CE 1102
FUNDAMENTALS OF CIVIL ENGINEERING

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CE 1102 - Fundamentals of Civil Engineering

- Scope of Civil Engineering
- Fluid mechanics, Hydrostatics
- Hydrodynamics
- Flow classification

Week 1-6

- Introduction to structural engineering
- Building construction & materials
- Highway Engineering

RESOURCES

- **Module Descriptor- Available in LMS**
- **Lesson Plan- Available in LMS**
- **Suggested list of further readings-Available in LMS**
- **Each week Lecture notes- Will be uploaded to LMS before the each week lecture**
- **Lecture recordings for each week- Will be uploaded to LMS after the each week lecture**
- **Any other specific learning materials will be uploaded to the LMS in each week**

Learning Outcomes

LO2: Estimate the stability of floating bodies and energy associated in moving fluids

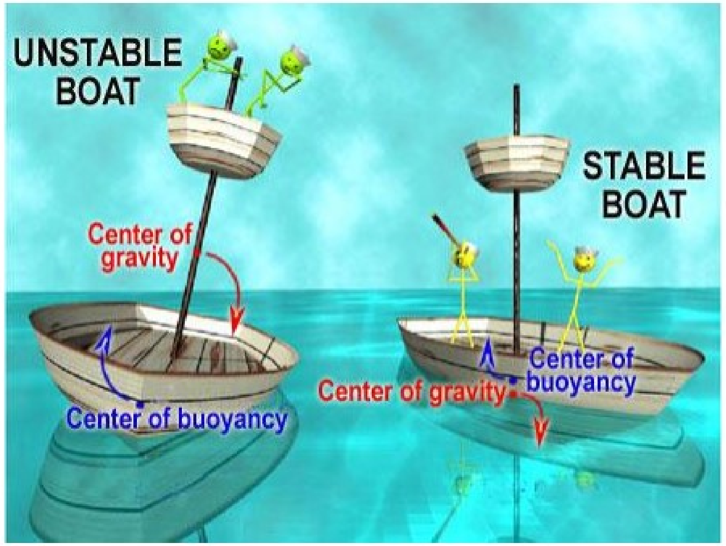
This LO will be covered from Chapter 2, Chapter 3 and Chapter 4

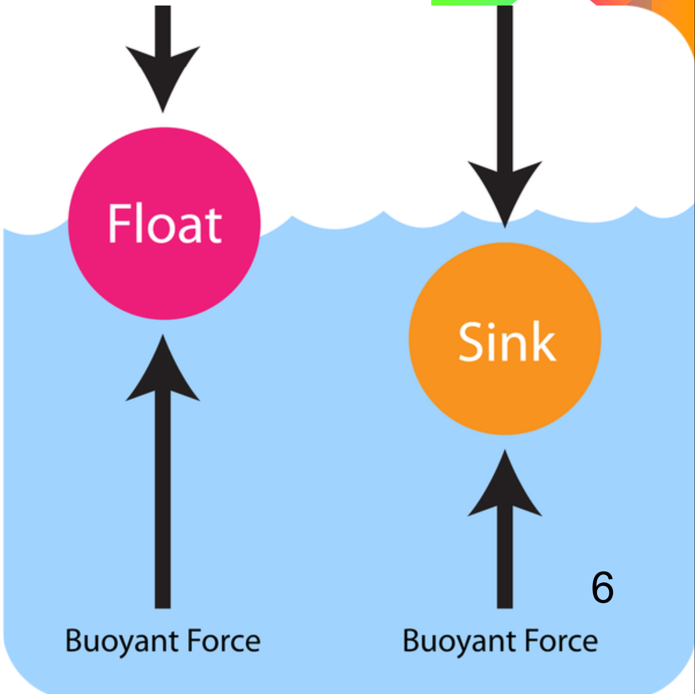
Chapter 2: Fluid mechanics, Hydrostatics
Chapter 2-Part 1- Introduction to Fluid Mechanics and Hydrostatics,
Chapter 2-Part 2- Properties of Fluid
Chapter 2-Part 3-Buoyancy – Stability of Floating Bodies, Metacentre

Chapter 3: Hydrodynamics: Applications of Bernoulli's Equation
Momentum Equation

Chapter 4: Flow classification: Laminar and turbulent flow

Chapter 2: Part 3- Buoyancy, Floatation and Stability





Archimedes' Principle

When a stationary body is completely submerged in a fluid (such as hot air balloon), or floating so that it is only partially submerged (Such as ships), the resultant fluid force acting on the body is called the **buoyant force**.

Archimedes' principle states that the buoyant force has a magnitude equal to the weight of the fluid displaced by the body and is directed vertically upward.

