FLUID MECHANICS
4M3

Dr. NIRAJ BALA

INTRODUCTION

Fluid Mechanics is the study of

i) Physical behavior of fluids and fluid systems, and laws governing the fluid behavior.

ii) Action of forces on fluids and their resulting flow patterns.

Classification

- HYDROSTATICS: study of fluids at rest
- KINEMATICS: study of fluids in motion
- DYNAMICS: study of fluids in motion + forces

Solids, liquids and gases

i) Solid is compact and rigid, liquid fits itself to the shape of container, gases fills up the whole of the vessel containing it.

ii) A solid has volume and shape, liquid has volume but no shape, a gas has neither.

iii)Liquids are incompressible, gases are compressible, exceptions are always there.

Fluid is a material continuum that is unable to withstand a static shear stress.

Unlike an elastic solid which responds to a shear stress with a recoverable deformation, a fluid responds with an irrecoverable flow.

Fluid and Flow

- Fluid offer no permanent resistance to shear force and possesses a characteristic ability to flow or change its shape.
- Flow means that the constituent fluid particles continuously change their positions relative to one another.
- The tendency of continuous deformation of a fluid is called fluidity, and act of continuous deformation is called flow.

IDEAL AND REAL FLUIDS

- IDEAL: incompressible and inviscid, no surface tension

  $\mu=0, \quad \sigma=0, \quad \rho = \text{constant}$

  $K = -dp/dv/v = \infty$

  Imaginary, do not exist in nature. e.g. air and water.

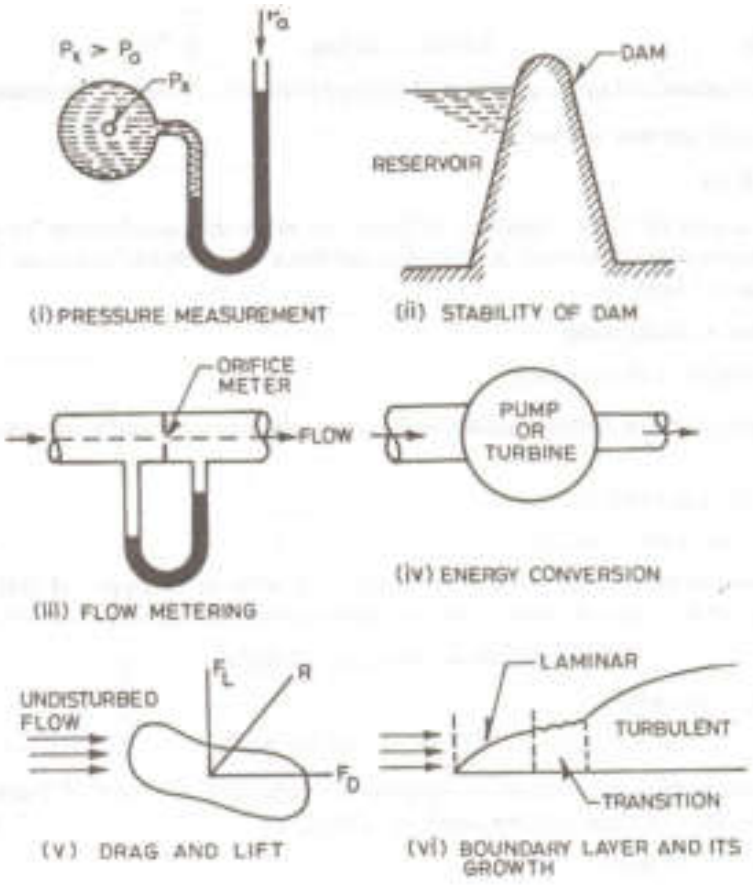
- REAL: tangential or shear forces always come into play.

CONTINUUM

- A continuous and homogenous fluid medium in called continuum.

  Fluid properties are treated to be same at a point and identical in all directions from a specified point.

Significance of Fluid Mechanics



Queries

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Units and Dimensions

- Dimension is a name which describes the measurable qualities or characteristics of an object such as mass, length, time and temperature etc.

- Unit is an accepted standard for measuring the dimension or quality.
- E.g. density – kg/m^3

  force- $kgm/s^2 = N$ or newton $[MLT^{-2}]$

  pressure – $N/m^2 =$ Pascal or Pa $[ML^{-1}T^{-2}]$

  Work – $Nm = J$ or joule $[ML^2T^{-2}]$

  Power – $J/s = W$ or watt $[ML^2T^{-3}]$

Physical Properties of Fluids

- System

- Property

- Intensive and Extensive Properties

  Intensive – independent on mass.

  Extensive –depends on mass.

Terms

- Specific weight

$$w = W/V = mg/V = N/m^3 = [M\ L^{-2}T^{-2}]$$

- Mass density

- Specific gravity

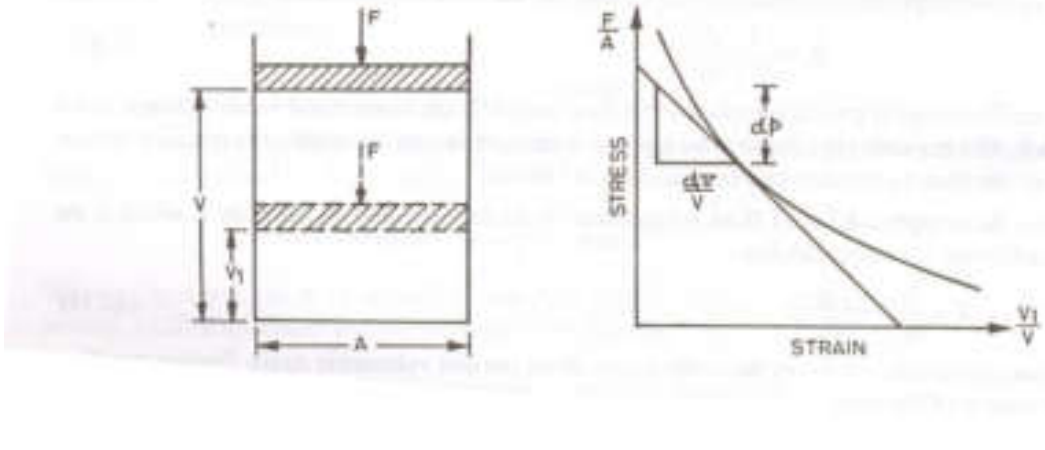
- Specific volume

Gas Laws

- Boyle's Law

- Charles Law

Compressibility and Bulk Modulus



Coefficient of compressibility

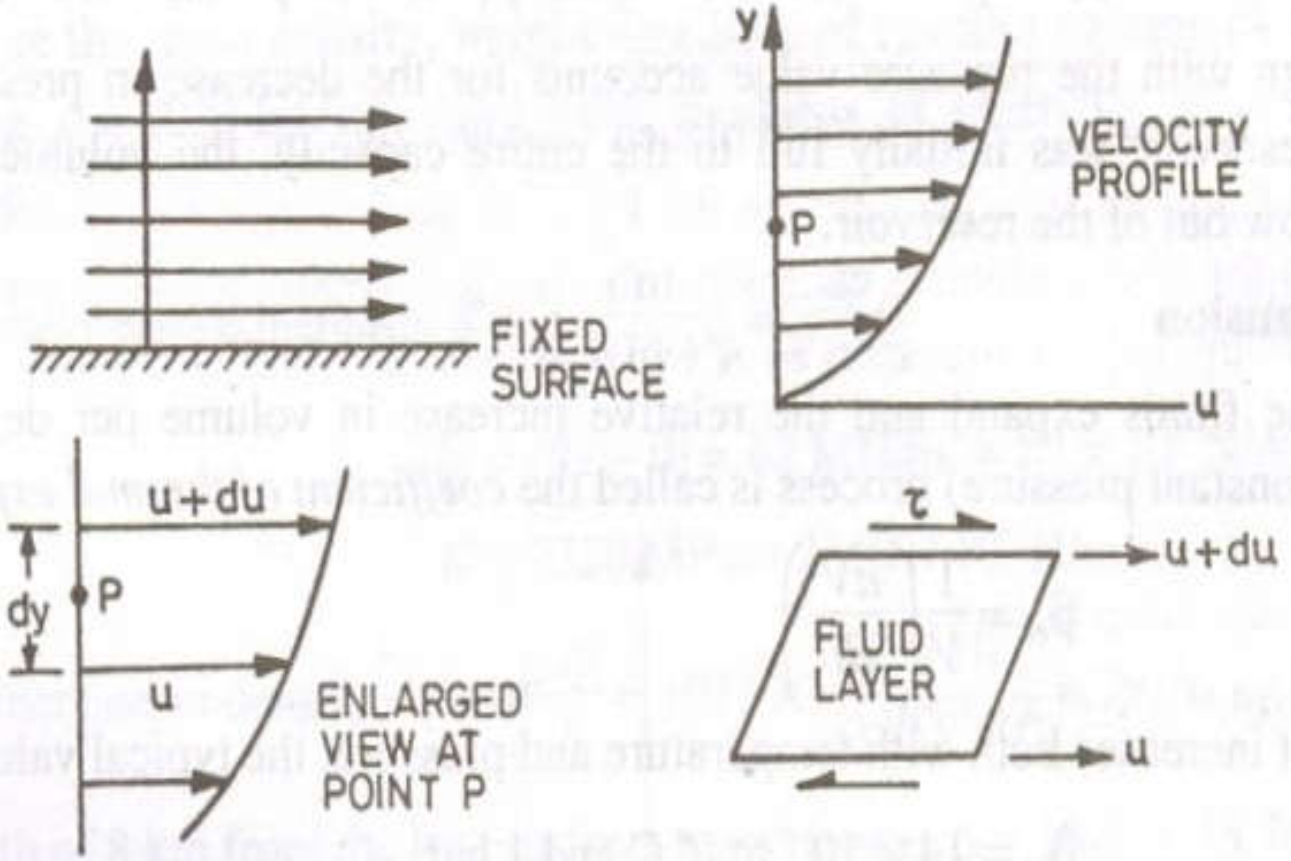
- $\beta_c = -1/V\ [\ dv/dp\ ]$

- Bulk modulus of elasticity

$$K = 1/\beta_c = -dp/dV/V$$

Viscosity

- Property of a fluid by virtue of which it offers permanent resistance to shear or angular deformation

