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Fluid Mechanics

PRESSURE AND FLUID STATICS

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Chapter Description

- Expected Outcomes
  - Define relationship between Absolute Pressure and Gauge Pressure .
  - Calculate pressure by different measurement devices: mercuric Barometer, Piezometer, Manometer and etc.
  - Compute Hydrostatic Force on Submerged Plane.

TOPICS

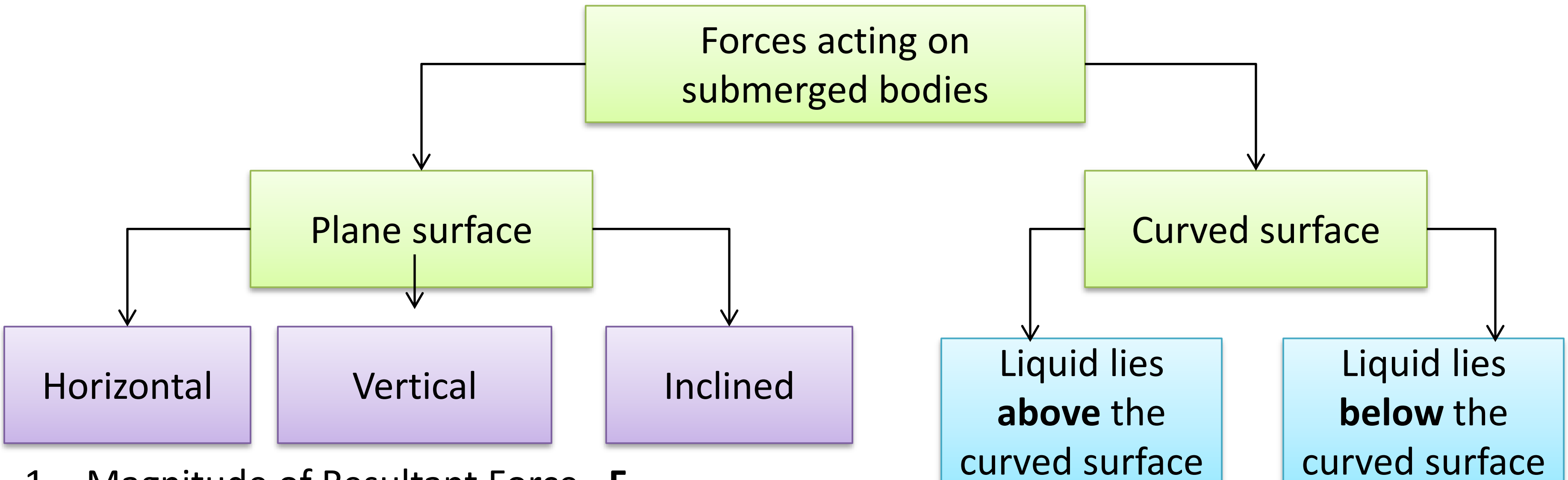
WEEK	CHAPTER	TOPIC		
3 19 – 21 Sept	**2**	**Pressure and Fluid Statics**		
		2.1	Pressure	
			2.1.1	Absolute Pressure and Gauge Pressure
			2.1.2	Pressure and Force
		2.2	Pressure Measurement Devices	
			2.2.1	The Barometer
			2.2.2	The Manometer
4 26 – 28 Sept		2.3	Fluid Statics	
			2.3.1	Introduction to Fluid Static
			2.3.2	Hydrostatic Forces on Plane Surface
5 3 – 5 Oct			2.3.3	Hydrostatic Forces on Curved Surface
			2.3.4	Buoyancy and Stability
			2.3.5	Fluid Flow Concept

2.3 Fluid Static

- Introduction to Fluid Static
- Hydrostatic Forces on Plane Surface
- Hydrostatic Forces on Curved Surface
- Buoyancy and Stability
- Fluid Flow Concept