Buoyancy

- Objects feel lighter when submerged in a liquid
- You could use a spring scale to prove this
- This implies that an upward force is exerted by the fluid on the immersed body
- This force is called the **buoyant force, F_B**

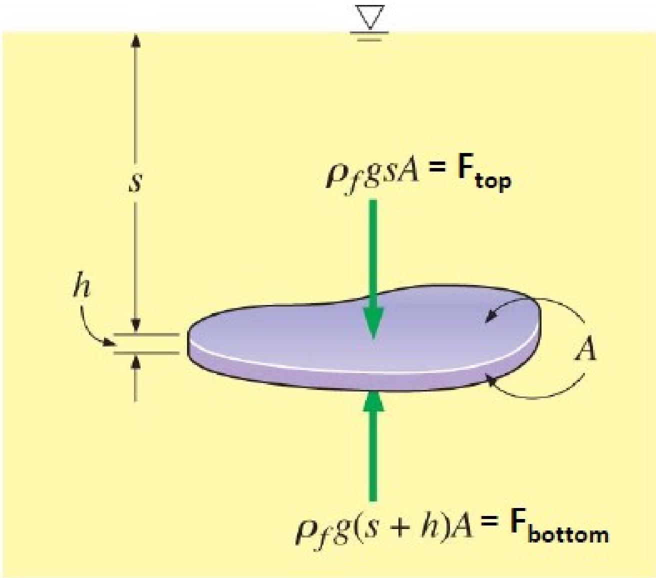
Buoyancy

- Also known as up thrust, is an upward force exerted by a fluid that opposes the weight of an immersed object.

❖Examples of civil engineering applications; **oil rigs, pontoons and transportation by water**

Buoyancy

- Consider the flat plate
- It has thickness, h, and a constant area, A, on the top and bottom.
- The top surface is a distance, s, from the free surface.
- The difference is a net upward force, the **buoyant force**

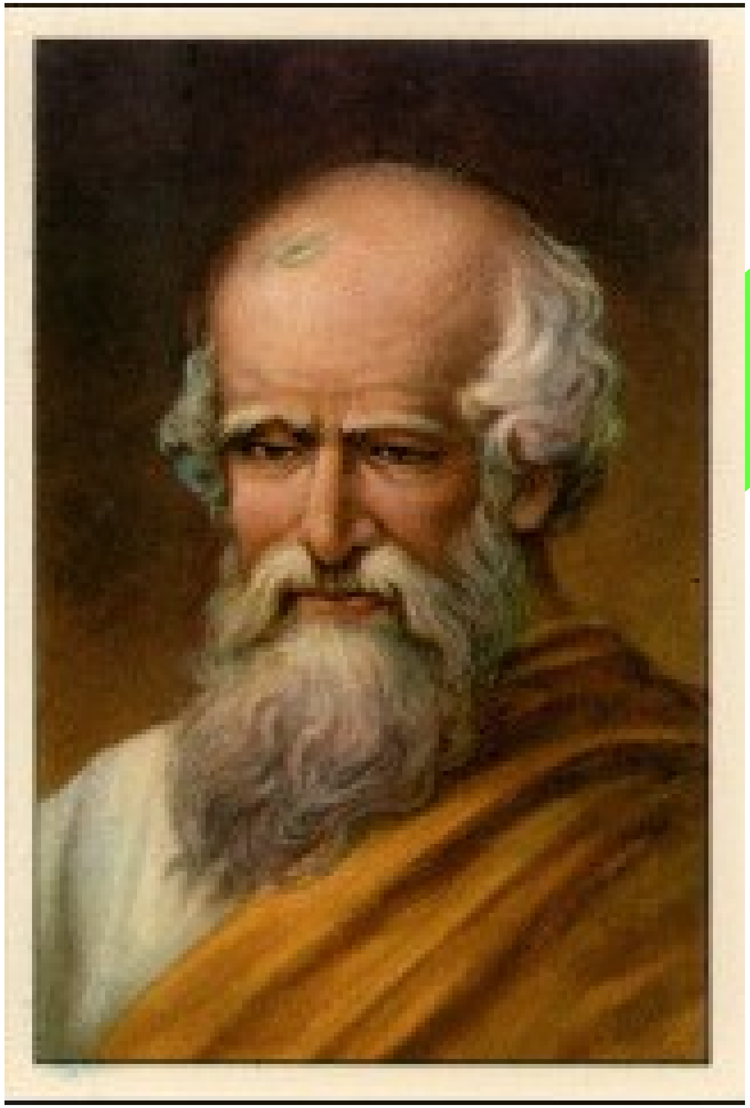


$$\boxed{F_B = F_{bottom} - F_{top} = \rho_f g(s+h)A - \rho_f gsA = \rho_f ghA = \rho_f gV}$$

the buoyant force ($F_B=\rho_f gV$) acting on the plate is equal to the weight of the liquid displaced by the plate

□ NOTE 1: the buoyant force does not rely on the distance from the free surface
□ NOTE 2: the density of the solid body is not a factor

This result is commonly referred to as ***Archimedes' principle in honor of Archimedes 1287–212 B.C.2, a Greek mechanician and mathematician*** who first enunciated the basic ideas associated with hydrostatics.



