Chemical Engineering 374

Fluid Mechanics

Pressure and Fluid Statics

Spiritual Thought

"We don't always know the details of our future. We do not know what lies ahead. We live in a time of uncertainty. We are surrounded by challenges on all sides. Occasionally discouragement may sneak into our day; frustration may invite itself into our thinking; doubt might enter about the value of our work. In these dark moments Satan whispers in our ears that we will never be able to succeed, that the price isn't worth the effort, and that our small part will never make a difference… We know that God keeps His promises. We need to fulfill our part to receive His blessings."

-Dieter F. Uchtdorf

OEP #2 (clip)

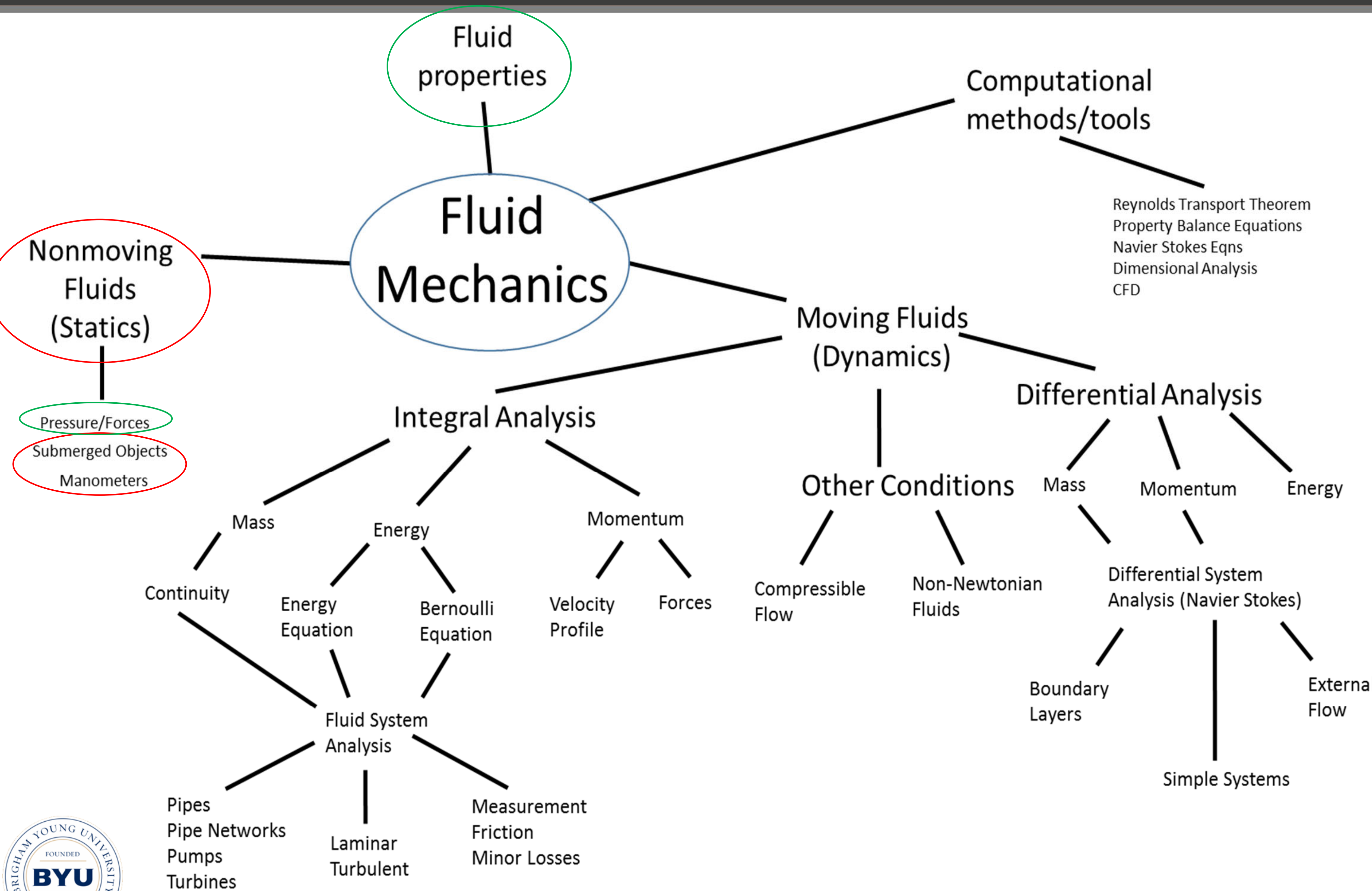
OEP #2

Open Ended Problem #2
Planet Naboo's Watery Core
Individual work only, Due 9/18/24 at beginning of class
(Don't be afraid to "Google" good assumptions!)