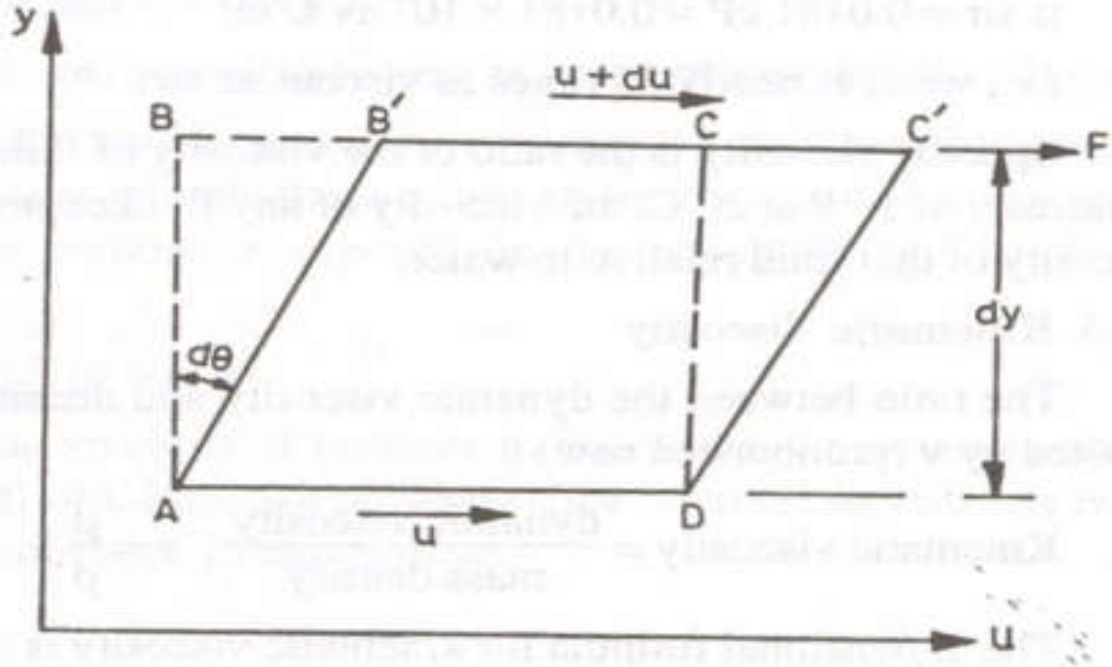

FIXED
SURFACE
y
P
VELOCITY
PROFILE
u
u+du
dy
P
u
ENLARGED
VIEW AT
POINT P
τ
u+du
FLUID
LAYER
u

Newton's Law of Viscosity

$$\text{tau} = du/dy \;;$$

- $\text{tau} = \mu\, du/dy$

Deformation of fliud element



Dimensional formula and units of Viscosity

- $\mathrm{Pa\ s} = \mathrm{Ns/m^2}$

Kinematic viscosity

Effect of temperature on viscosity

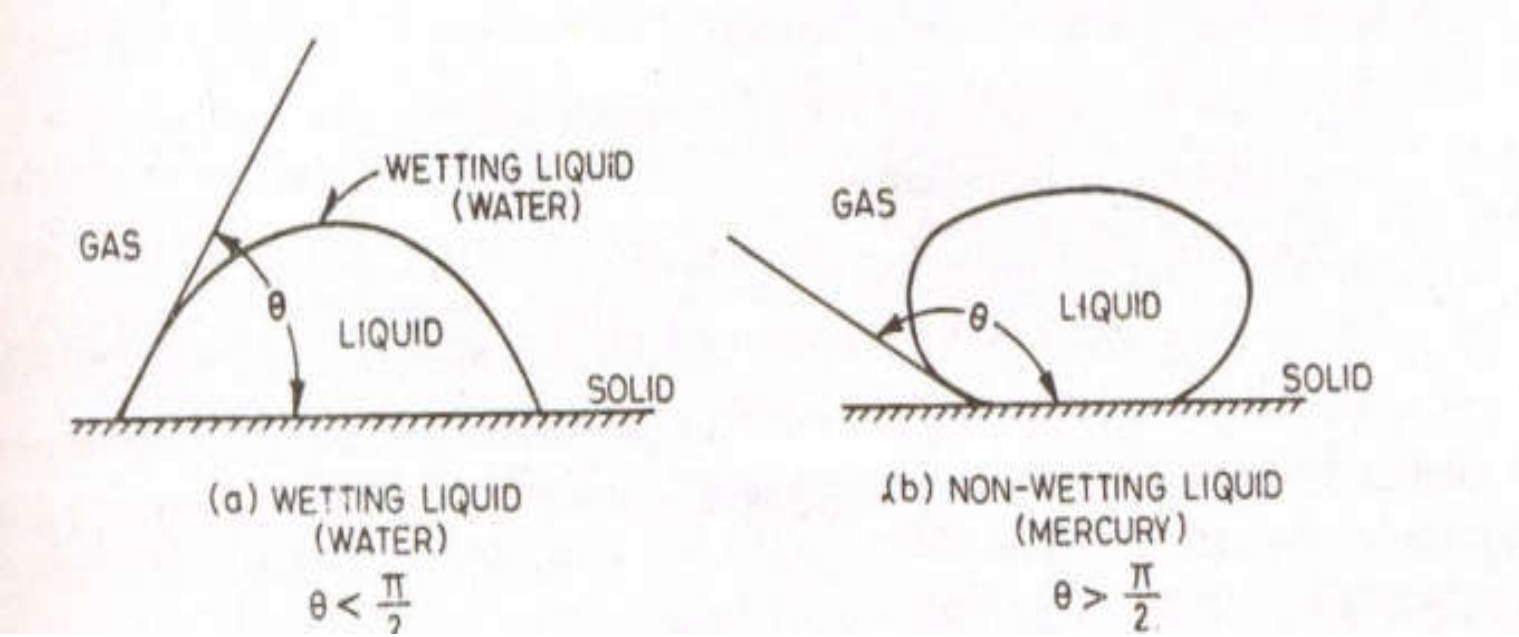
Surface Tension and Capillarity

- **Cohesion and Adhesion**

- Cohesion refers to the force with which the neighboring or adjacent fluid molecules are attracted towards each other.

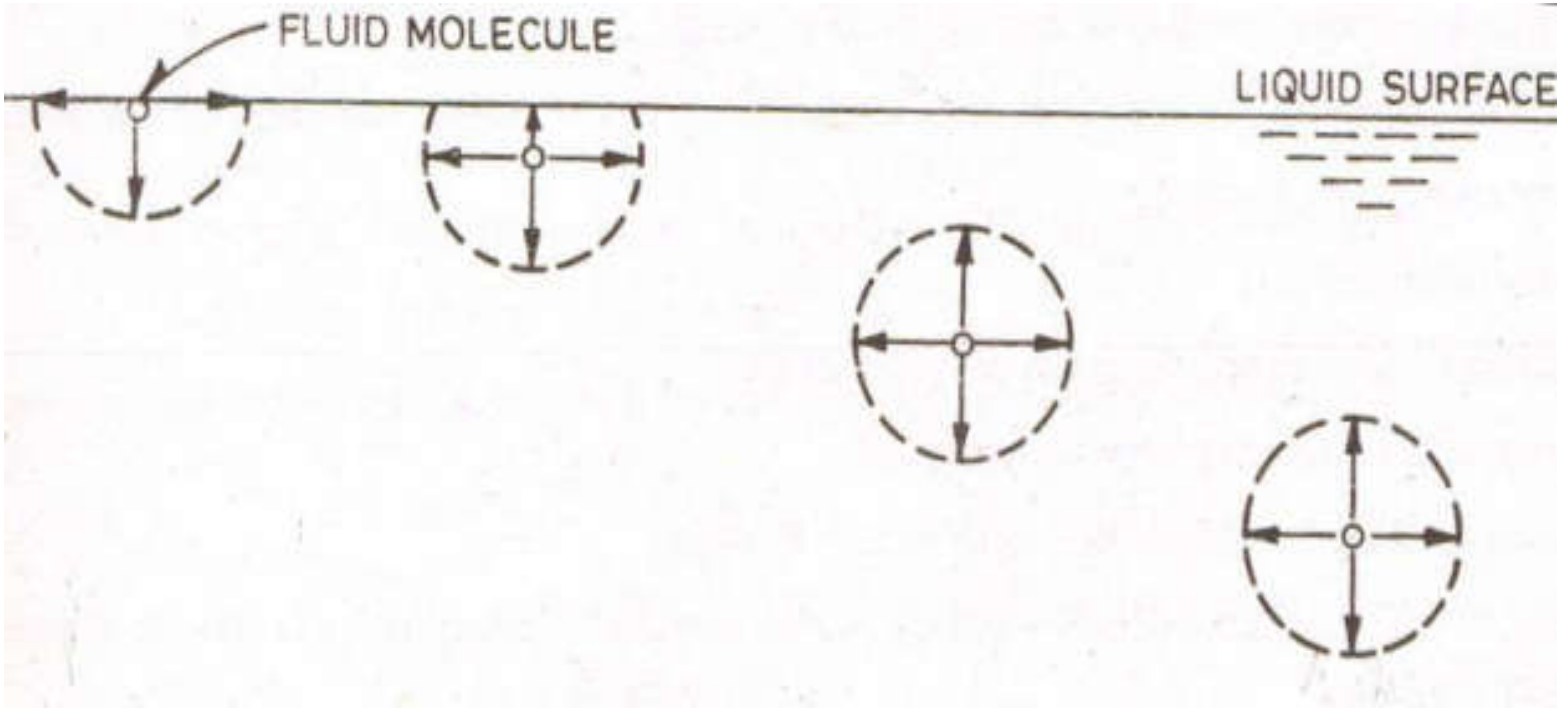
- Adhesion represents the adhering or clinging of fluid molecules to the solid surface with which they come in contact.