Buoyancy – Floating Bodies

The weight of the entire body must be equal to the buoyant force

$$W_{body} = F_B$$

which is the weight of the fluid whose volume is equal to the volume of the submerged portion of the body

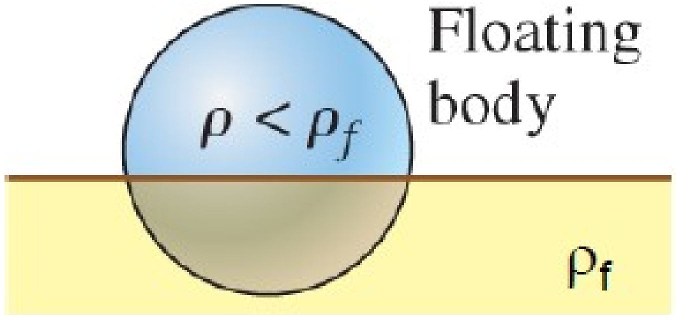
$$\boxed{W_{body} = \rho_{body} g V_{total}} \quad \text{and} \quad \boxed{F_B = \rho_f g V_{submerged}}$$

$$\rho_{body} g V_{total} = \rho_f g V_{submerged}$$

$$\rho_{body} V_{total} = \rho_f V_{submerged}$$

Buoyancy

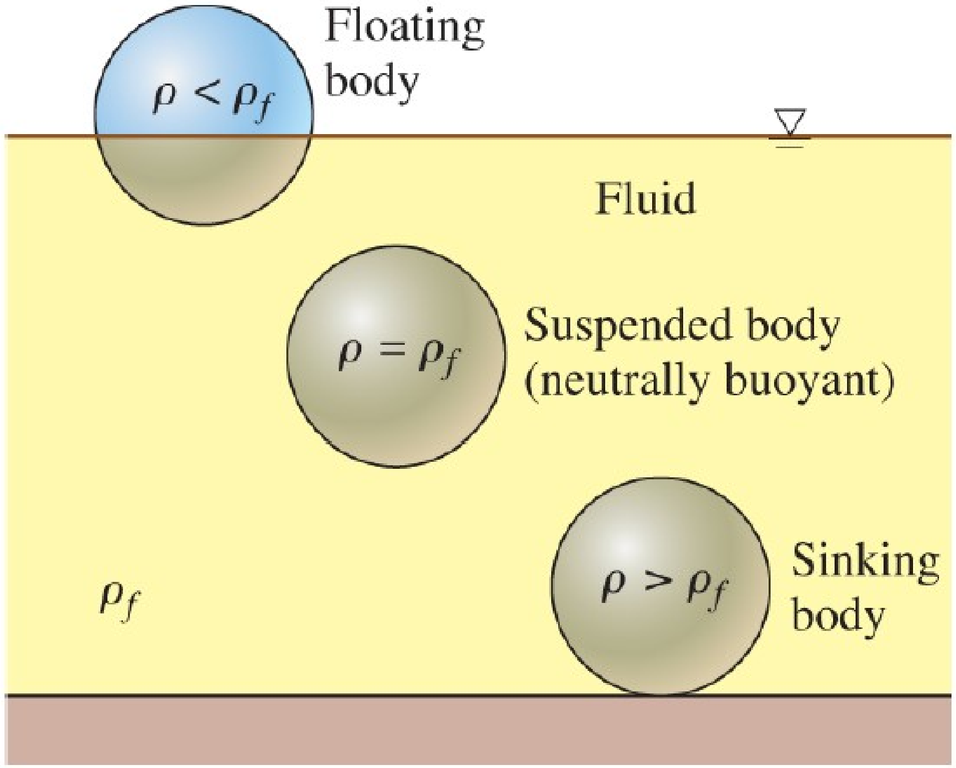
$$\boxed{\frac{V_{submerged}}{V_{total}} = \frac{\rho_{body}}{\rho_f}}$$



Buoyancy

The buoyancy force FB is equal only to the displaced volume, $\rho_f g V_{displaced}$

submerged means the same as displaced



Three scenarios are possible

$\rho_{body} < \rho_{fluid}$: Floating body
$\rho_{body} = \rho_{fluid}$: Neutrally buoyant
$\rho_{body} > \rho_{fluid}$: Sinking body