Star Wars Episode 1 Clip

Master Jin and Obi-Wan need to find and take the fastest way from the Gungan city in the ocean to the Naboo capital, but there is significant danger in taking this path. One obvious risk is being eaten by massive sea creatures. An additional risk is being crushed by the hydrostatic pressure of the oceans. Neglecting the teeth/jaws of the predators, at what point(s) do the Jedi (and Jar-Jar) run the greatest risk of being crushed, and how significant is that risk?

Fluids Roadmap



Key Points

- Buoyancy
  - Statics, Force Balance
- Pressure Measurement
  - Barometer
  - Bordon Tube
  - Manometer
  - Others
- Surface forces on submerged objects

Buoyancy

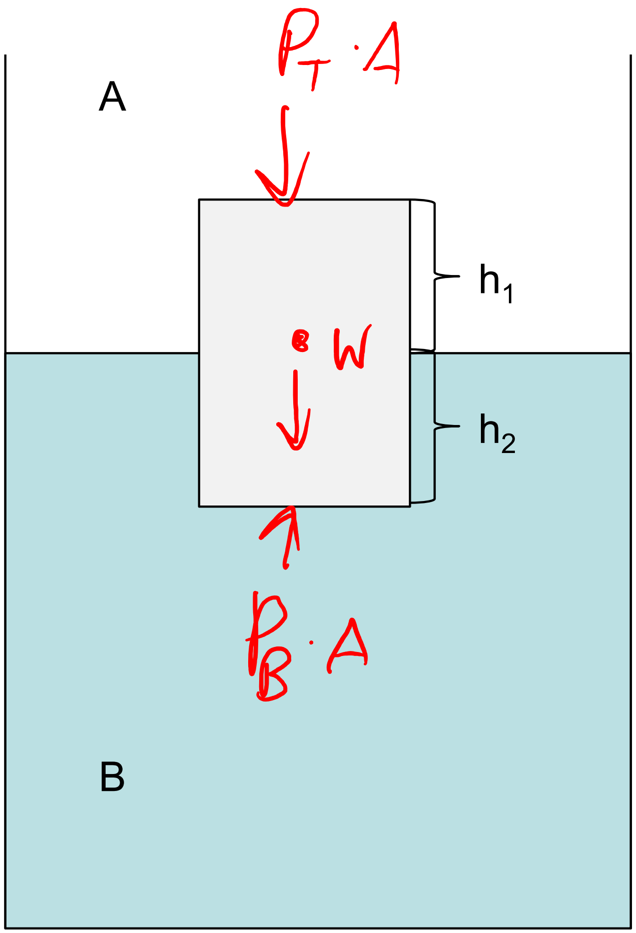
Analysis

- Force Balance? $\sum F = 0$ 3 Forces

W, Bottom Pressure, Top Pressure

$$0 = P_B \cdot A - P_T \cdot A - W$$

$$\therefore W = P_B \cdot A - P_T \cdot A$$



- Bottom Pressure?