2.3.1 Introduction Fluid static

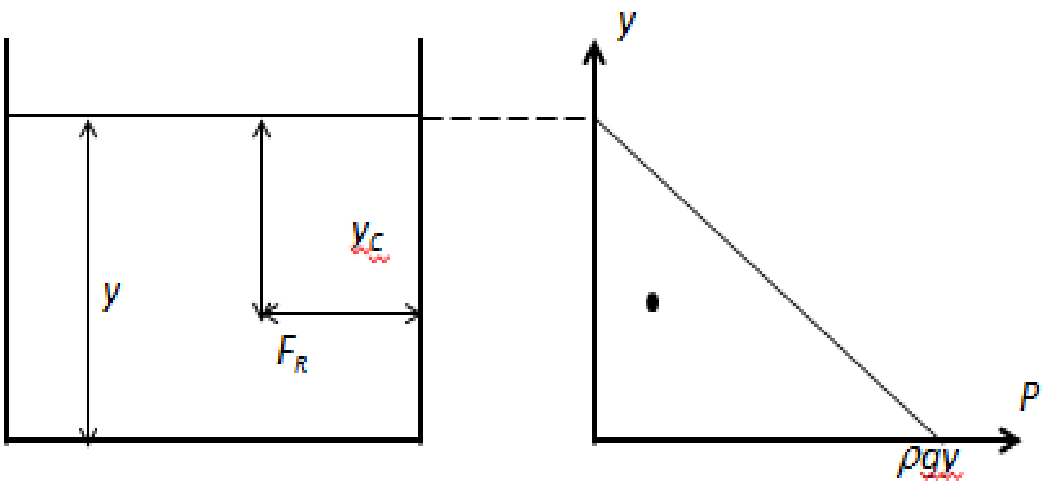
- Fluid static = Fluid at rest
- The element will be in equilibrium and the summation of the component forces acting in any direction must be zero.



1. Magnitude of Resultant Force, $\mathbf{F_R}$
2. Direction of the force
3. Line of action of the force or Centre of Pressure, $\mathbf{C_P}$

2.3.2 Hydrostatic Forces on Vertical Plane Surface

- The hydrostatic forces form a system of parallel forces
- Need to determine the magnitude of the force and its point of application, called as **center of pressure**.
- The pressure ***P*** on a plane horizontal surface in a fluid at rest will be the same at all points. If the area of the plane surface is A, thus the resultant force,
- $\boldsymbol{F_R = PA}$ (Magnitude of resultant force on plane surface)
- Centroid of area and the resultant force acts normal to the area at the centroid of the area.