Wetting and Non-wetting liquids



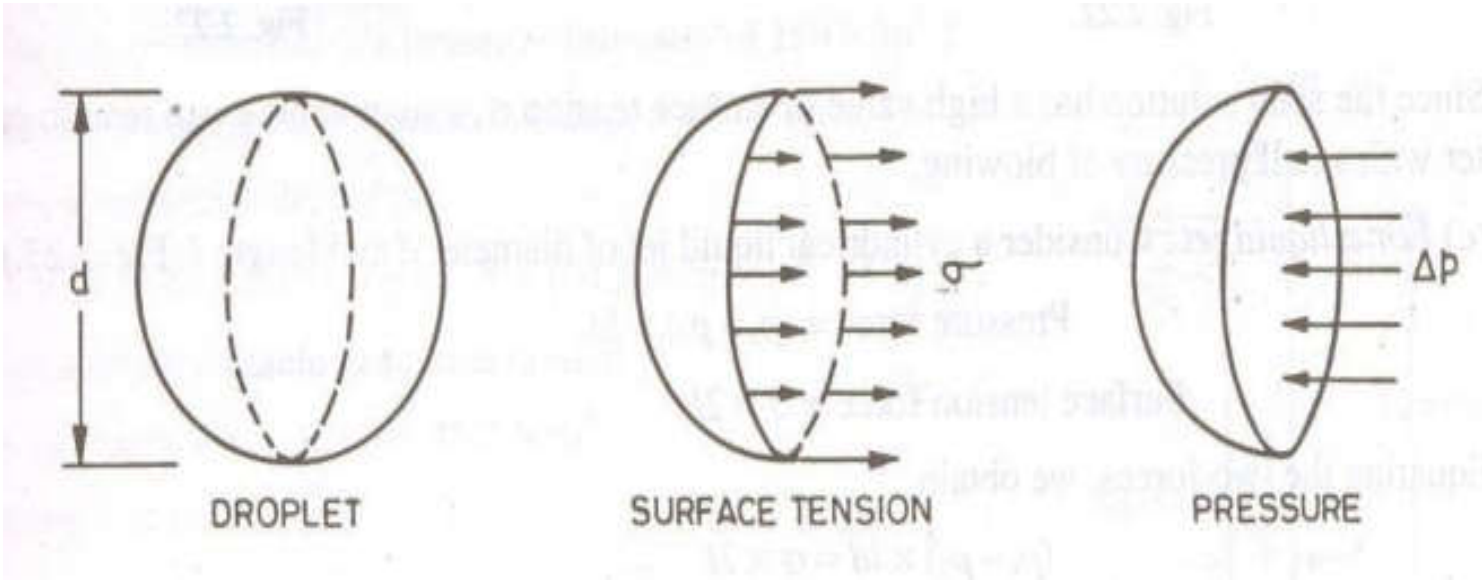
Surface Tension

Forces of attraction on a liquid molecule

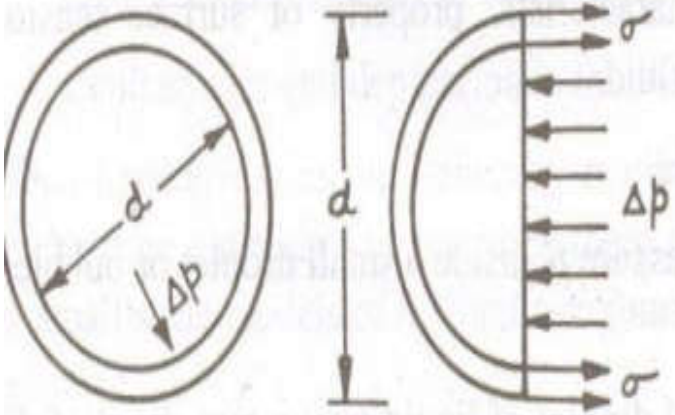


Pressure inside a water droplet and Soap Bubble

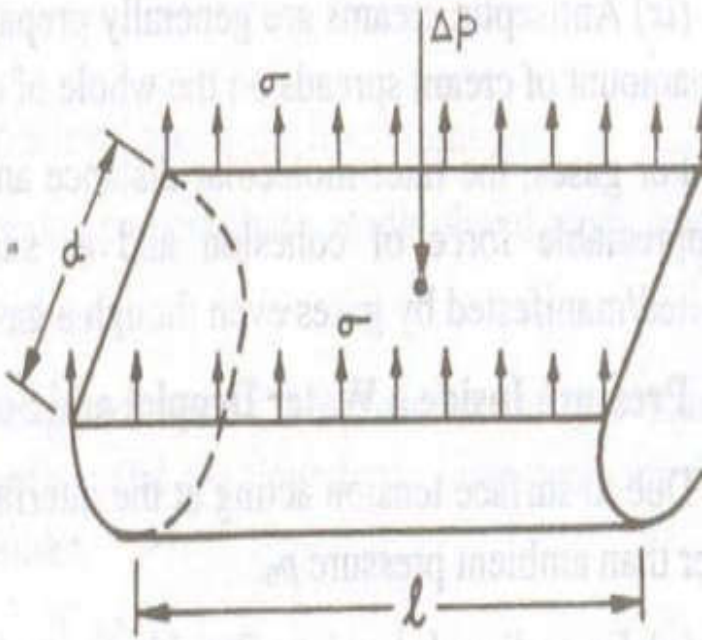
- For a Liquid droplet



For a soap bubble

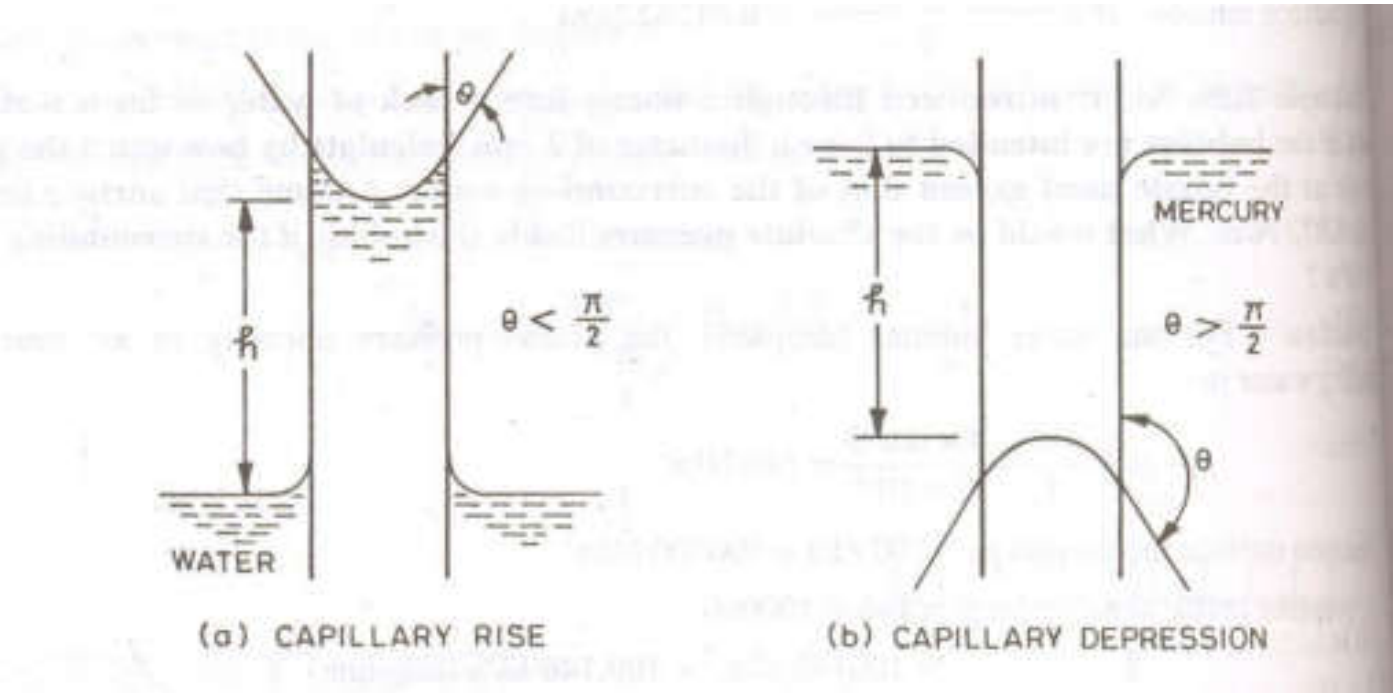


For a liquid jet

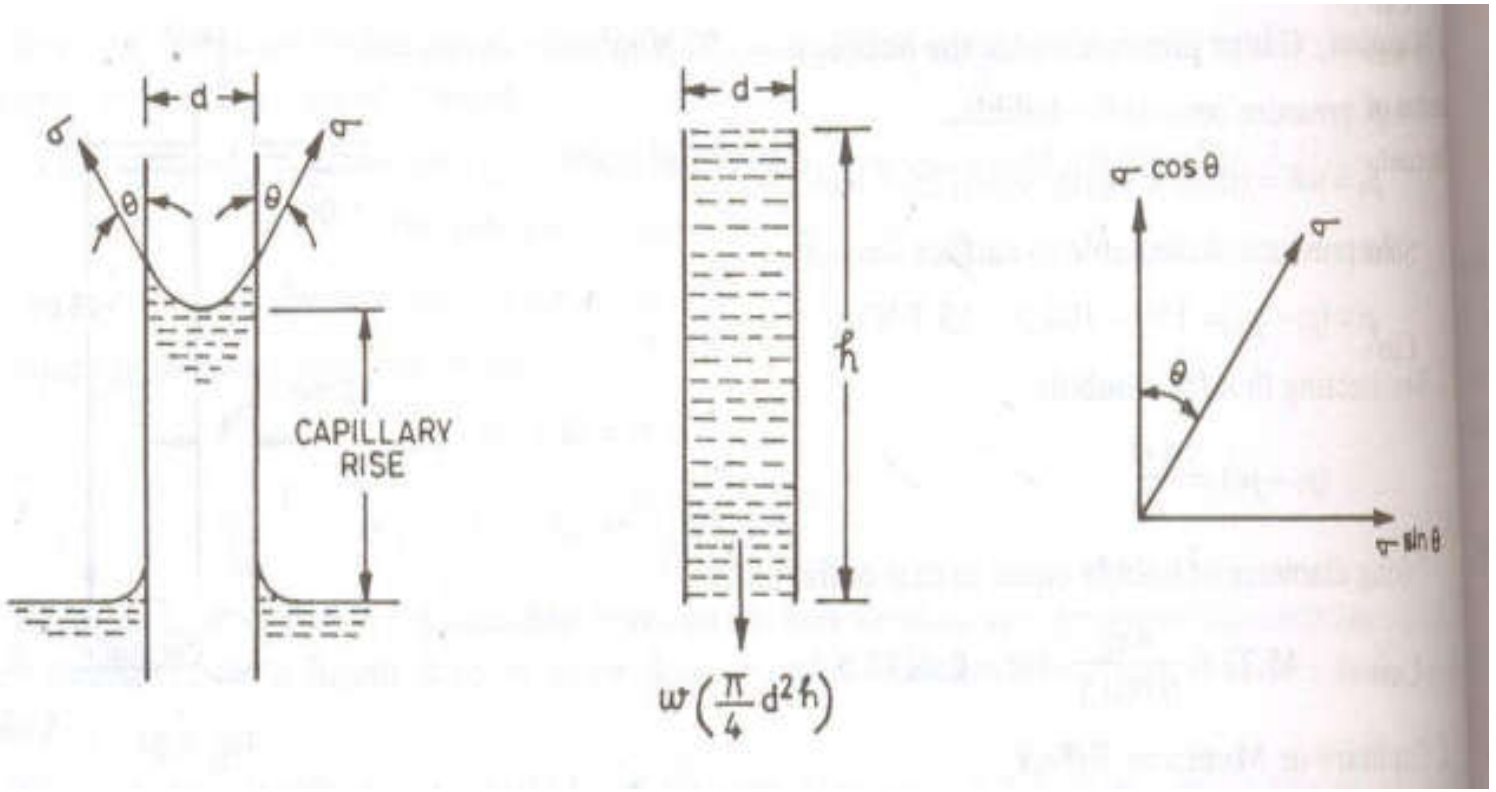


Capillary or Meniscus Effect

- Capillary rise and depression

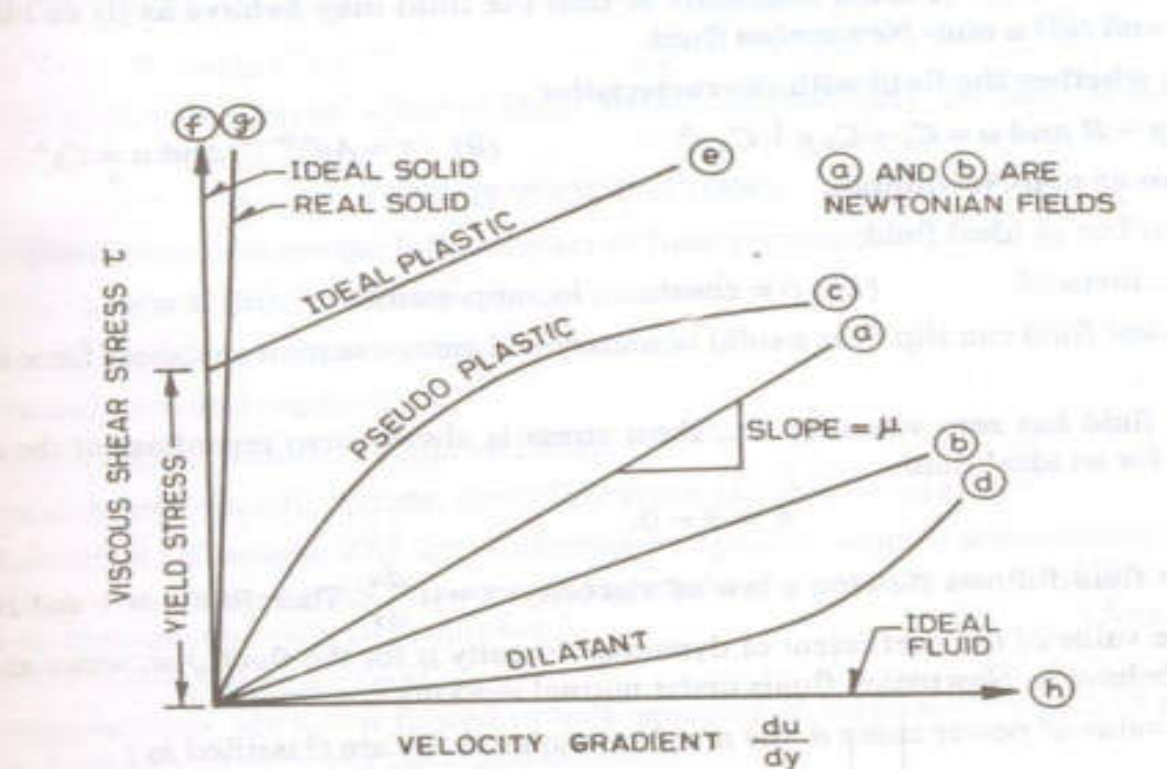


Rise or depression of liquid in a capillary tube



Newtonian and Non- Newtonian Fluids

- Variation of shear stress with velocity gradient (time rate of deformation)



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Fluid Statics

Study of fluid at rest:

Pressure: fluid element is acted upon by two types of forces body forces and surface forces.