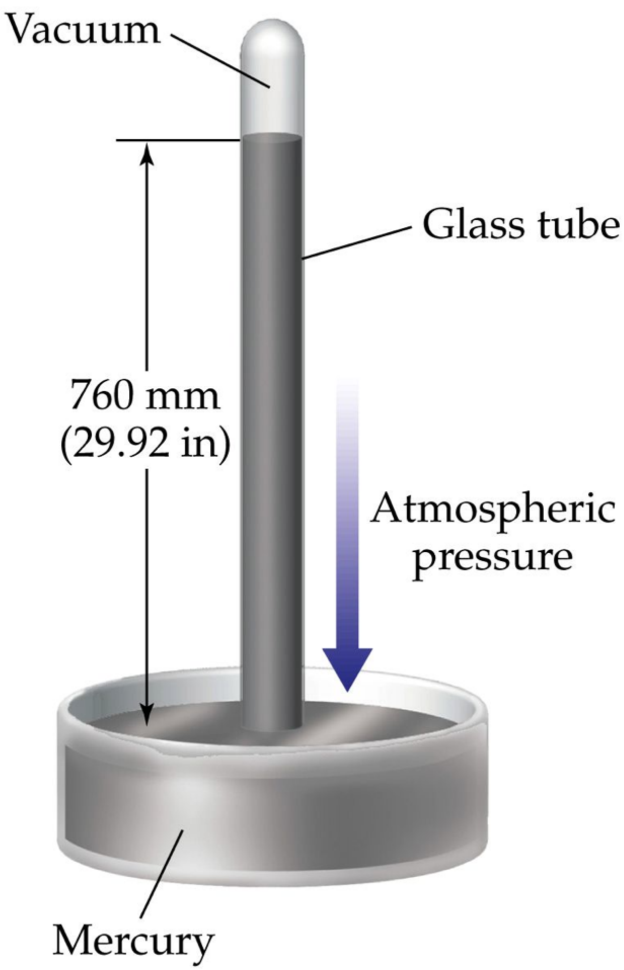
$$P_B = P_T + \rho_A g h_1 + \rho_B g h_2$$

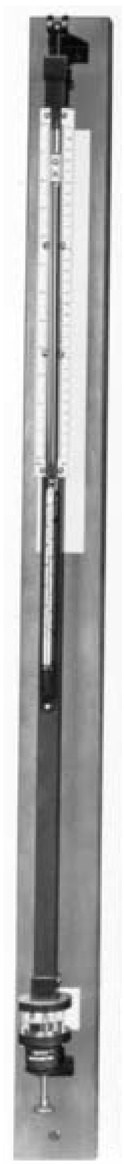
- Force of Buoyancy?

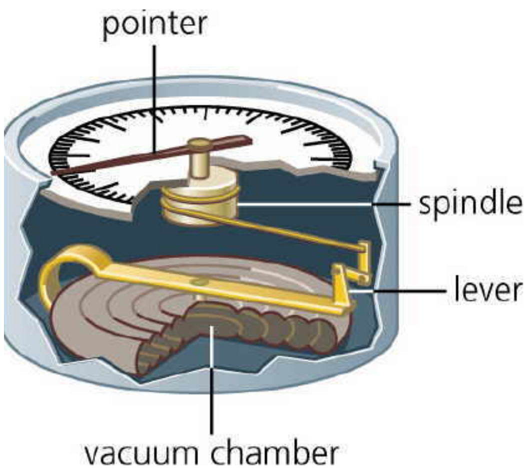
$$W = F_B = \cancel{P_T A} + \rho_A g h_1 A + \rho_B g h_2 A - \cancel{P_T A}$$

$$F_B = \rho_A g h_1 A + \rho_B g h_2 A \Rightarrow \text{weight of displaced fluid (A\&B)}$$