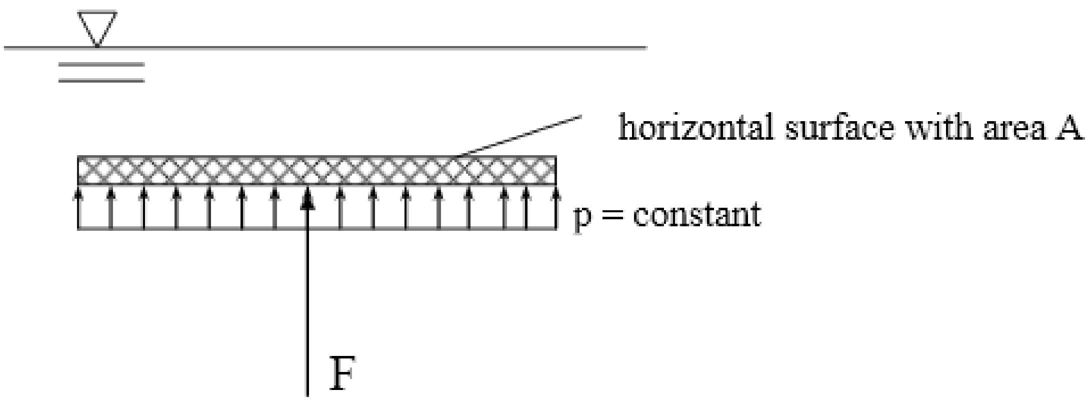
$$F_R = P \times A$$

$$F_R = \frac{\rho g y}{2} \times (b \times y)$$

$$F_R = \frac{1}{2} \rho g y^2 b$$

$$C_P = \frac{I_x}{A y_c} + y_c$$

Horizontal plane



$$F_R = P \times A$$

$$F_R = \rho g y \times (b \times w)$$

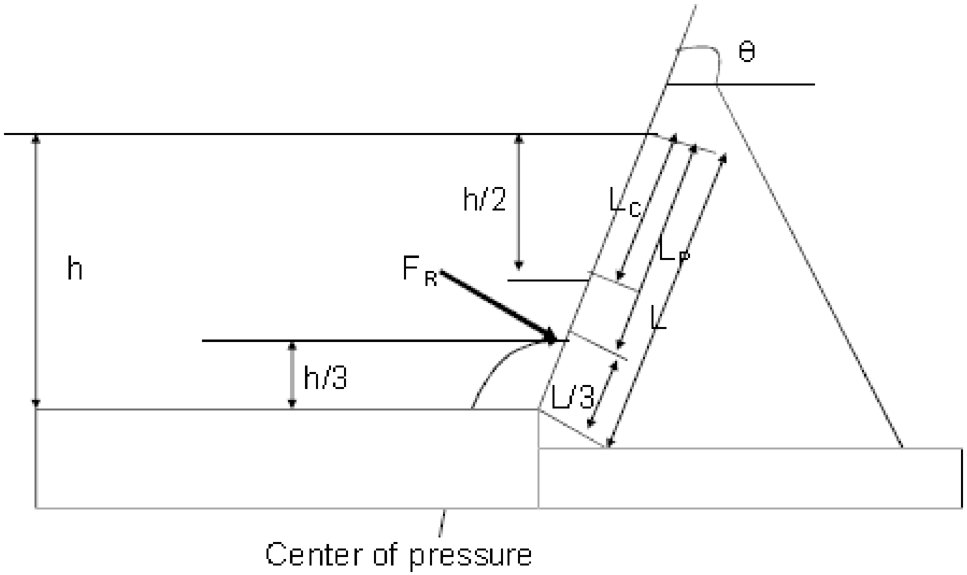
Inclined Plane

- Rectangular wall

$$F_R = P \times A$$

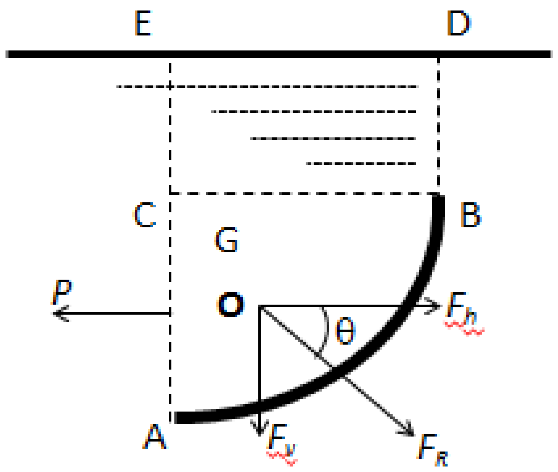
$$F_R = \rho g\left(\frac{y}{2}\sin\theta\right)\times\left(b\times y\right)$$