$p = dF/dA = F/A = [\, FL^{-2} \,] = N/m^2$

$1 \text{ bar} = 10^5 \, N/m^2 = 100 \text{ kPa}$

Pascal's Law

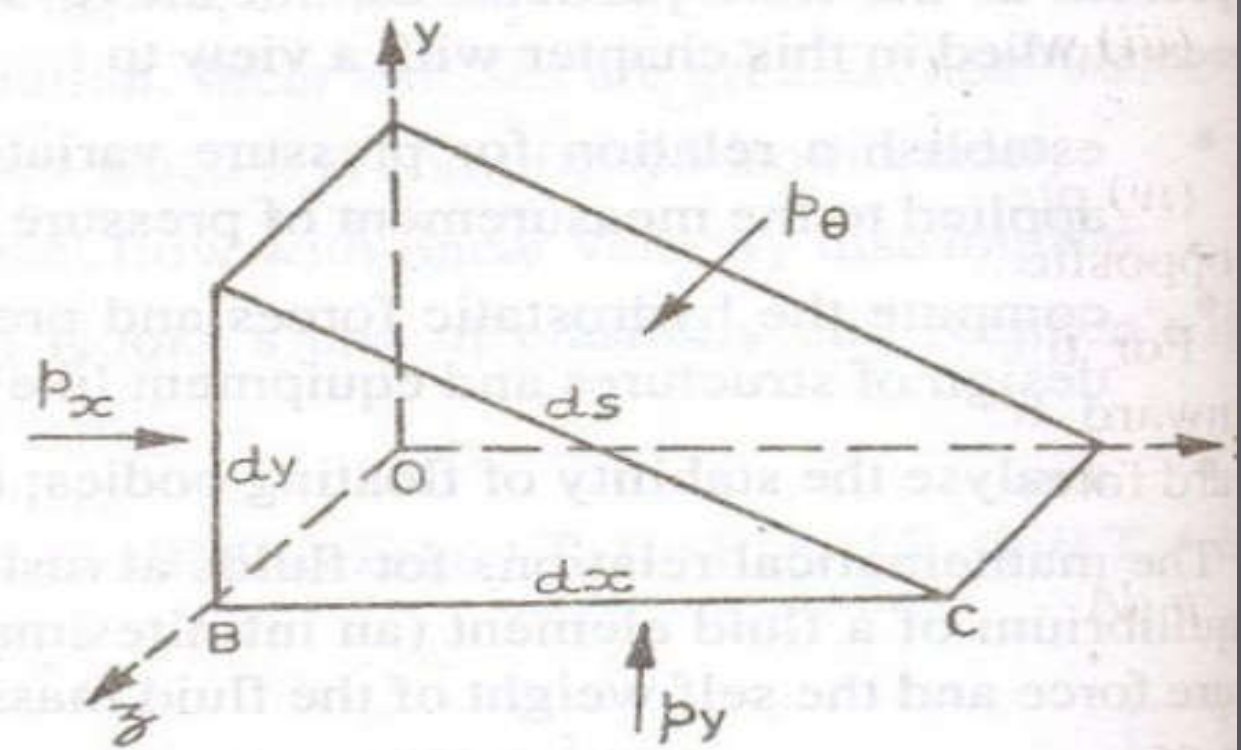
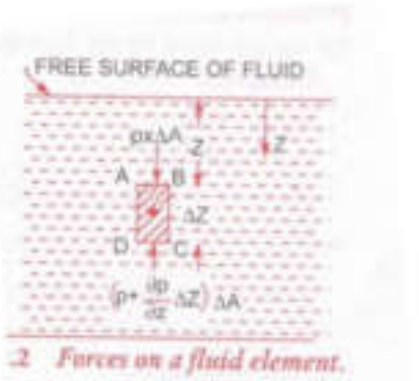


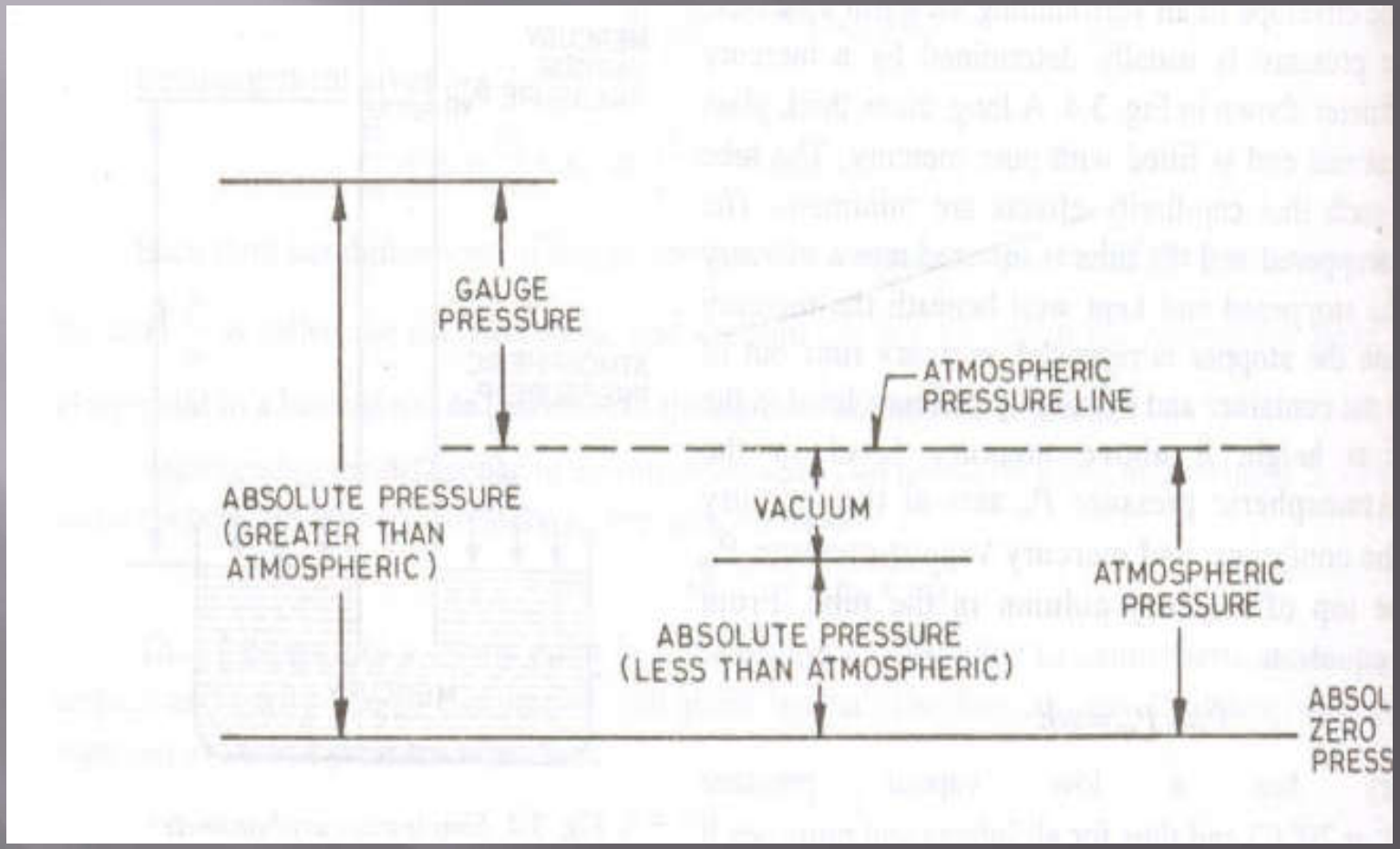
Fig. 3.1.

Hydrostatic Law



2 Forces on a fluid element.

Relation between absolute, gauge and atmospheric pressure



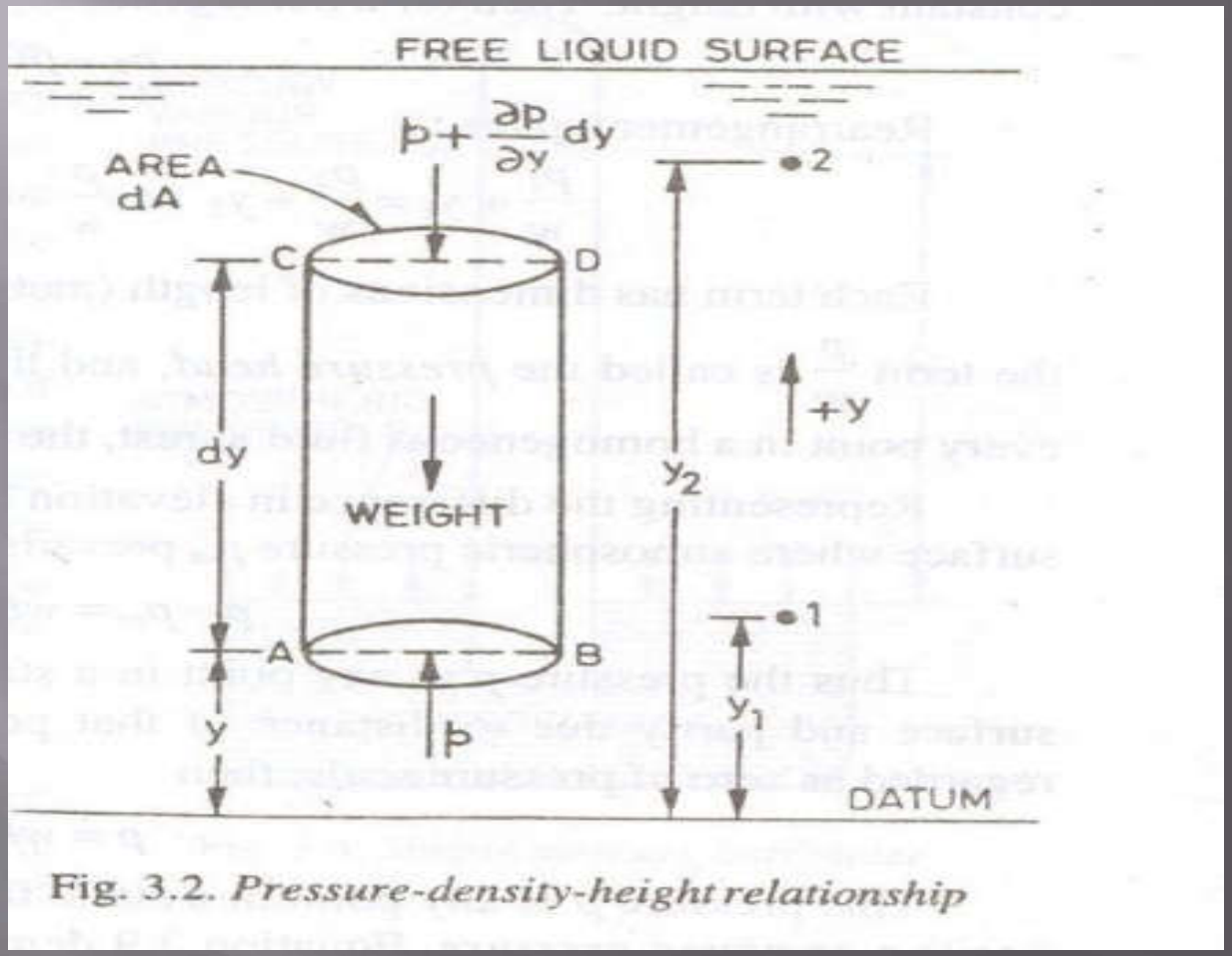
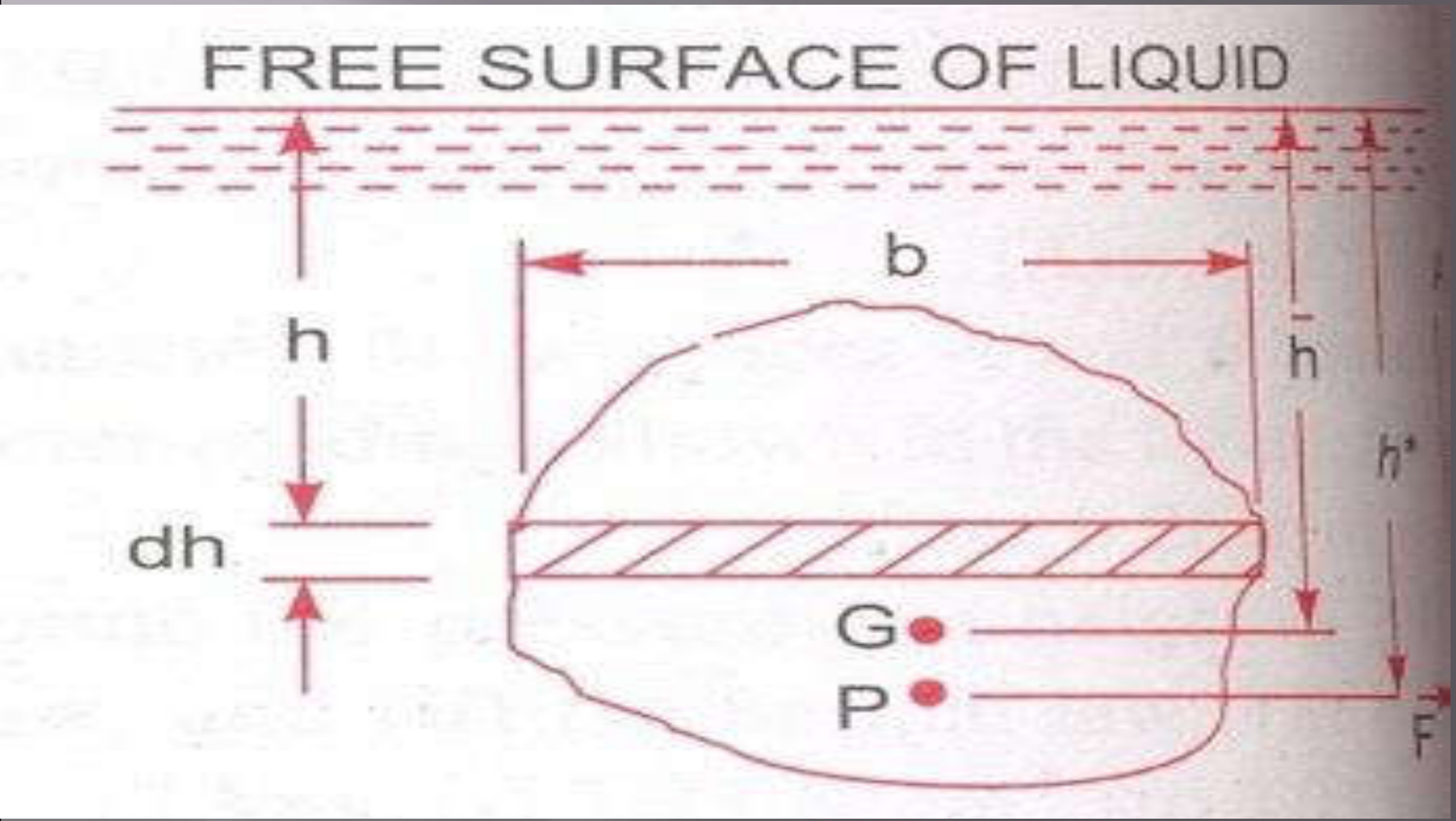