Example: Floating Dry dock

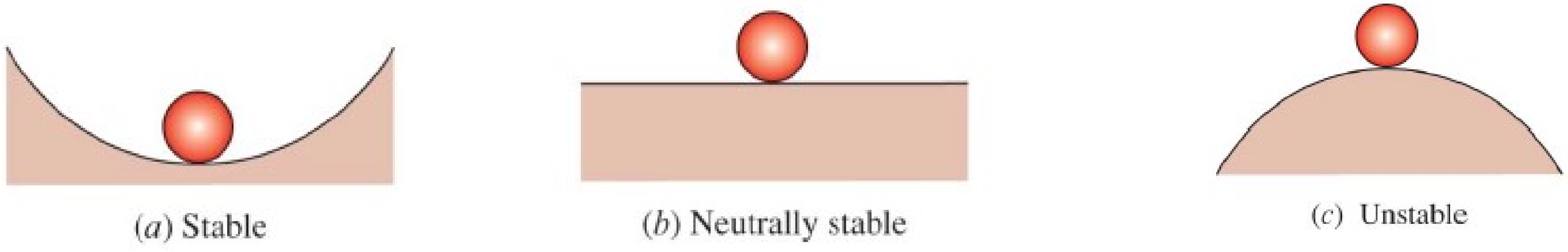
Auxiliary Floating Dry Dock Resolute (AFDM-10) partially submerged

Submarine undergoing repair work on board the AFDM-10

Using buoyancy, a submarine with a displacement of 6,000 tons can be lifted!

Stability of Bodies

- Buoyancy alone is often not enough, consider ships or submarines, they also need to be stable
- Think of a ball on different surfaces as examples
- Immersed or floating bodies in static equilibrium have a weight force balanced by a buoyant force and are stable in the vertical direction
- If a neutrally buoyant body is moved, it will equalise at that point
- Floating body raised / lowered will return to original position
- Floating body – vertical stability
- Neutrally buoyant body – neutral stability



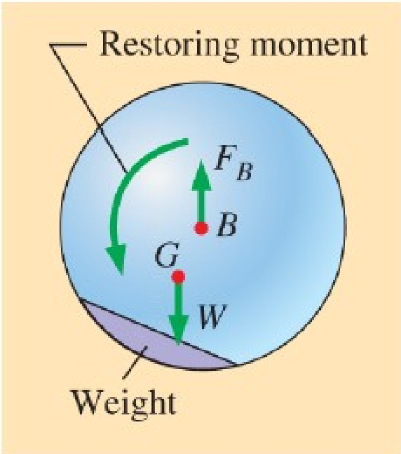
Stability of Immersed Bodies

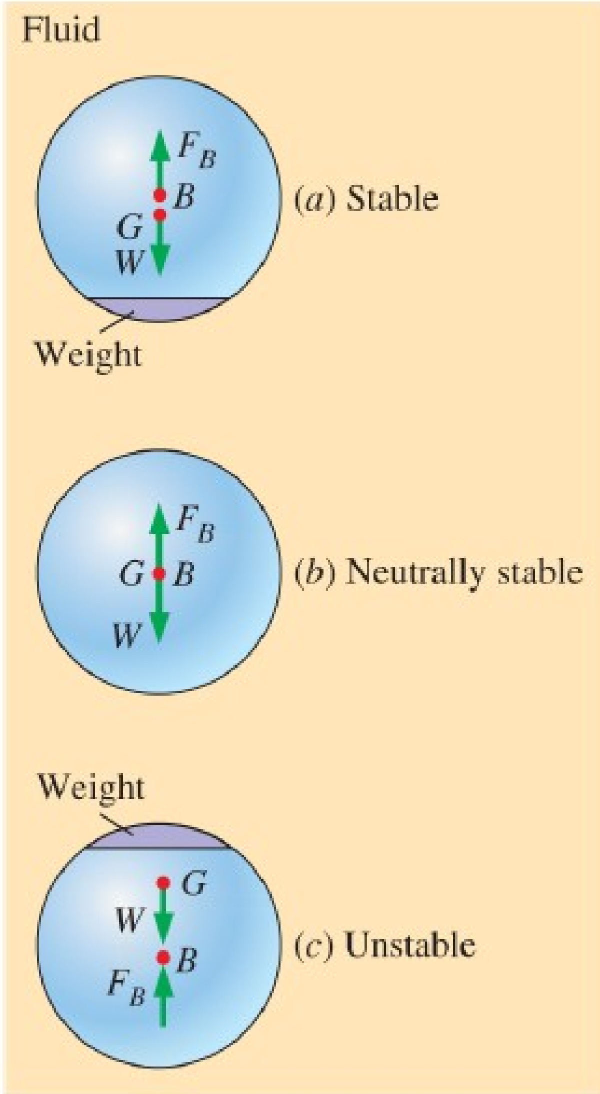
The rotational stability of immersed bodies depends upon the relative location of the centre of gravity G and centre of buoyancy B.