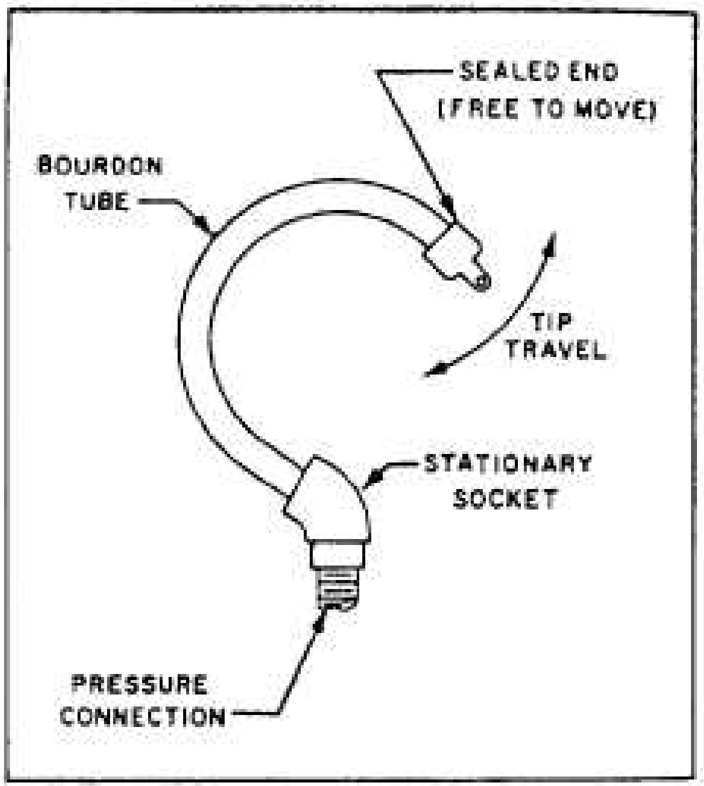
Barometer

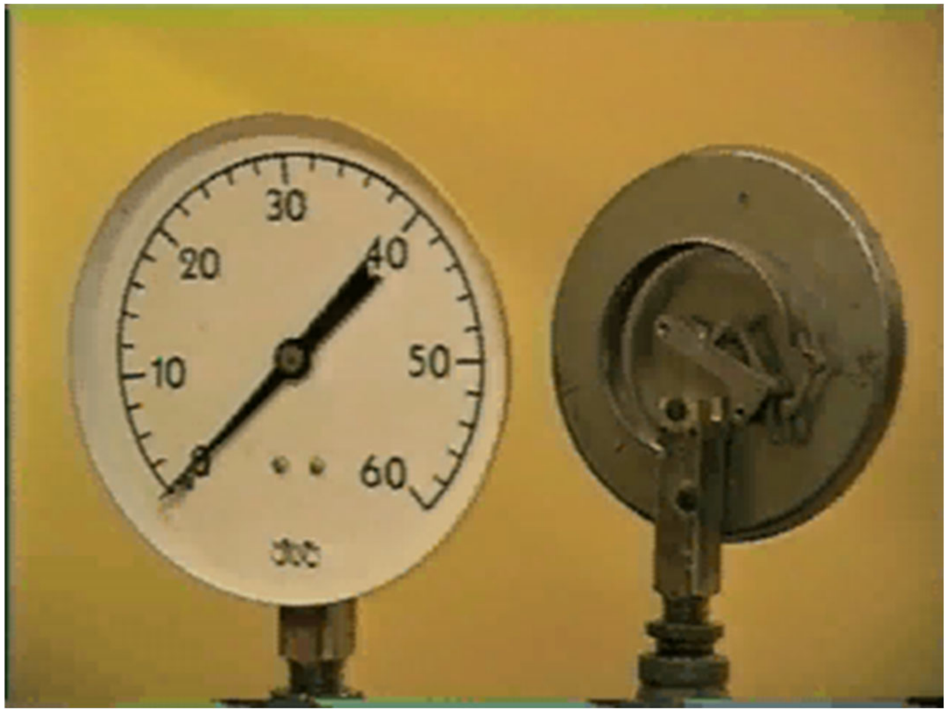

Vacuum
Glass tube
760 mm
(29.92 in)
Atmospheric
pressure
Mercury




pointer
spindle
lever
vacuum chamber

Bourdon Tube





Bourdon Tube Demonstration

flash-swf-converter.com

Bourdon Tube Gauge

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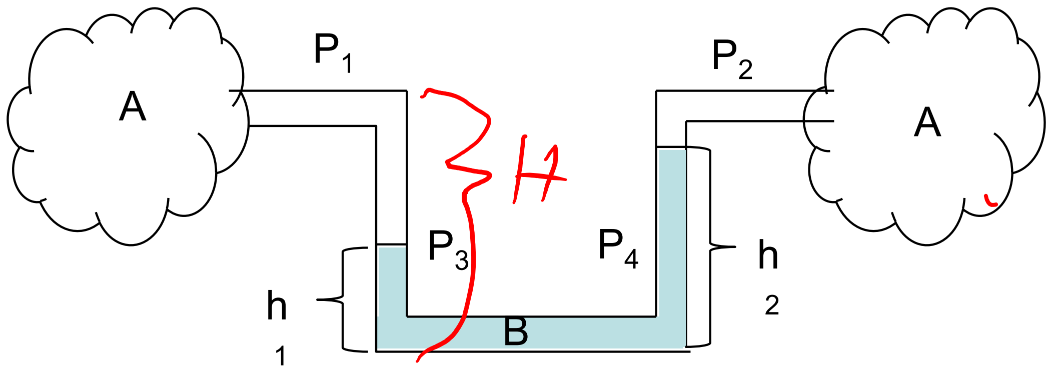
Manometers