$$C_P = \frac{I_x \sin^2\theta}{A y_c} + y_c$$



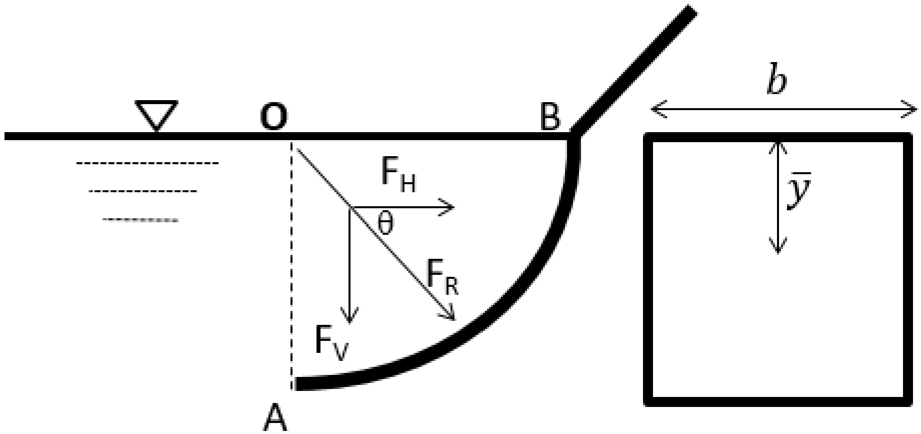
2.3.3 Hydrostatic Forces on Curved Surface

- If a surface is curved, the forces produced by fluid pressure on the small elements making up the area will not be parallel and therefore must be combined vectorially. It is convenient to calculate the horizontal and vertical components of the resultant force.
- In below, AB is an immersed surface and F_h and F_v are the horizontal and vertical components of the resultant force F_R.
- Figures below show :
  - the liquid lies above the curved surface
  - the fluid is below the curved surface.



a) Liquid above the curved surface

- The liquid lies above the curved surface



$$F_H = \rho g A h_c$$

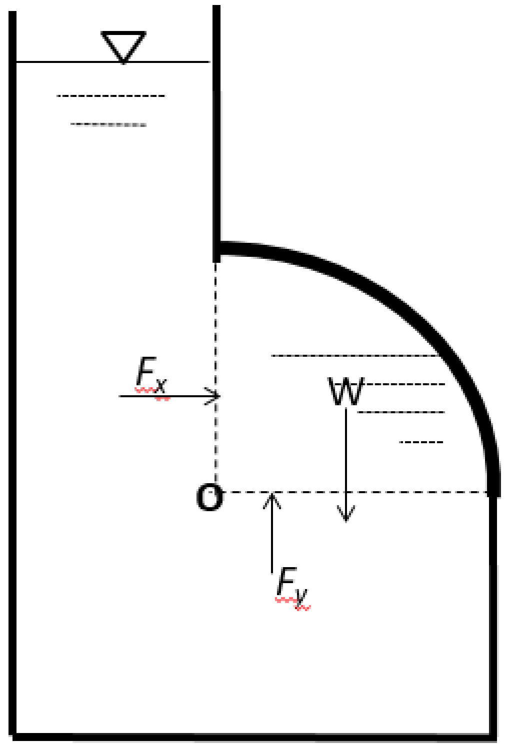
$$F_V = mg = \rho g v = \gamma v$$

$$F_R = \sqrt{(F_V^2) + (F_H^2)}$$

$$\theta = \tan^{-1} \frac{F_V}{F_H}$$

b) Liquid below the curved surface

- When a curved surface is above the liquid, the weight of the liquid and the vertical component of the hydrostatic force act in the opposite directions.



