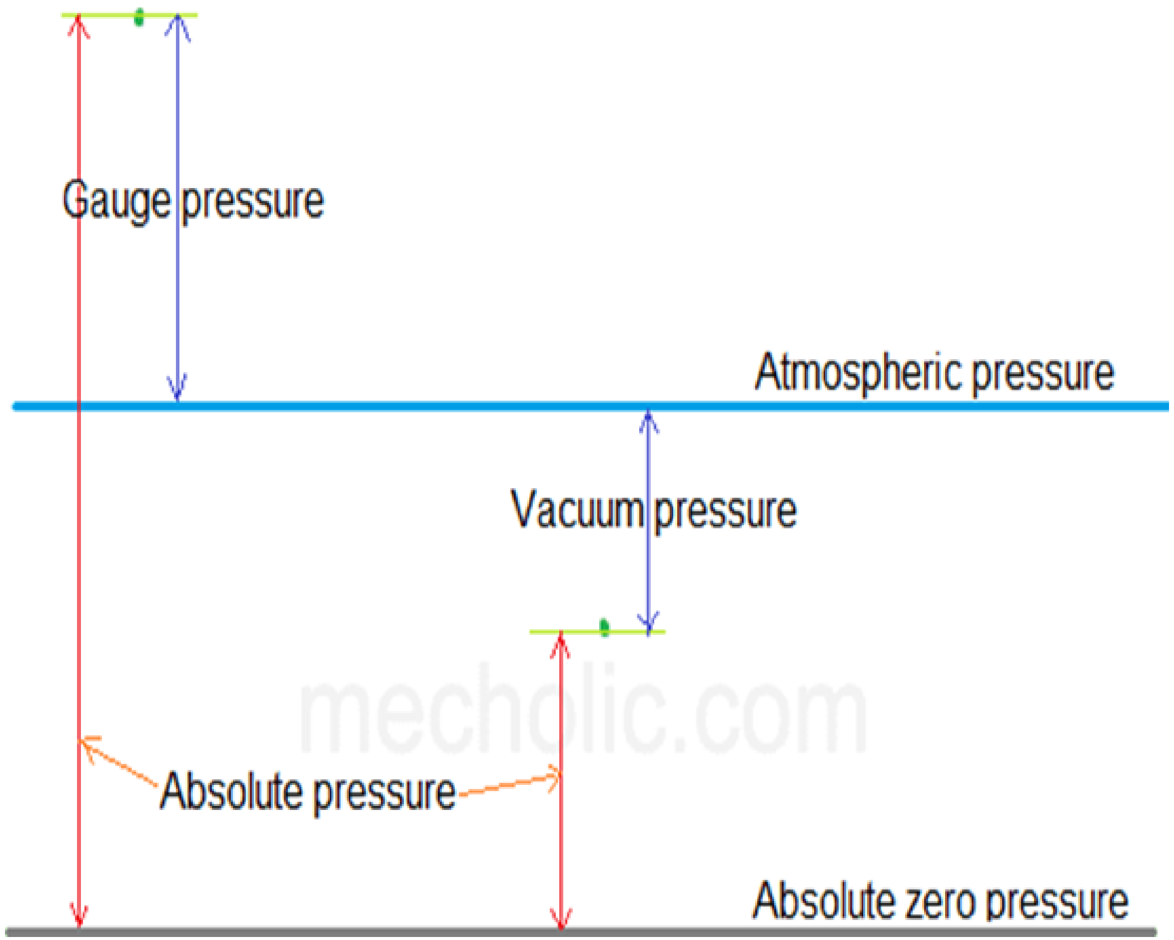
FLUID MECHANICS
(BTME 301-18)

Unit 2: Fluid Statics

PRESSURE MEASURING SYSTEM

- In one system, it is measured above the absolute zero or complete vacuum and it is called the Absolute pressure.
- In other system, pressure is measured above the atmospheric pressure and is called Gauge pressure.