- Common in Labs
  - Fluid column → measure ΔP
  - Works for small to medium ΔP



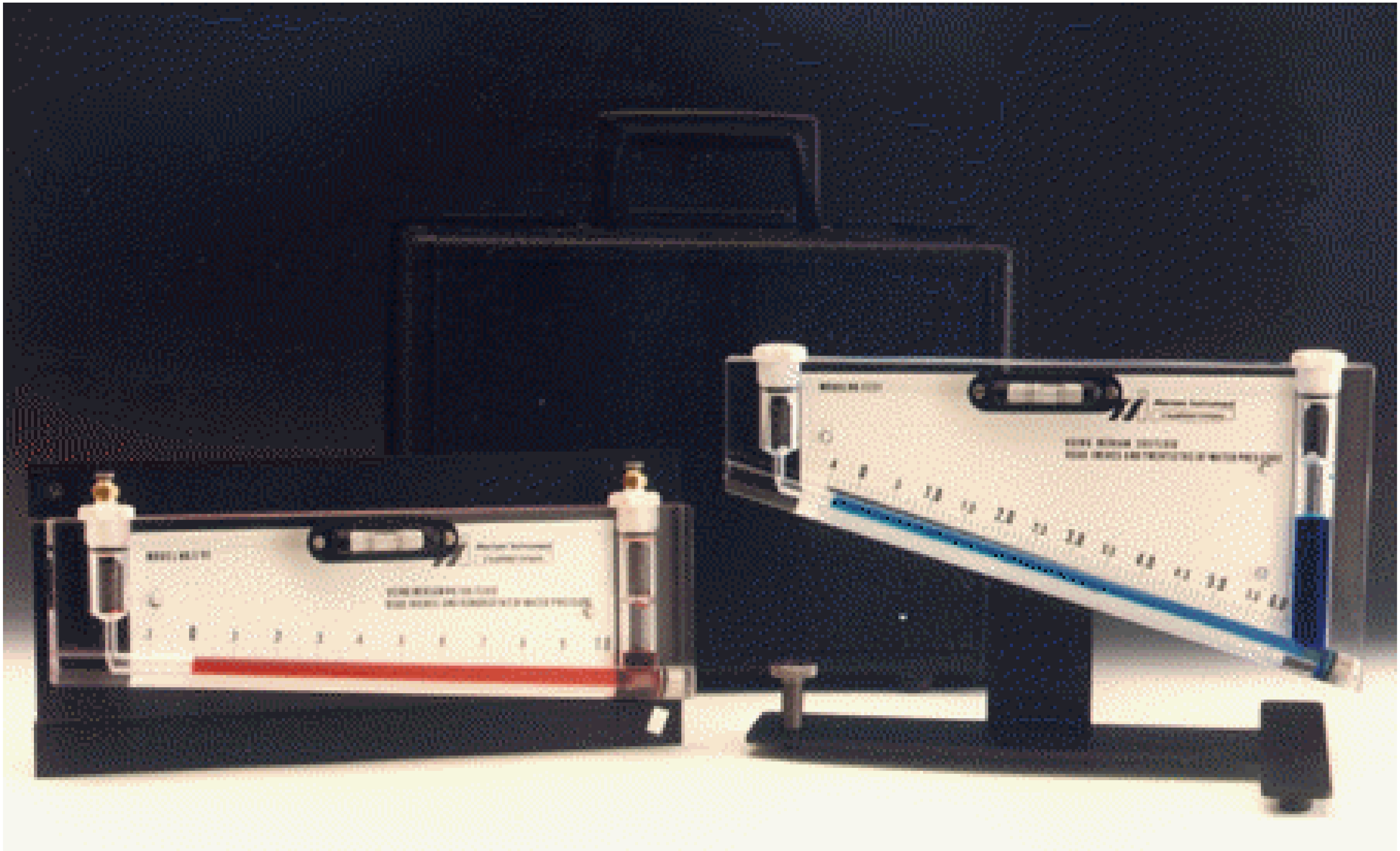
If A is gas, then
$\Delta P = \rho_B g (h_2 - h_1)$

Know pressure at P_1 → what is pressure at B?