- Horizontal force component,

$$F_H = F_x$$

- Vertical force component,

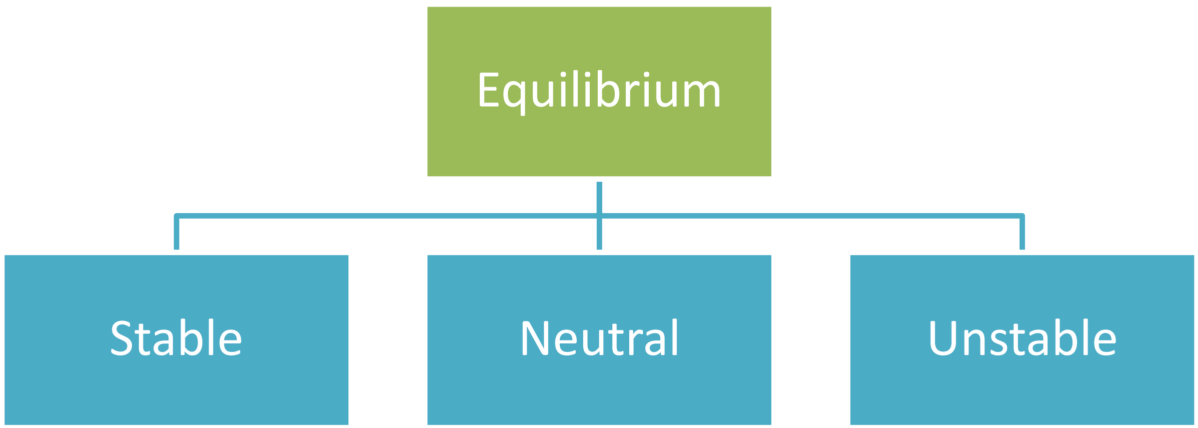
$$F_V = F_y - W$$

- Resultant force,

$$F_R = \sqrt{\left(F_V^2\right) + \left(F_H^2\right)}$$

2.3.4 Buoyancy and Stability

- Stability of Floating Bodies



- **Archimedes' principle :** The buoyant force acting on a body immersed in a fluid is equal to the weight of the fluid displaced by the body, and it acts upward through the centroid of the displaced volume.

Buoyant force

- A flat plate with thickness ***h***
- Submerged in liquid of density ρ_f
- Submerged parallel to free surface at distance ***s***
- The top force (acting downward);

$$F_{top} = \rho_f gs \times A$$

- The bottom force (acting upward);

$$F_{bottom} = \rho_f g(s+h) \times A$$

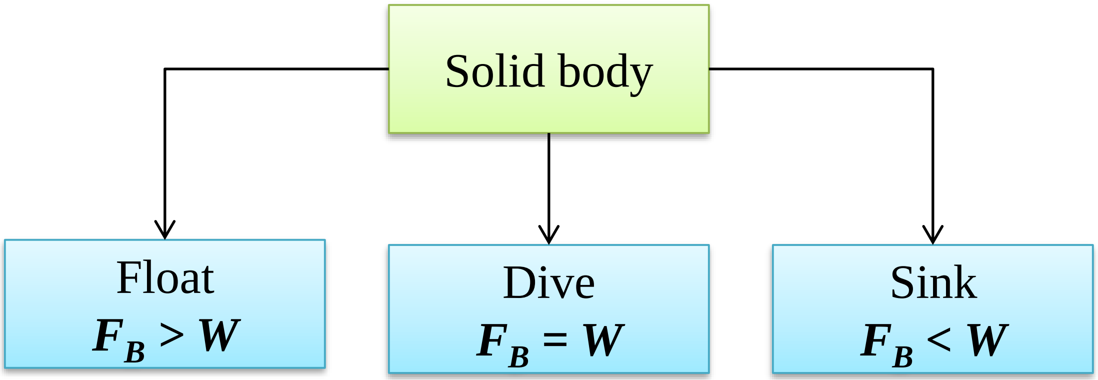
- The difference between 2 forces is Buoyant Force, FB
- The buoyant force acting on the plate is equal to the weight of the liquid by the plate. - Archimedes

$$F_{bottom} - F_{top} = \lfloor \rho_f g(s+h) \times A \rfloor - \lfloor \rho_f gs \times A \rfloor = \rho_f gh \times A = \rho_f gV$$

volume displaced = weight of liquid

Stability of submerged and floating bodies

- For floating bodies, the weight of the entire body must be equal to the buoyant force.
- A solid body dropped into a fluid will sink, float, or remain at rest at any point (depending on its density relative to the density of the fluid).



- Neutral buoyancy occurs when a body stays in a given position wherever it is submerged in a fluid. An object whose average specific weight is equal to that of the fluid is neutrally buoyant.