G below B: stable
G coincides with B: neutrally stable.
G above B: unstable

The centre of buoyancy, B, is the centroid of the displaced volume

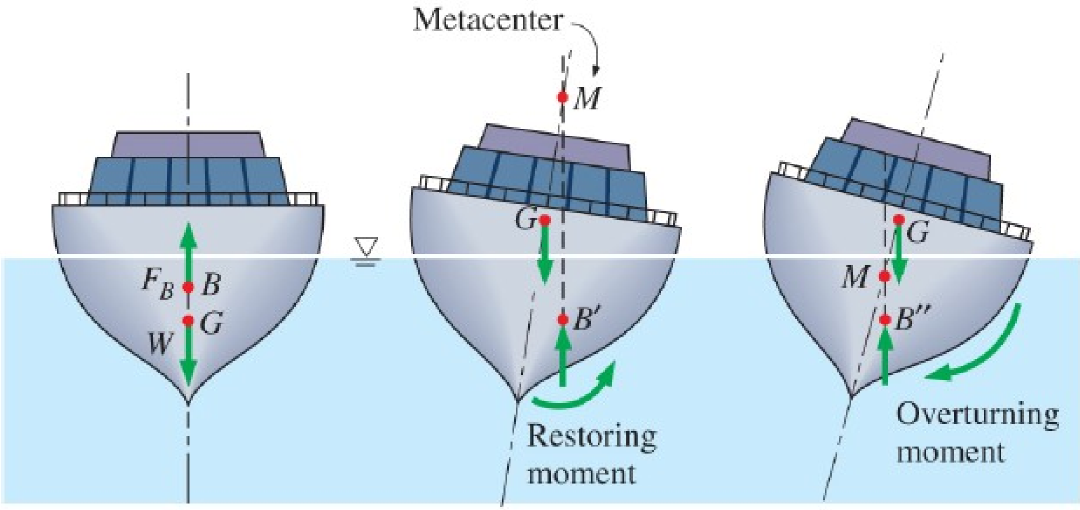
Rotational disturbance





Submarine: engines and crew quarters at the bottom
Hot air balloon: basket is at the bottom

Stability of Floating Bodies



(a) Stable (b) Stable (c) Unstable

❖ **If body is bottom heavy (*G lower than B*), it is always stable.**

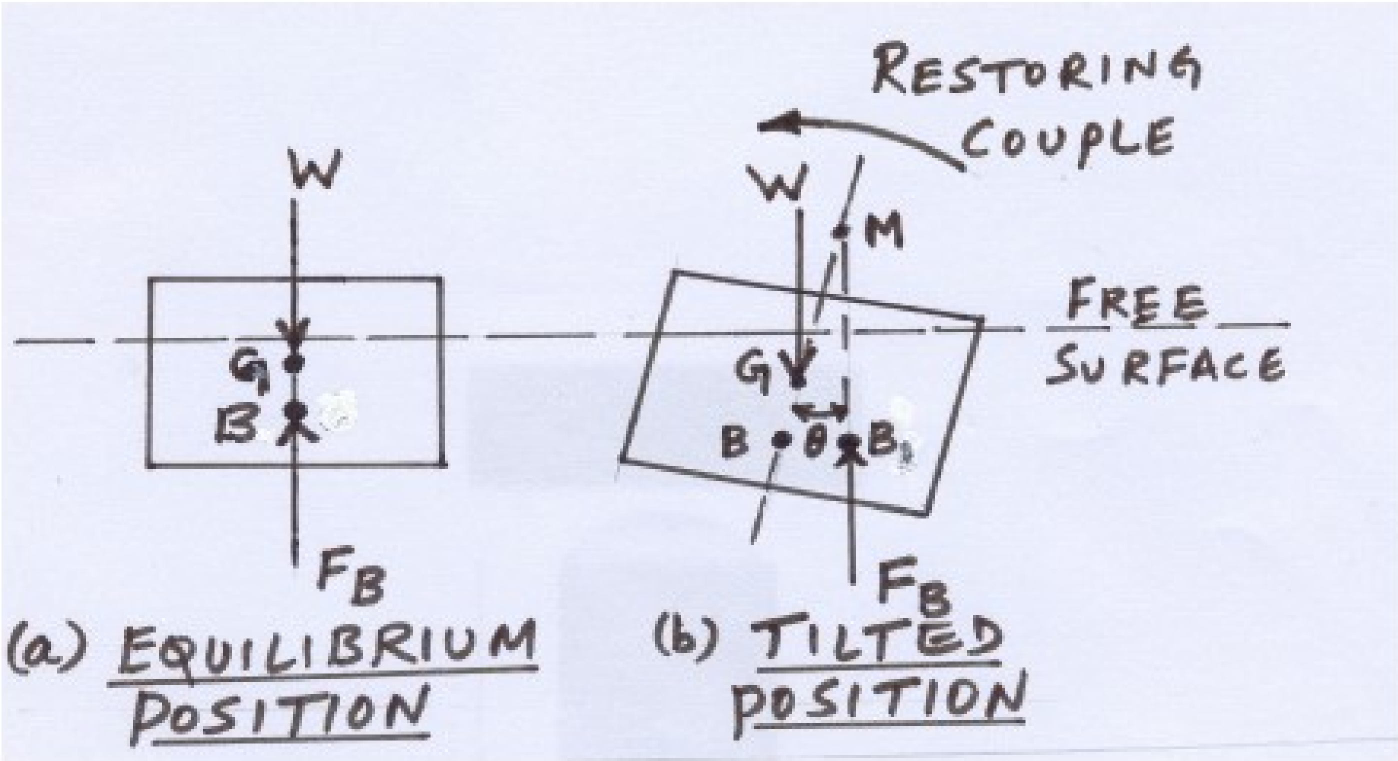
❖ Floating bodies can be stable **when G is higher than B due** *to* shift in location of centre buoyancy and creation of restoring moment.