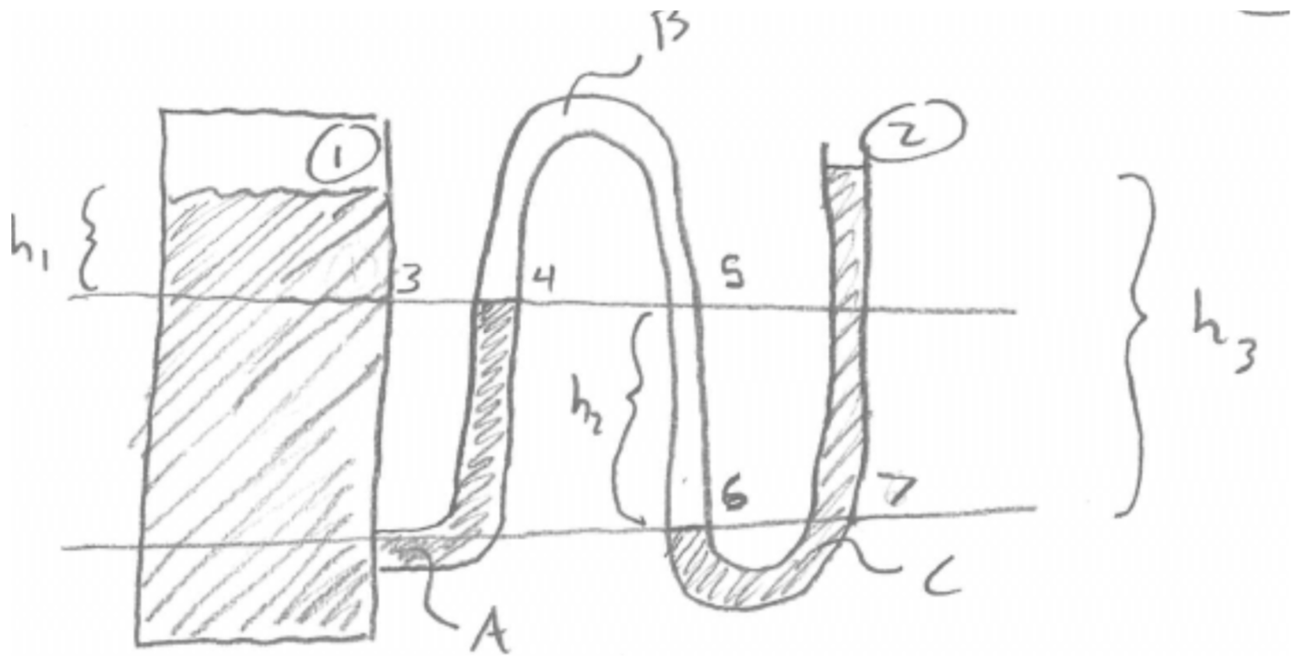
$P_1 + \rho_A g (H - h_1) + \rho_B g h_1 - \rho_B g h_2 - \rho_A g (H - h_2) = P_2$

$P_2 - P_1 = (\rho_B - \rho_A) g (h_2 - h_1) \Rightarrow \Delta P = \Delta \rho g \Delta h$

Manometer



Manometer Example



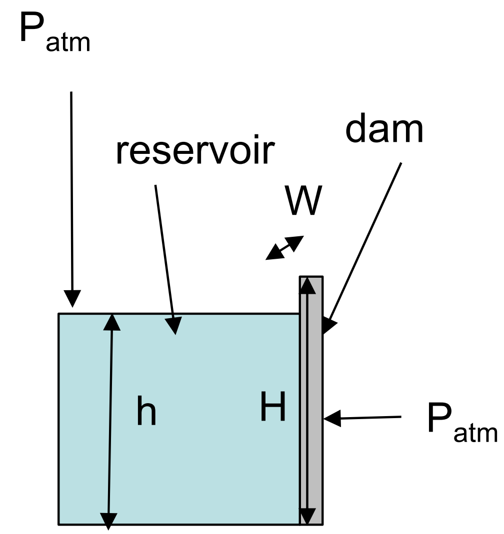
$$P_2 = P_1 + \rho_A g h_1 + \rho_B g h_2 - \rho_C g h_3$$