Fig. 3.2. *Pressure-density-height relationship*

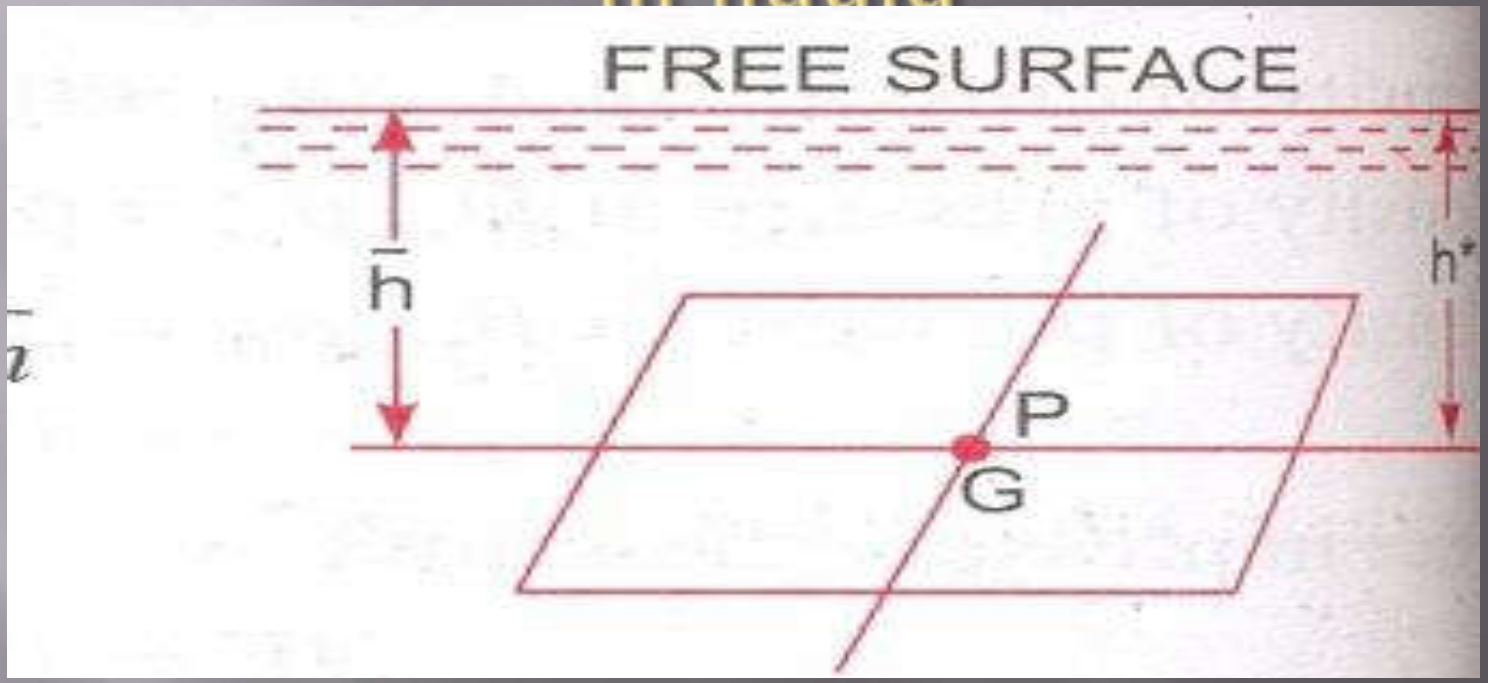
Hydrostatic forces on surfaces

- **Total pressure** is defined as the force exerted by a static fluid on a surface either plane or curved when the fluid comes in contact with the surfaces. This force always acts normal to the surface.
- **Centre of pressure** is the point of application of the total pressure on the surface.
- Four cases of submerged surfaces on which the total pressure force and centre of pressure is to be determined i.e. Vertical plane surface, Horizontal plane surface, Inclined plane surface, Curved surface.

Vertical plane surface submerged in liquid



Horizontal plane surface submerged in liquid



Inclined plane surface submerged in liquid

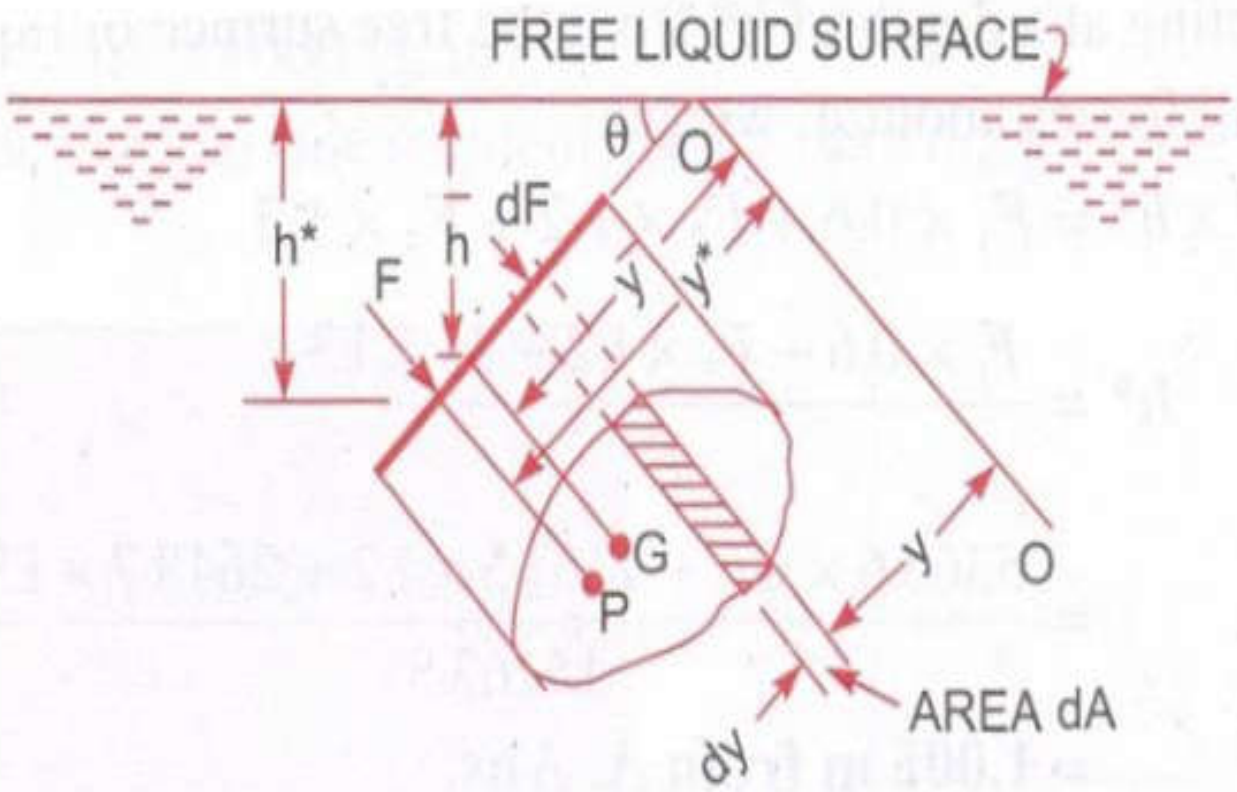
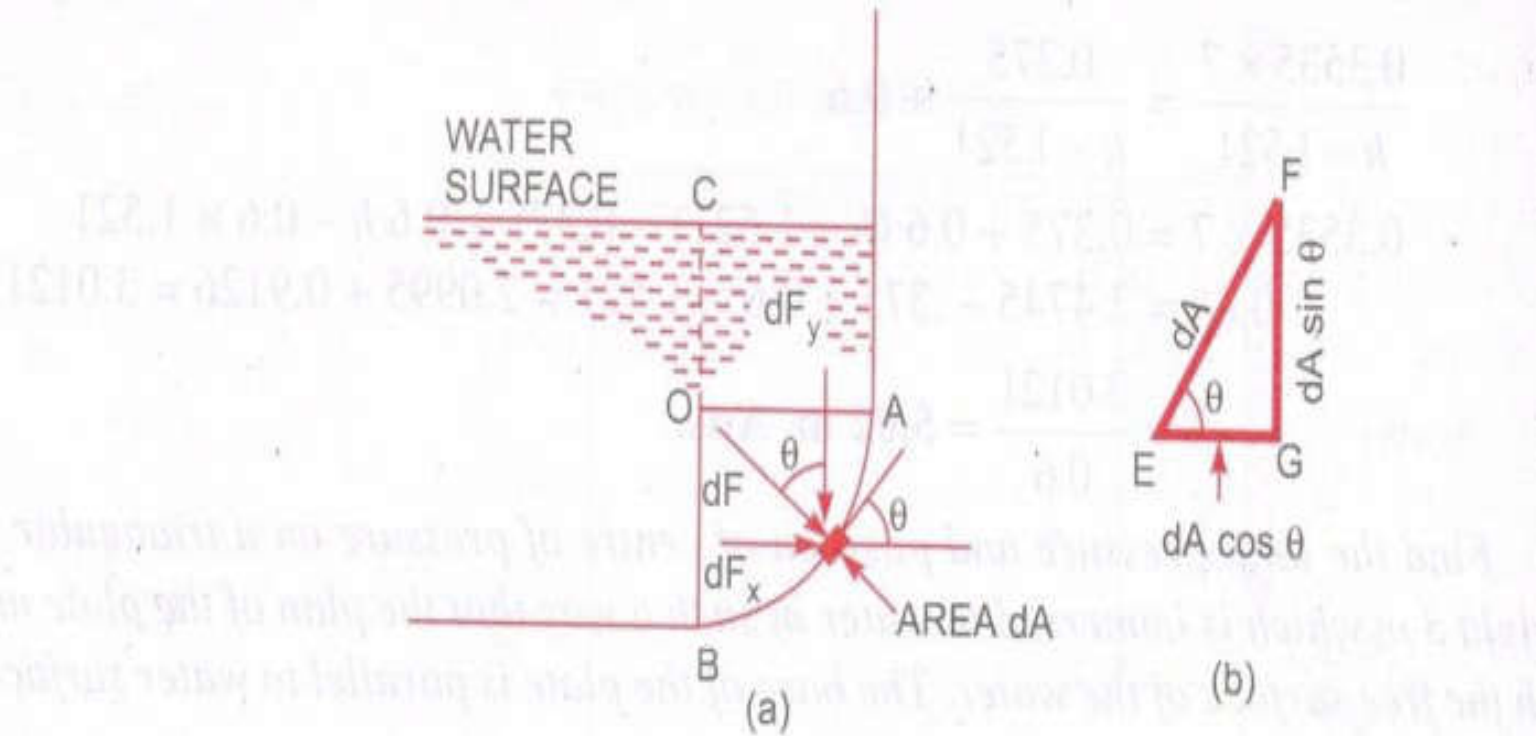