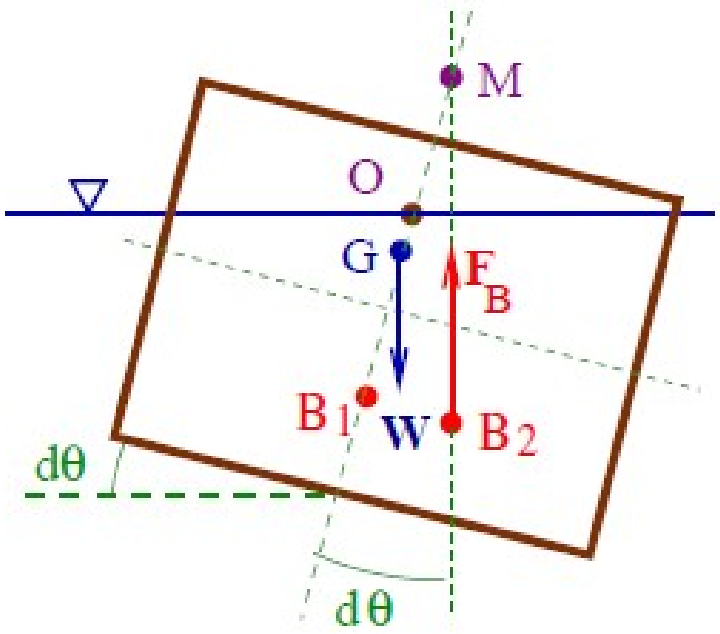
❖ Measure of stability is the metacentric height *GM.* **The larger the length of GM, the more stable the ship is (if M above G).**

G – centre of gravity
B – centre of buoyancy
M - metacenter

Floating bodies: Terminology

Consider a floating body given a small angular deflection. The magnitude of the buoyancy force will stay the same, (weight force does not change) but the location of the centre of buoyancy changes.





Metacenter (M) : The point of intersection between the original line of action and new line of action of the buoyancy force

O = Waterline point about which boat rolls.

B_1 = original buoyancy point.

B_2 = buoyancy point after displacement.

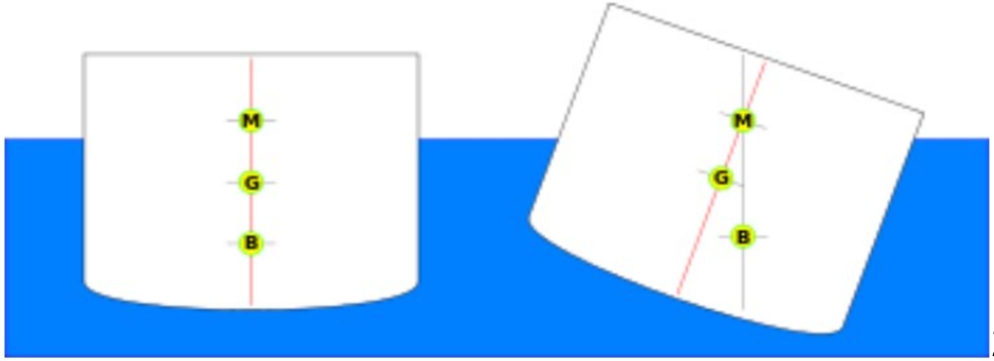
The line of action of the original buoyancy force (through the center of gravity) and new buoyancy force intersect at the metacenter.

The center of gravity (G) moves as mass is added or removed, so the **metacentric height (GM)** changes as mass is added or removed.

If [M] is above [G], the Restoring Couple acts on the body in its displaced position and tends to turn the body to the original position - **Floating body is in stable equilibrium.**

If [M] were below [G], the couple would be an Over-turning Couple and the body would be in **Unstable Equilibrium**.