- **ABSOLUTE PRESSURE:** It is defined as the pressure which is measured with reference to absolute vacuum pressure.
- **GAUGE PRESSURE:** It is defined as the pressure, which is measured with the help of a pressure measuring instrument, in which the atmospheric pressure is taken as datum. The atmospheric on the scale is marked as zero.
- **VACUUM PRESSURE:** It is defined as the pressure below the atmospheric pressure

  i) Absolute pressure = Atmospheric pressure+ gauge pressure

  $p_{ab} = p_{atm} + p_{guage}$

  Vaccum pressure= atmospheric pressure - Absolute pressure
- The atmospheric pressure at sea level at 15^0C is $10.13 N/cm^2$ or $101.3 KN/m^2$ in S I Units and 1.033 Kg f/cm^2 in M K S System.
- The atmospheric pressure head is 760mm of mercury or 10.33m of water.

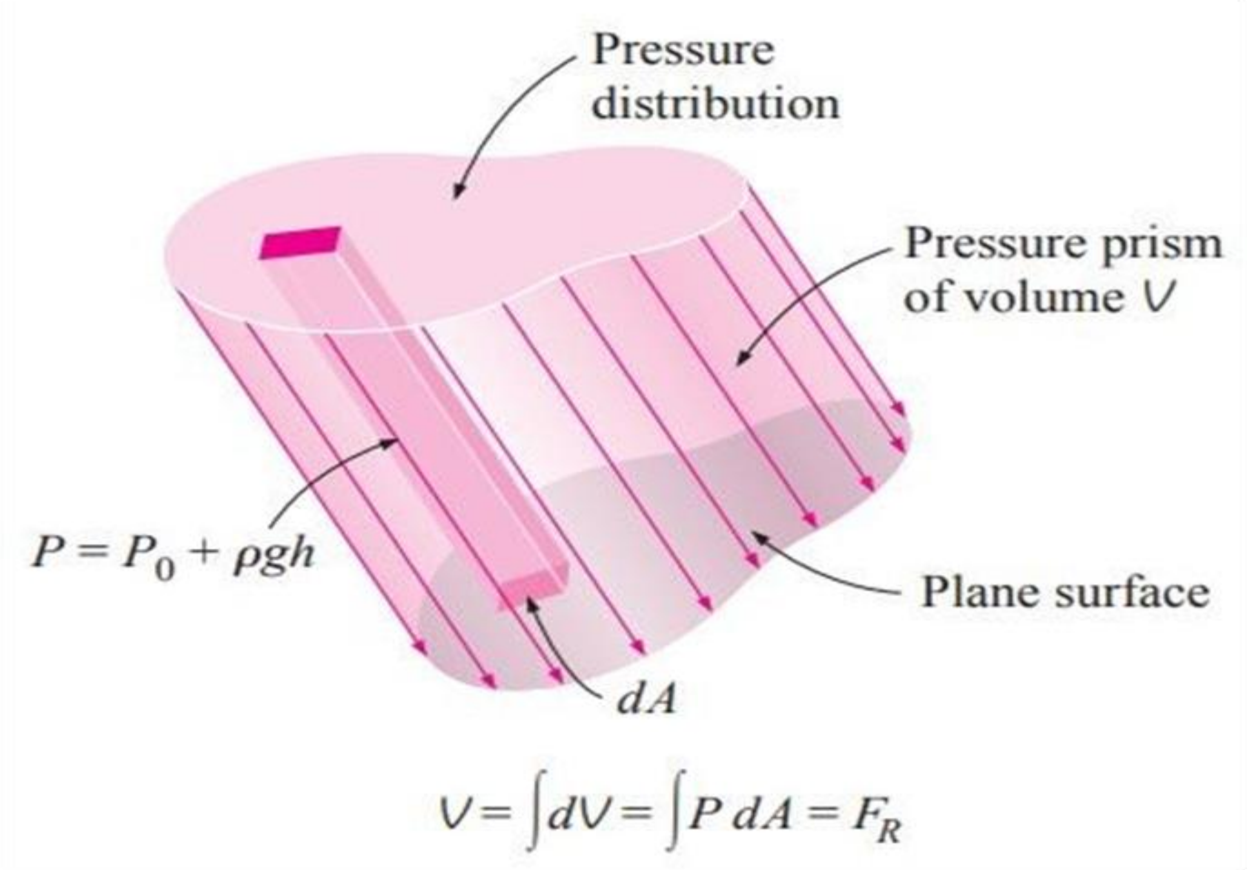
- The pressure of a fluid is measured by the fallowing devices.
  - Manometers
  - Mechanical gauges.