Fig. 3.18 *Inclined immersed surface.*

Curved surface submerged in liquid



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Chapter – 2
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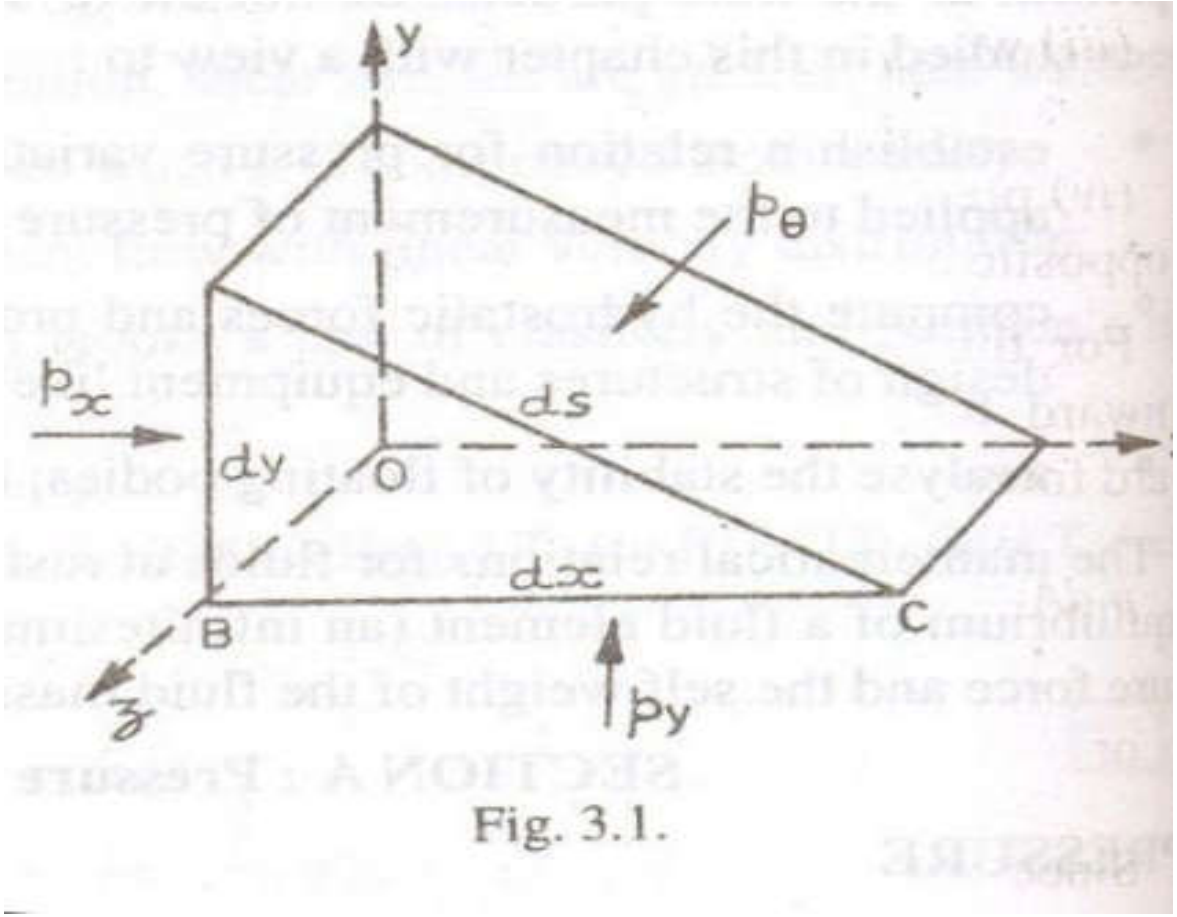
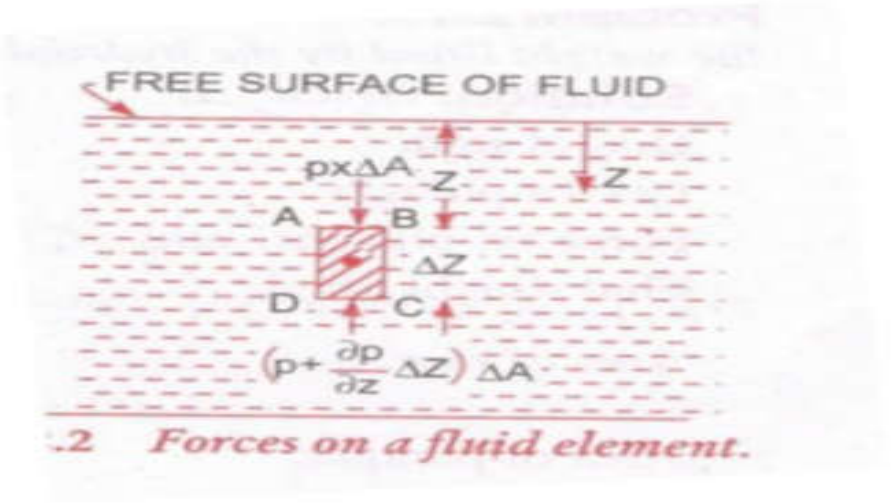


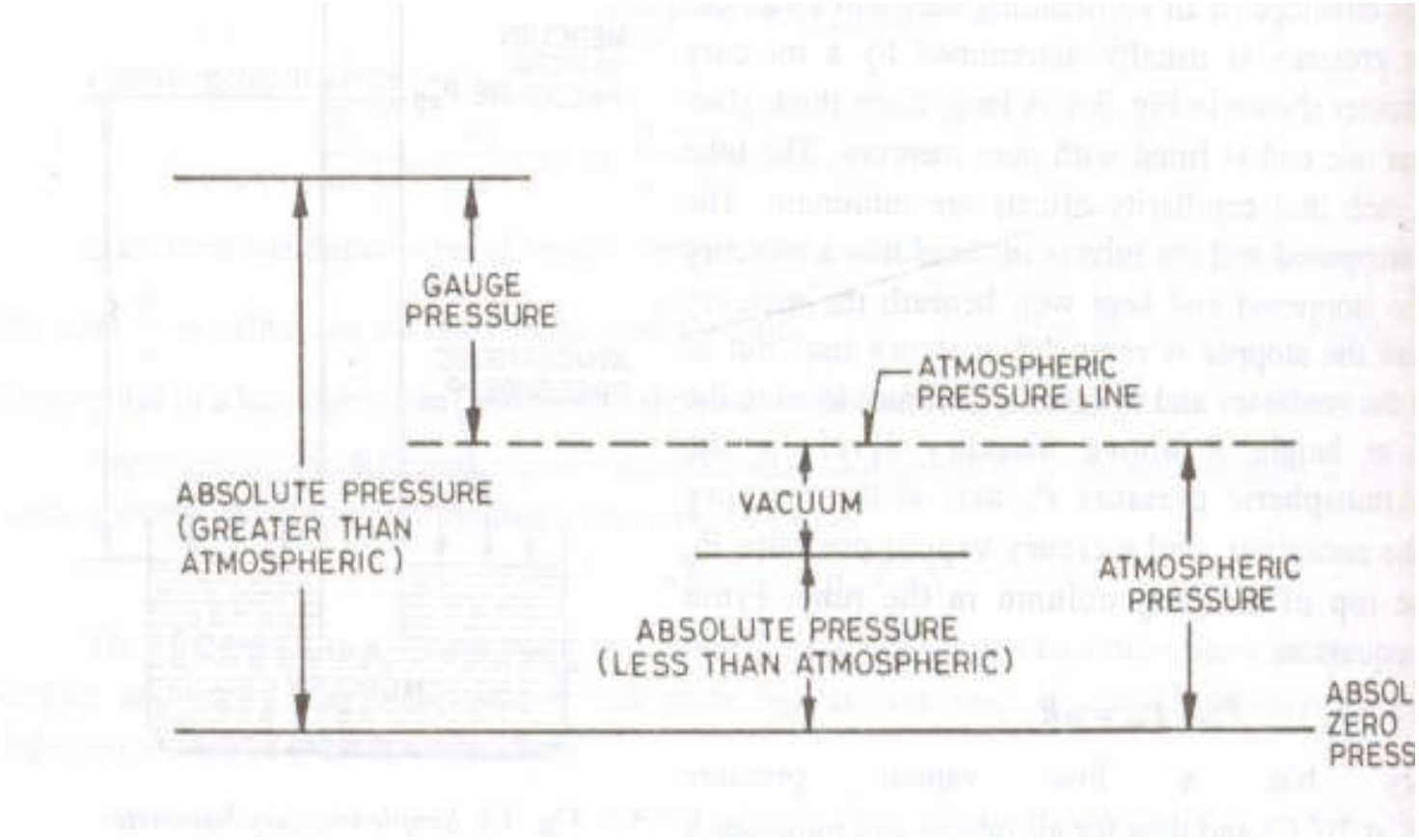
Fig. 3.1.