If [M] coincides with [G], the body will assume a new position without any further movement and thus will be in **Neutral Equilibrium.**



$$\boxed{GM = BM - BG}$$

BM = [Second moment of the area of the plane of flotation about the centroidal axis perpendicular to the plane of rotation / Immersed Volume]

$$\boxed{BM = (I_{YY} / V)}$$

- I_{YY} is the moment of inertia of the floating object about the longitudinal axis
- V=volume of liquid displaced by the object,

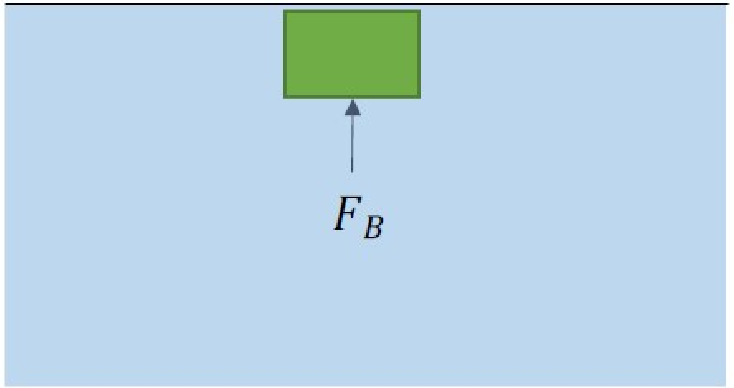
$$\boxed{I = \frac{Lb^3}{12}}$$

Positive Stability (GM) > 0 i.e. the metacenter lies above the center of gravity.
Negative Stability (GM) < 0 , i.e. the metacenter lies below the center of gravity.
Neutral stability occurs when GM = 0 , i.e. the metacenter coincides with the center of gravity.

Example 1

What is the buoyant force on a 0.3 m^3 box which is fully submerged in freshwater (density = 1000 kg/m^3)?

Solution:



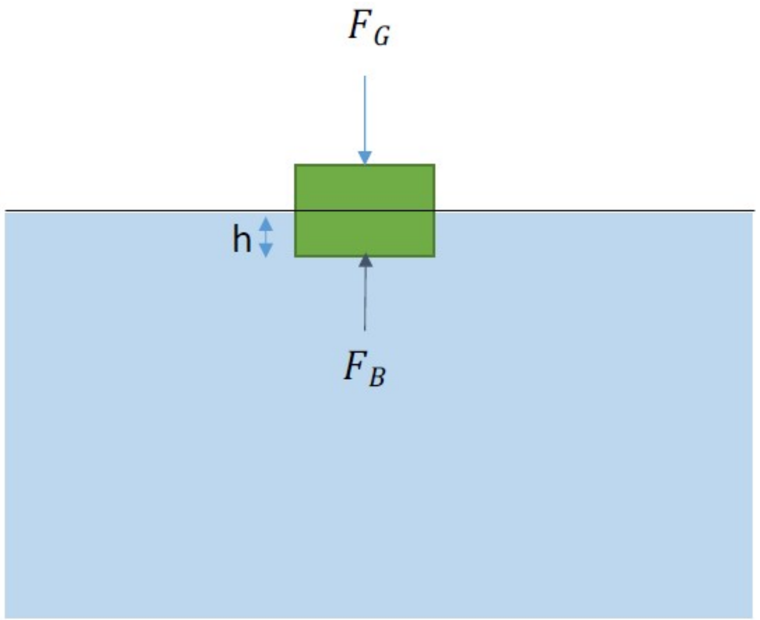
$$F_B = \rho_{fluid} V g$$

$$= (1000\ \text{kg/m}^3)(0.3\ \text{m}^3)(9.81\ \text{m/s}^2)$$

$$= \underline{2940\ \text{N}}$$

Example 2

A rectangular boat made out of concrete with a mass of 3000 kg floats on a freshwater lake (ρ = 1000 kg/m³). If the bottom area of the boat is 6 m², how much of the boat is submerged?