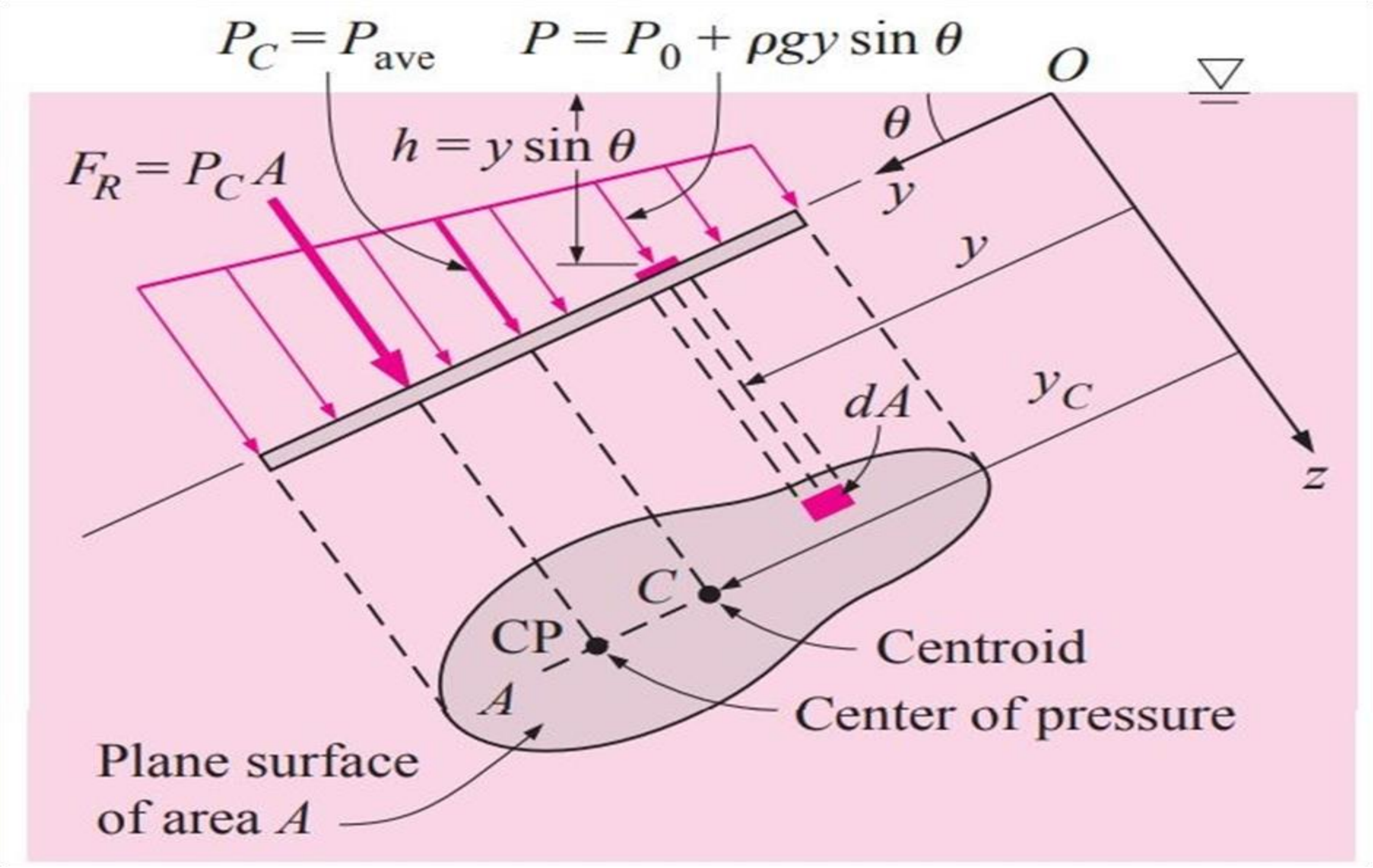
- **Manometers:** Manometers are defined as the devices used for measuring the pressure at a point in a fluid by balancing the column of fluid by the same or another column of fluid. They are classified as:
  - Simple Manometers
  - Differential Manometers

- **Mechanical Gauges:** These are defined as the devices used for measuring the pressure by balancing the fluid column by the spring or dead weight.
- The commonly used Mechanical pressure gauges are:
  - Diaphragm pressure gauge
  - Bourdon tube pressure gauge
  - Dead - Weight pressure gauge
  - Bellows pressure gauge.