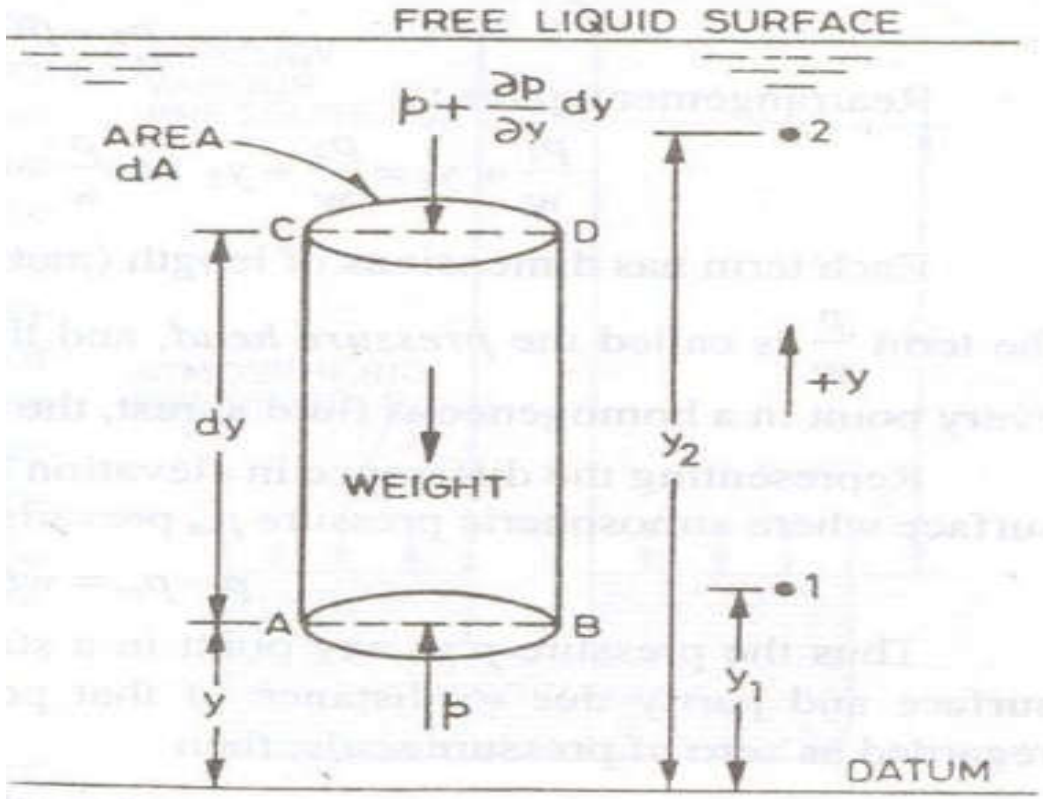
Pressure-Density-Height Relationship: Hydrostatic Law



.2 *Forces on a fluid element.*

Relation between absolute, gauge and atmospheric pressure





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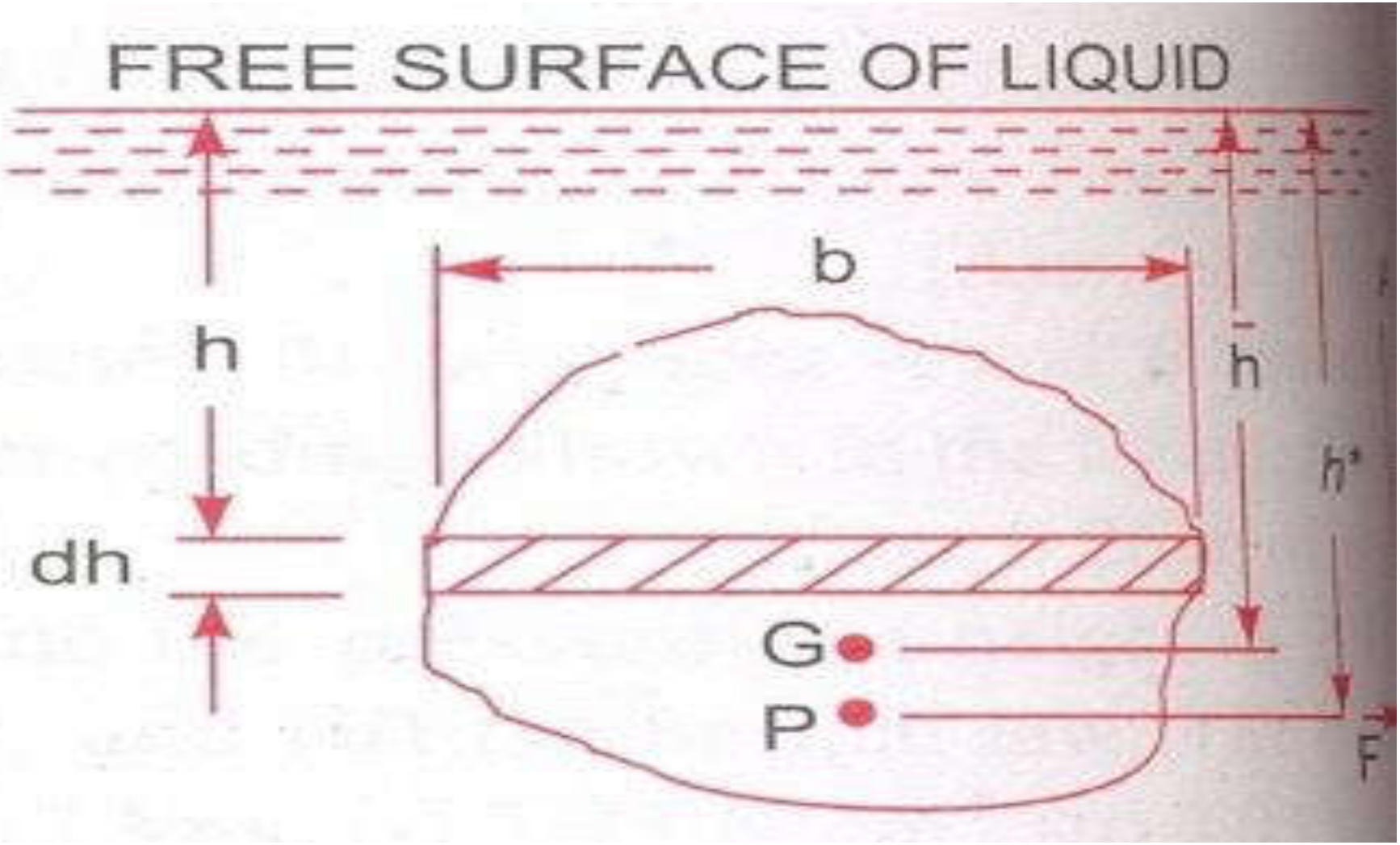
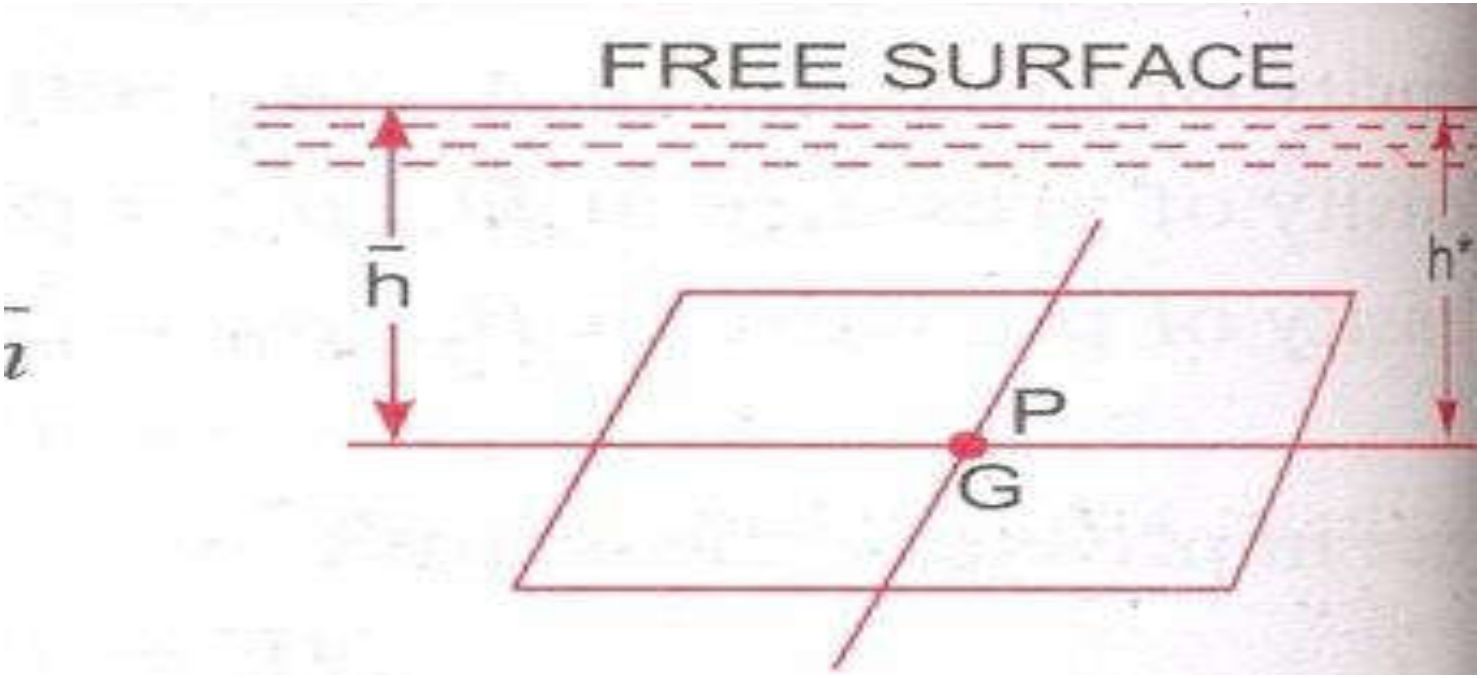
Vertical plane surface submerged in liquid



Horizontal plane surface submerged in liquid



Inclined plane surface submerged in liquid

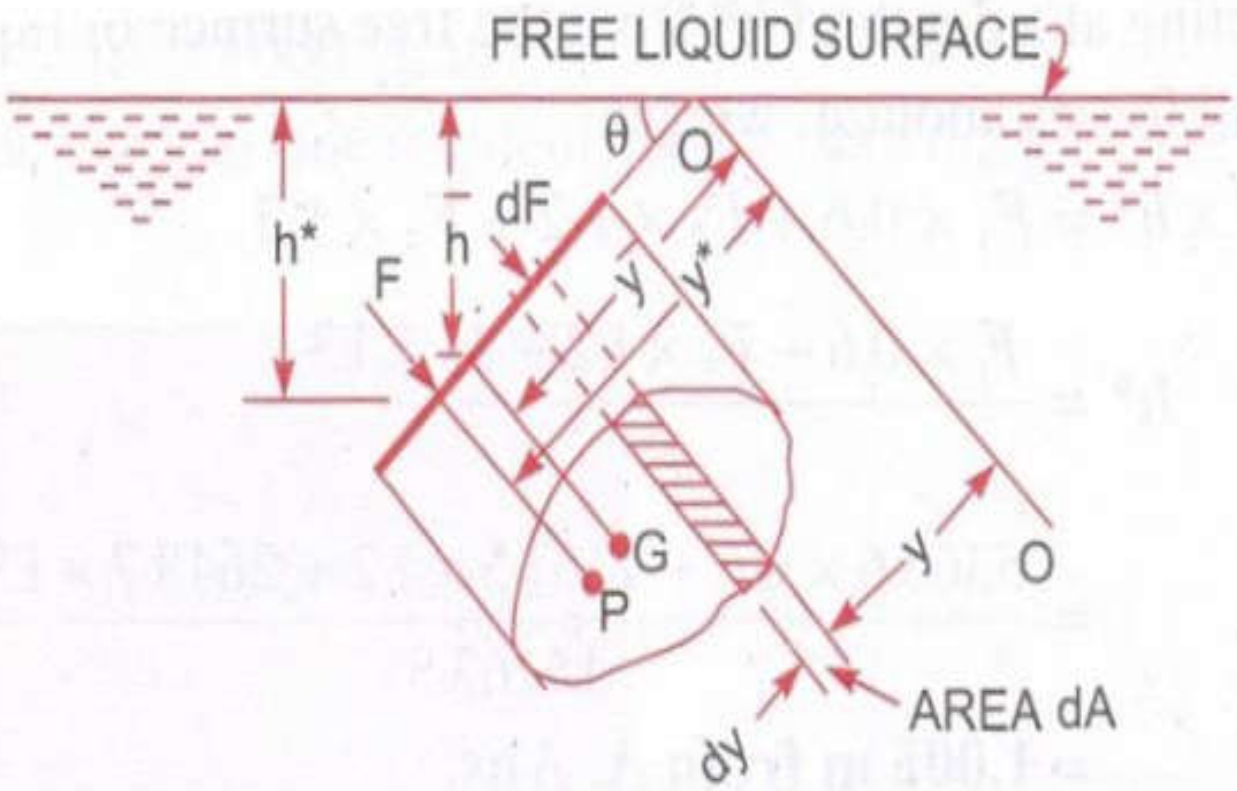
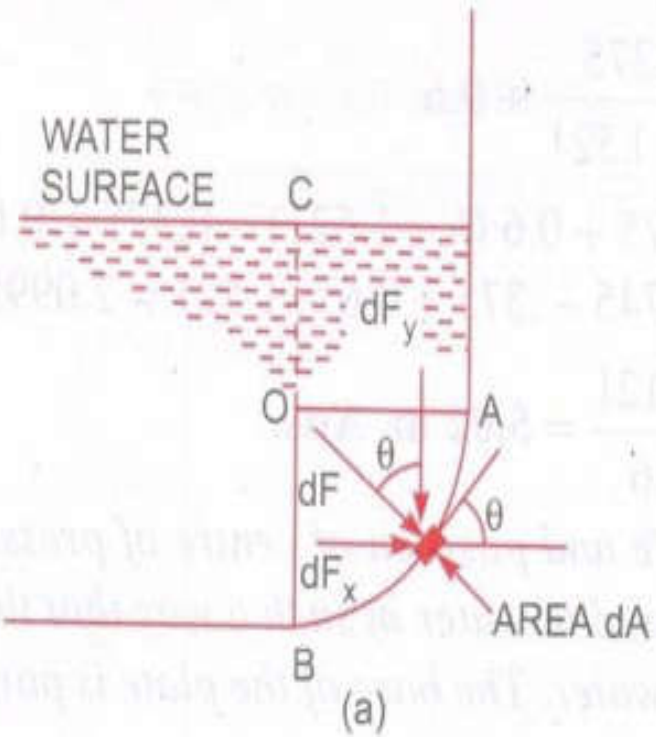


