^3$  (MKS)  
 $\text{g/cm}^3$  (CGS)

$$1 \text{ g/cm}^3 = \frac{10^{-3} \text{ kg}}{10^{-6} \text{ m}^3} = 1000 \text{ kg/m}^3$$

② Specific Weight / Weight Density  $\rightarrow$  It is defined as weight per unit volume of a fluid substance.

$$\cdot \text{ Specific weight} = \frac{mg}{V} = \rho g$$

$$\cdot \text{ units} \rightarrow \text{N/m}^3 \quad (\text{SI})$$

③ Specific Gravity (S)

• It is the ratio of density of a fluid substance to the density of standard fluid substance

• For liquids, standard fluid is water at  $4^\circ\text{C}$  ( $\rho_w = 10^3 \text{ kg/m}^3$ )

• For gases, standard fluid is air.

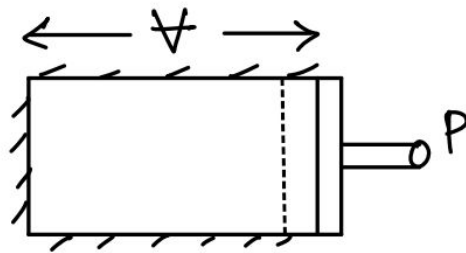
$$\cdot \text{ eg} \rightarrow S_{\text{Hg}} = 13.6 \Rightarrow \rho_{\text{Hg}} = 13.6 \rho_w$$
$$\Rightarrow \rho_{\text{Hg}} = 13.6 \times 10^3 \text{ kg/m}^3$$

#### ④ Compressibility ( $\beta$ )

- It is defined as the reciprocal of bulk modulus of elasticity of fluids.

$$\beta = \frac{1}{K} \rightsquigarrow \text{Bulk Modulus of Elasticity}$$

• eg  $\rightarrow$



$$K = \frac{dP}{\frac{-dV}{V}}$$

- In general,

$$m = \rho \cdot V = \text{constant}$$

$$\Rightarrow dm = \rho \cdot dV + V \cdot d\rho = 0$$

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

$$\Rightarrow K = \frac{dP}{\frac{d\rho}{\rho}}$$

$$K = \rho \cdot \frac{dP}{d\rho}$$

$$\beta = \frac{1}{\rho} \cdot \frac{d\rho}{dP}$$

- If density is not changing w.r.t. Pressure,

$$\frac{d\rho}{dP} = 0$$

$$\Rightarrow \beta = 0 \quad (\text{Incompressible})$$

If density is changing w.r.t. pressure, then

$$\frac{d\rho}{dP} \neq 0$$

$$\Rightarrow \beta \neq 0 \quad (\text{Compressible})$$

- For liquids (compressible)  
at  $T = 20^\circ\text{C}$ ,  $P = 1 \text{ atm}$ ,  $\rho_w = 998 \text{ kg/m}^3$   
 $P = 100 \text{ atm}$ ,  $\rho_w = 1003 \text{ kg/m}^3$   
%. change =  $\frac{1003 - 998}{998} \times 100$

$$= 0.501\%$$

$$\Rightarrow \beta \approx 0$$

$\Rightarrow$  Generally, liquids are treated as incompressible