Hydrostatic Thrusts

- Due to the existence of hydrostatic pressure in a fluid mass, a normal force is exerted on any part of a solid surface which is in contact with a fluid.




$P_C = P_{ave}$
$P = P_0 + \rho g y \sin\theta$
O
θ
$h = y \sin\theta$
$F_R = P_C A$
y
y
y_C
dA
z
C
CP
Centroid
Center of pressure
A
Plane surface
of area A

absolute pressure at any point on the plate is

Where,

h is the vertical distance of the point from the free surface and
y is the distance of the point from the x-axis

The resultant hydrostatic force F_R acting on the surface is determined by integrating the force **P dA** acting on a differential area **dA** over the entire surface area,

$$F_R = \int_A P\,dA$$

$$= \int_A (P_0 + \rho g y \sin\theta)\,dA$$

$$= P_0 A + \rho g \sin\theta \int_A y\,dA$$

first moment of area along the y-coordinate vertical distance of the centroid from the free surface of the liquid

$$F_R = (P_0 + \rho g y_C \sin\theta)A$$

$$= (P_0 + \rho g h_C)A$$

$$= P_C A = P_{ave} A$$

pressure at the centroid of the surface

$$= P_0 A + \rho g \sin\theta \int_A y \, dA$$

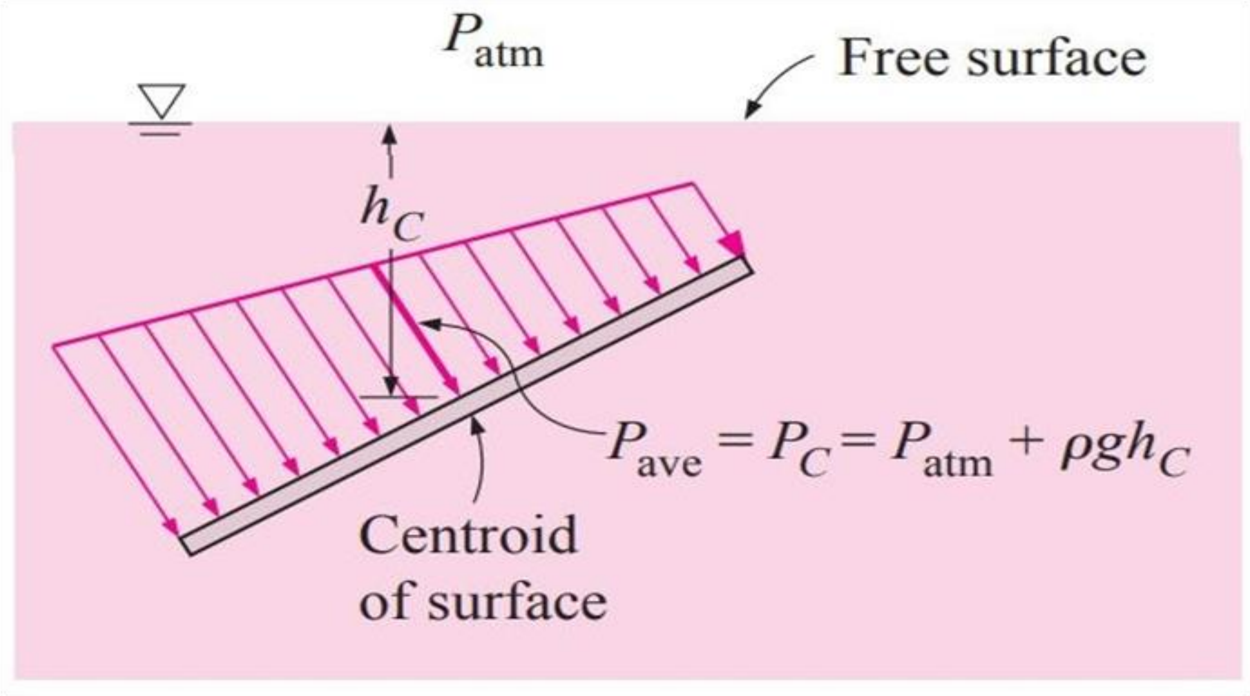
$$P_C = P_0 + \rho g h_C$$

pressure at the centroid of the surface is equivalent to the average pressure on the surface