Fig. 3.18 *Inclined immersed surface.*

Curved surface submerged in liquid



Buoyancy and Floatation

- Buoyancy:- When a body is immersed in a fluid, an upward force is exerted by the fluid on the body. This upward force is equal to the weight of the fluid displaces by the body and is called the force of buoyancy or simply buoyancy.
- Centre of Buoyancy:- the point, through which the force of buoyancy is supported to act. As the force of buoyancy is a vertical force and is equal to the weight of the fluid displaced by the body, the centre of buoyancy will be the centre of gravity of the fluid displaced.

Meta-centre

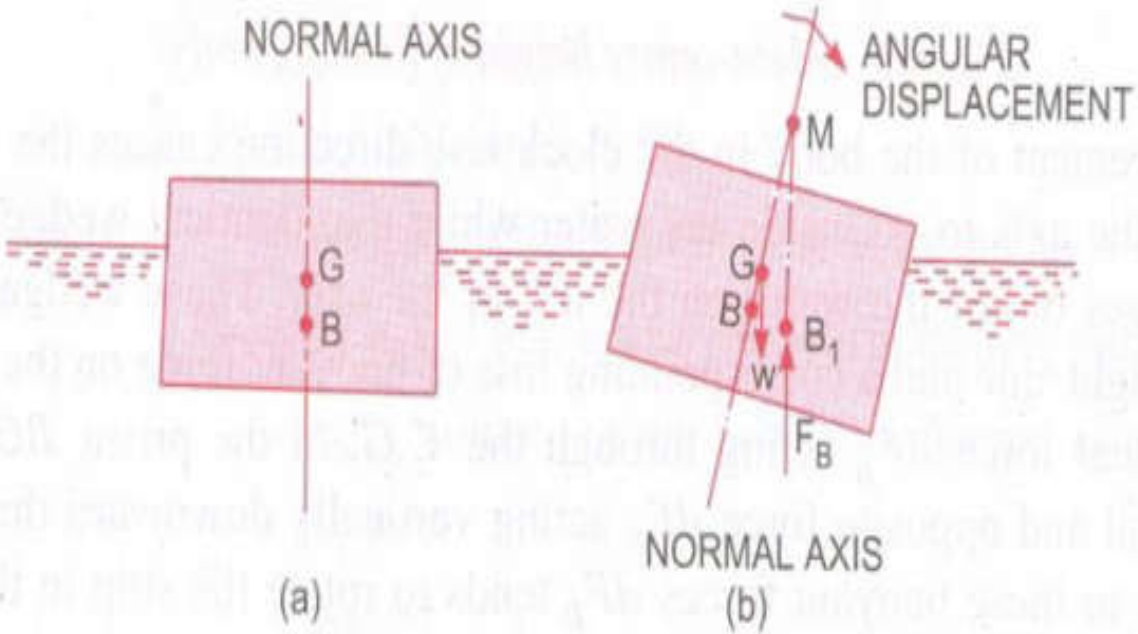


Fig. 4.5 *Meta-centre*

Analytical method for Meta-centre Height

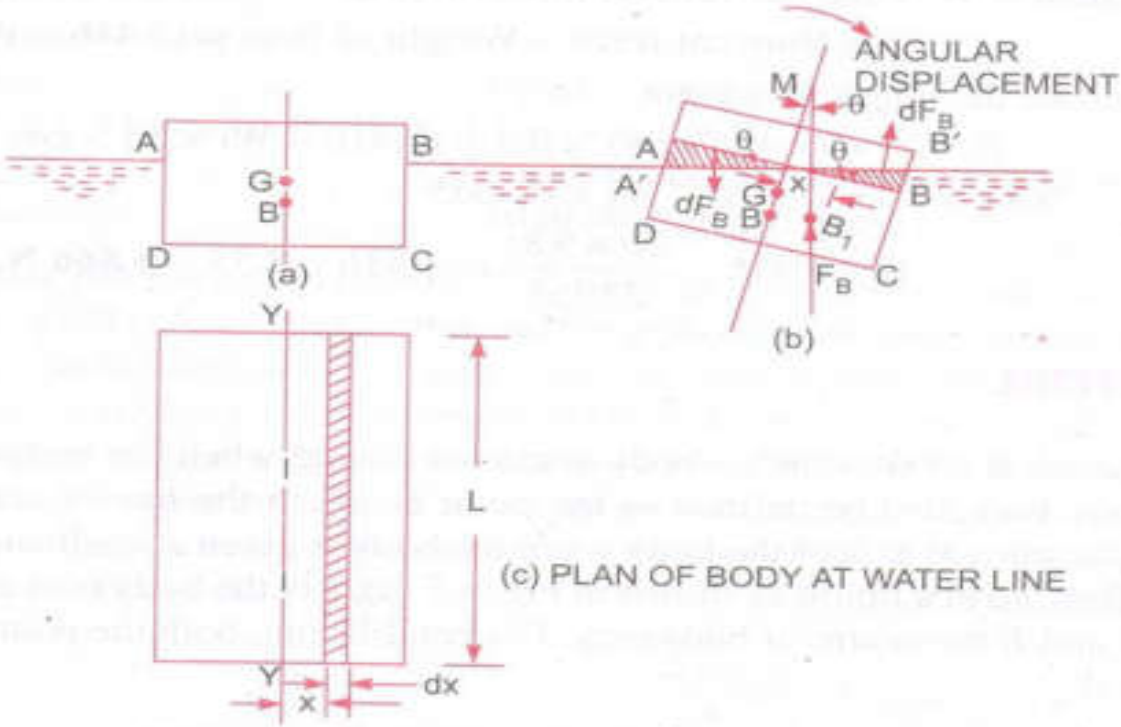


Fig. 4.6 *Meta-centre height of floating body.*

Experimental method of Determination of Meta-centric Height

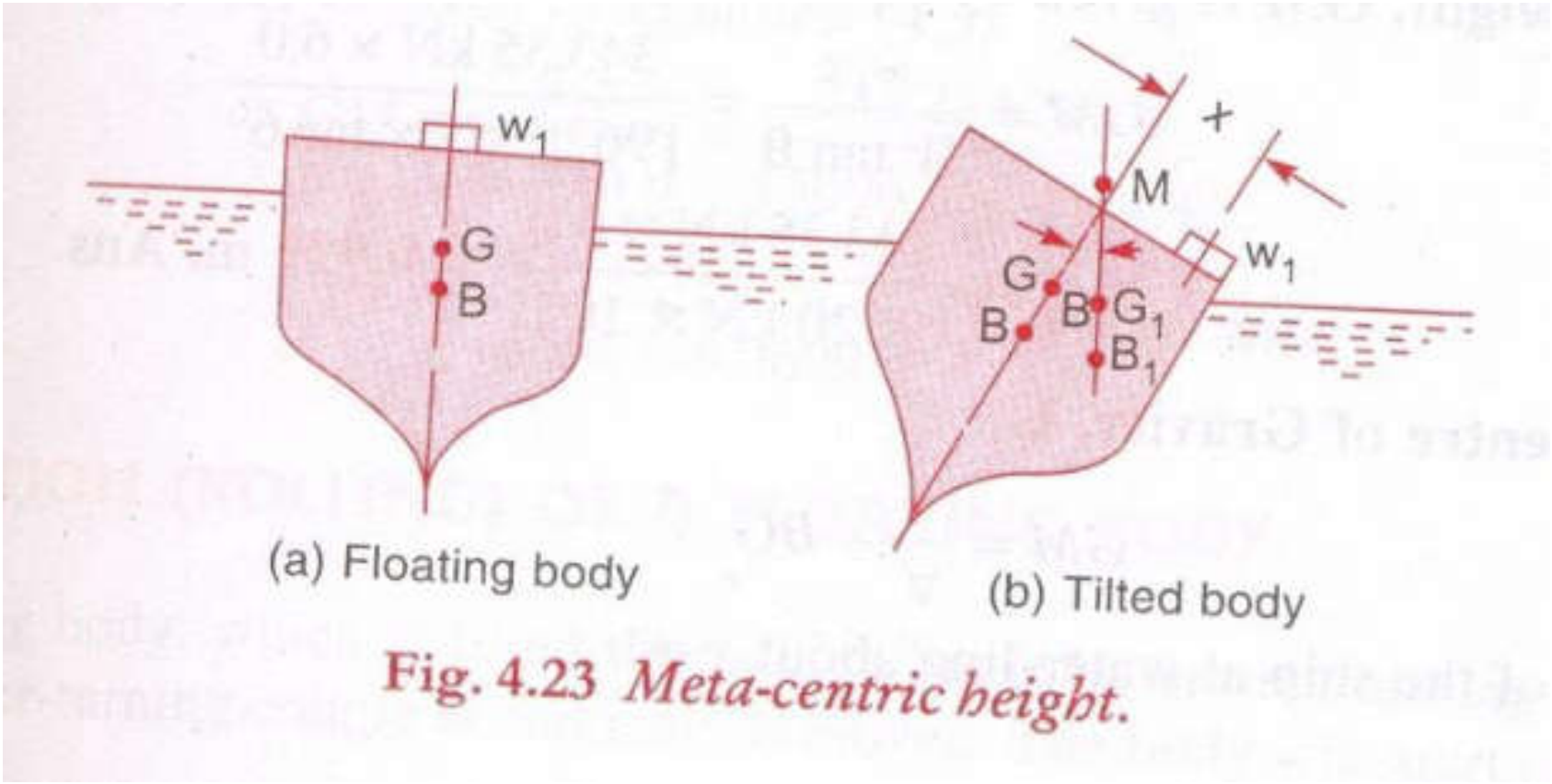


Fig. 4.23 *Meta-centric height.*