1 → 3 5 → 6 7 → 2

3 = 5 hop 6 = 7 hop

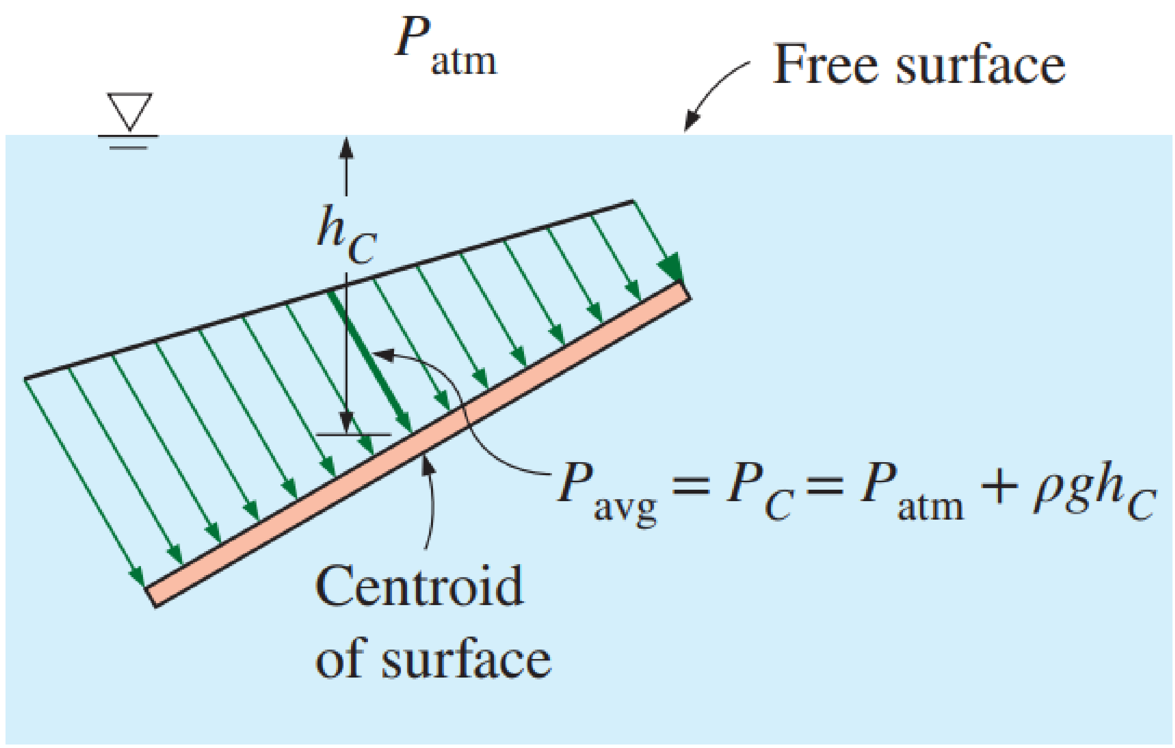
Forces on Surfaces

- Pressure vs. height?
- F = P*A
  - dF = PdA
  - dF = (P)W*dh
  - P = ρgh
  - Atm → both sides



3-4: Hydrostatic Forces on Submerged Plane Surfaces

The pressure at the centroid of a surface is equivalent to the *average* pressure on the surface.