$$h_C = y_C \sin\theta$$

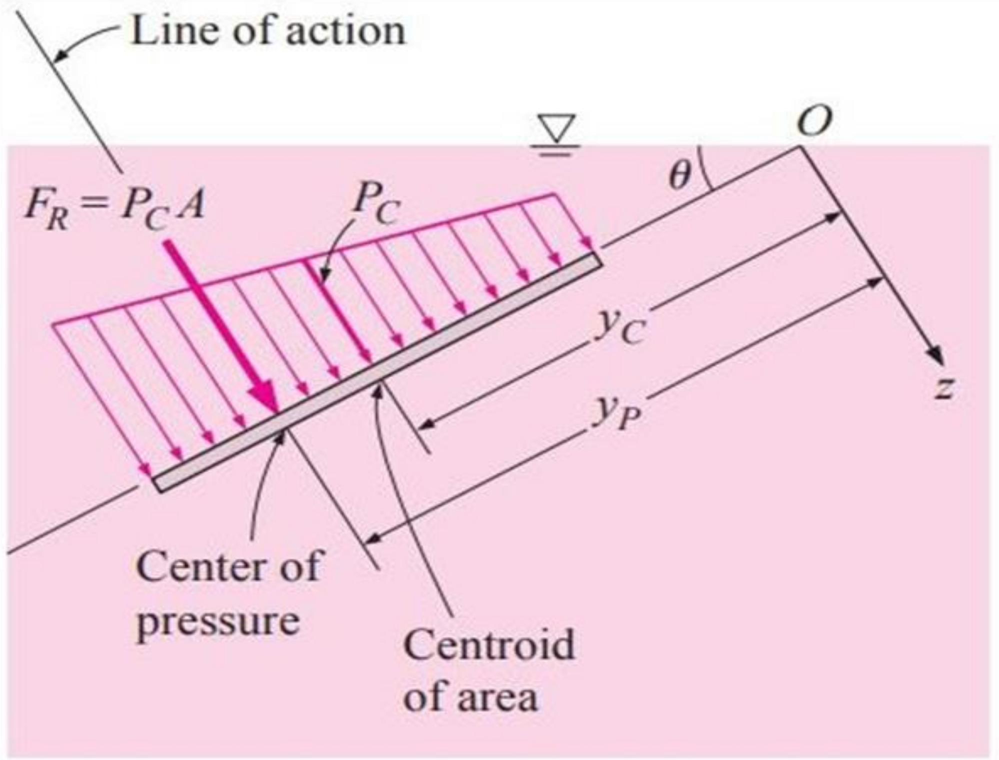
$$F_R = P_C A = P_{ave} A$$

The magnitude of the resultant force acting on a plane surface of a completely submerged plate in a homogeneous (constant density) fluid is equal to the product of the pressure $\mathbf{P_C}$ at the centroid of the surface and the area $\mathbf{A}$ of the surface



Determine the line of action of the resultant force F_R

- Two parallel force systems are equivalent if they have the same magnitude and the same moment about any point.
- The line of action of the resultant hydrostatic force, in general, does not pass through the centroid of the surface—it lies underneath where the pressure is higher.
- The point of intersection of the line of action of the resultant force and the surface is the **center of pressure.**
- The vertical location of the line of action is determined by equating the moment of the resultant force to the moment of the distributed pressure force about the x-axis



vertical location of the line of action is determined by equating the moment of the resultant force to the moment of the distributed pressure force about the x-axis.

$$y_P F_R = \int_A yP\, dA$$

$$= \int_A y(P_0 + \rho g y \sin\theta)\, dA$$

$$= P_0 \int_A y\, dA + \rho g \sin\theta \int_A y^2\, dA$$

(second moment of area
or
area moment of inertia)

$$I_{xx,\,O} = \int_A y^2\, dA$$

$$y_P F_R = P_0 y_C A + \rho g \sin\theta\, I_{xx,\,O}$$

where

y_P is the distance of the center of pressure from the x-axis second moments of area about two parallel axes are related to each other by the parallel axis theorem

$$I_{xx,\,O} = I_{xx,\,C} + y_C^2 A$$

where $I_{xx,\,C}$ is the second moment of area about the x-axis passing through the centroid of the area and y_C

Substituting the F_R, and the $I_{xx,\,O}$ and solving for y_P gives,

$$y_P F_R = P_0 y_C A + \rho g \sin\theta \, I_{xx,\,O}$$

$$F_R = (P_0 + \rho g y_C \sin\theta)A$$

$$I_{xx,\,O} = I_{xx,\,C} + y_C^2 A$$

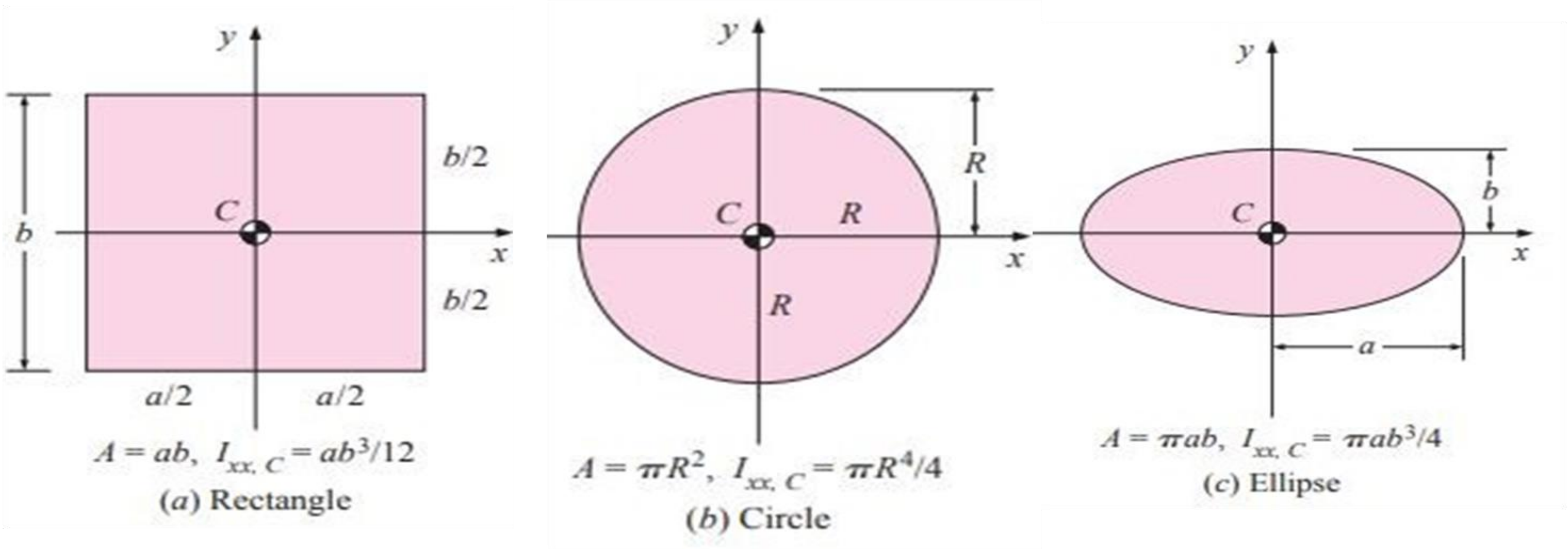
$$y_P = y_C + \frac{I_{xx,\,C}}{[y_C + P_0/(\rho g \sin\theta)]A}$$

For $P_0 = 0$, which is usually the case when the atmospheric pressure is ignored, it simplifies to