- [Access the text alternative for slide images.]()

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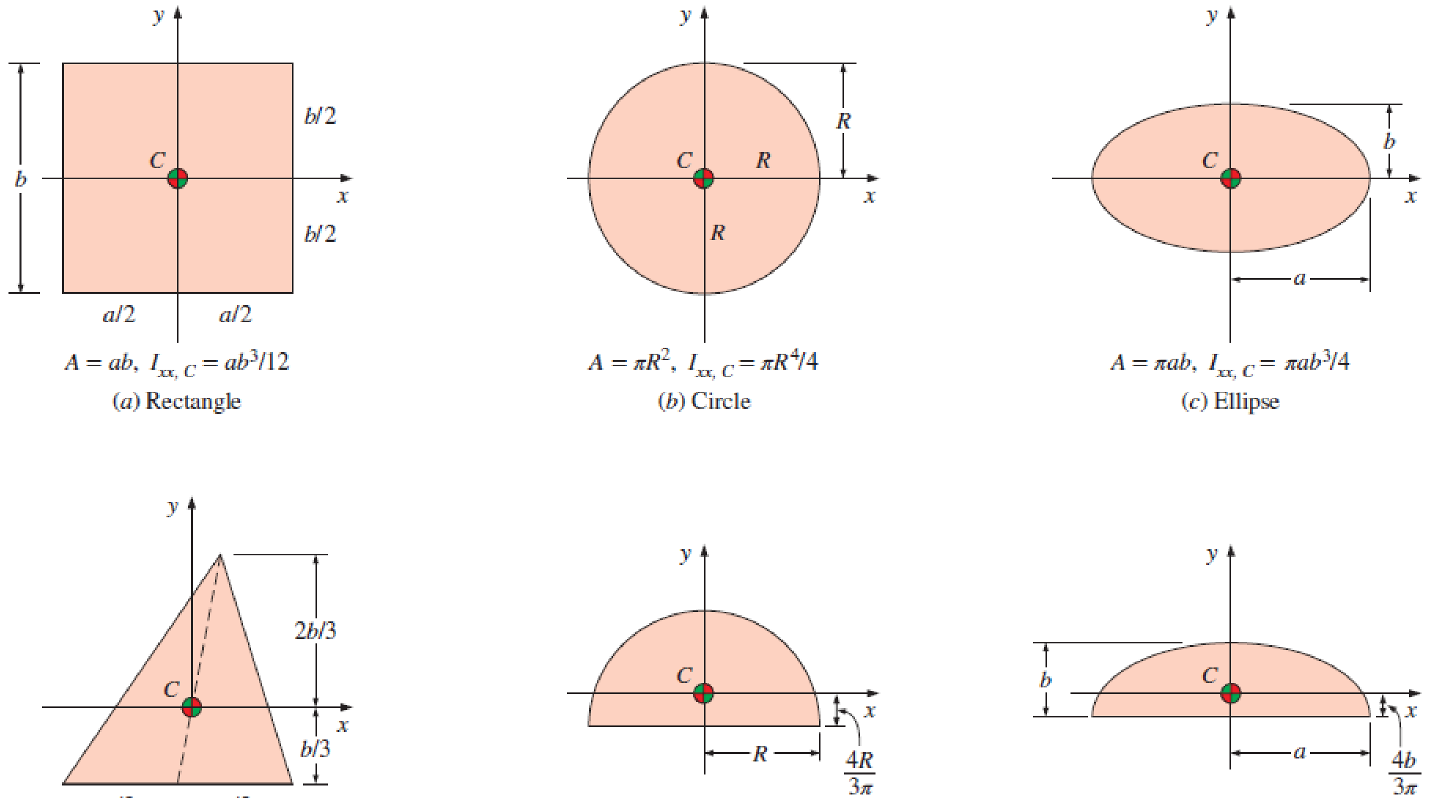
3-4: Hydrostatic Forces on Submerged Plane Surfaces



$A = ab,\ I_{xx,\,C} = ab^3/12$
(a) Rectangle
$A = \pi R^2,\ I_{xx,\,C} = \pi R^4/4$
(b) Circle
$A = \pi ab,\ I_{xx,\,C} = \pi ab^3/4$
(c) Ellipse
$A = ab/2,\ I_{xx,\,C} = ab^3/36$
(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

- The centroid and the centroidal moments of inertia for some common geometries.

- Access the text alternative for slide images.

Insights:

- F = $F = \frac{\rho g W H^2}{2} = \left(\rho g \frac{H}{2}\right)(HW)$
- Or P force evaluated at h=H/2
  - Linear pressure increase
  - Avg = half of line = H/2
  - Centroid = Area-Weighted Avg. Height
- Where does force act?
  - Center of pressure
- For rectangle, H/2 still; other shapes, centroid in book