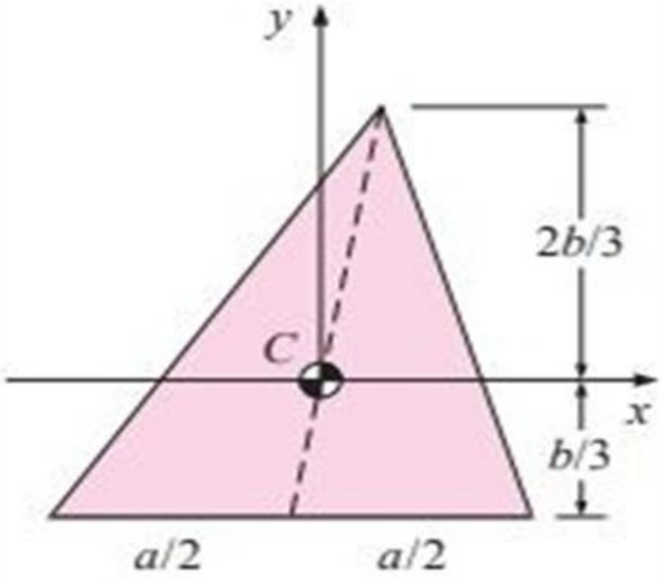
$$y_P = y_C + \frac{I_{xx,C}}{y_C A}$$

Where,

y_P, the vertical distance of the center of pressure from the free surface is determined from $h_P = y_P \sin\theta$

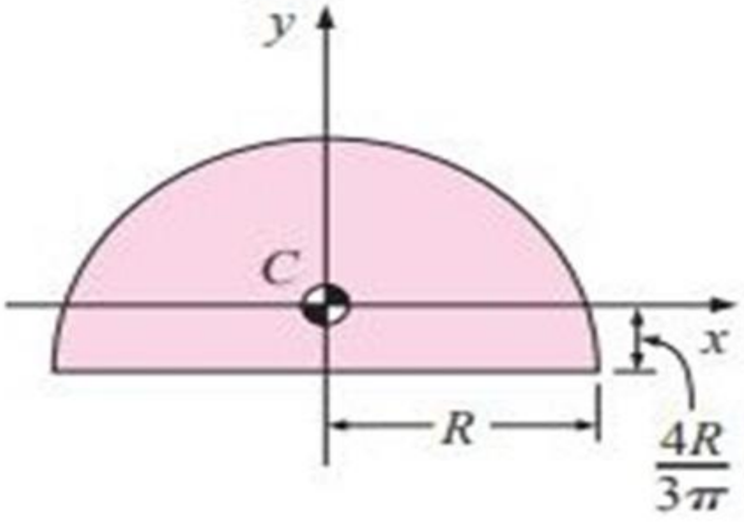


$I_{xx,\,C}$ values for some common areas



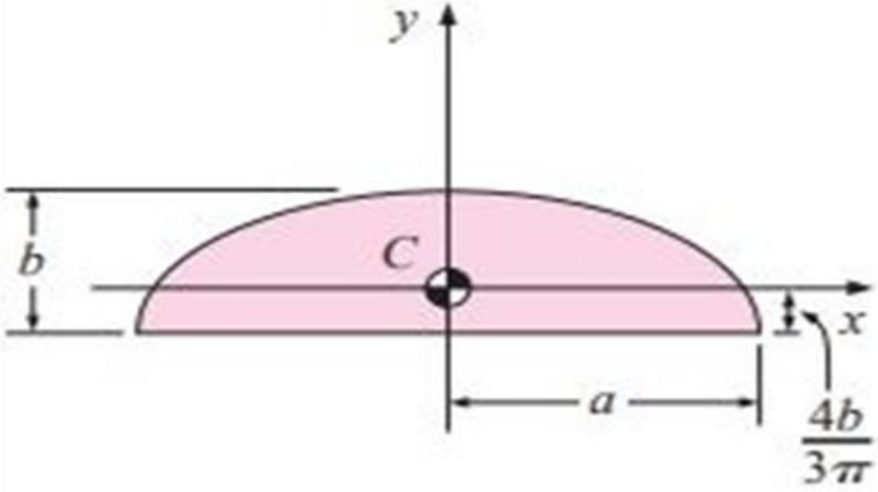
$A = ab/2,\ I_{xx,C} = ab^3/36$

(*d*) Triangle



$A = \pi R^2/2,\ I_{xx,C} = 0.109757R^4$

(*e*) Semicircle



$A = \pi ab/2,\ I_{xx,C} = 0.109757ab^3$

(*f*) Semiellipse

$I_{xx,C}$ values for some common areas