$$F_B = F_G$$

$$= mg$$

$$\rho_{fluid} V g = mg$$

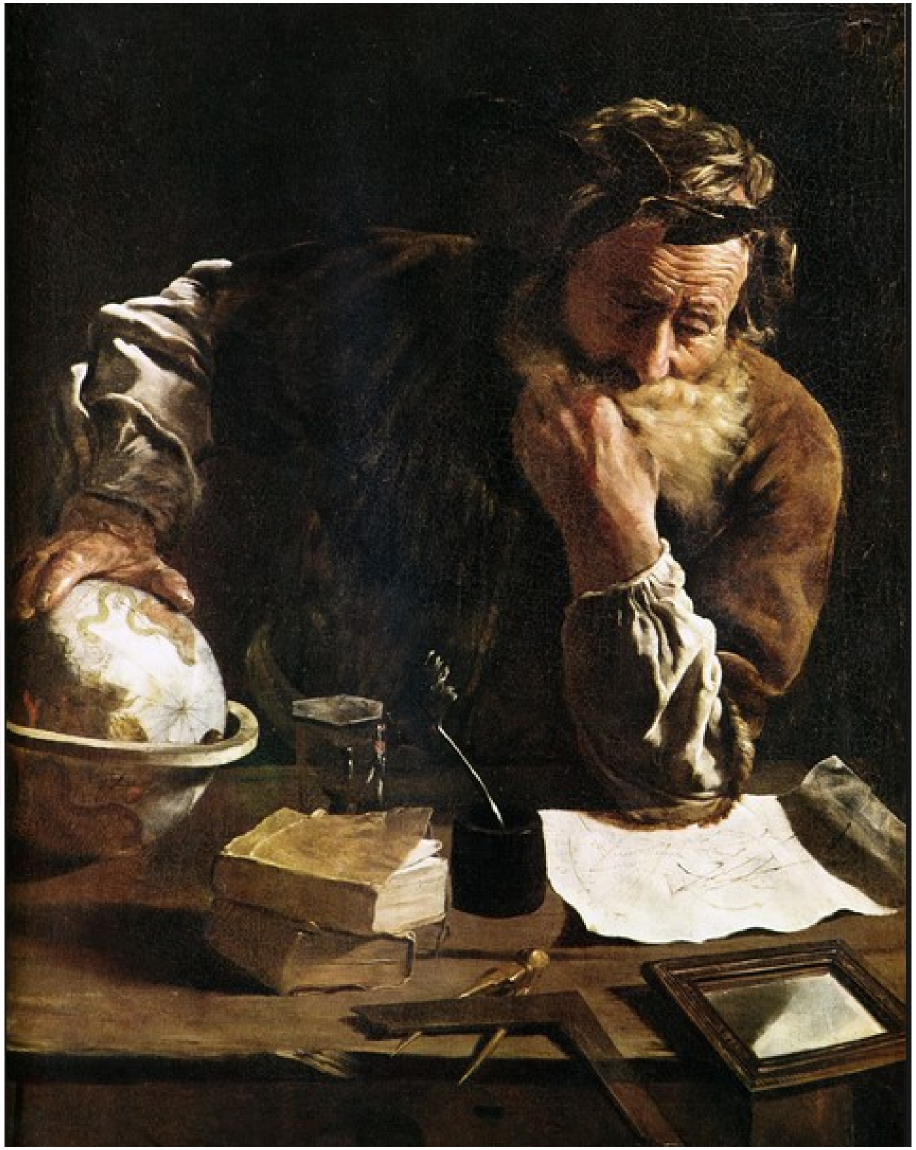
$$\rho_{fluid} (Ah) g = mg$$

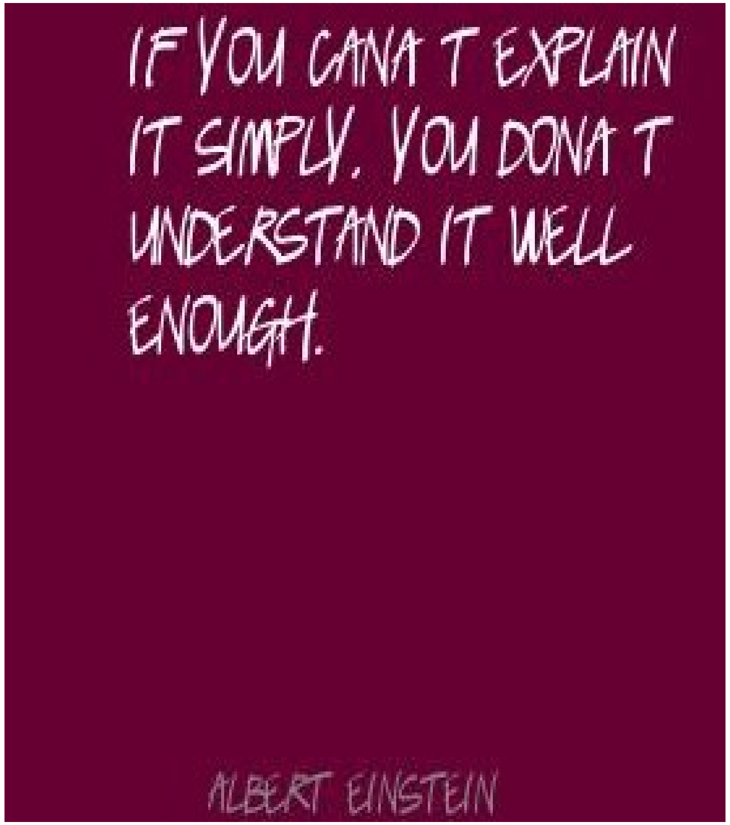
$$h = \frac{m}{\rho_{fluid} A} = \frac{3000\ kg}{(1000\frac{kg}{m^3})(6\ m^2)} = \underline{\mathbf{0.5\ m}}$$

Summary

Covered Chapter 2-Part 3- End of Chapter 2

- ❖ Buoyancy definition
- ❖ Stability of Bodies
- ❖ Stability of Floating Bodies
- ❖ Metacenter
- ❖ Problem solving (VERY IMPORTANT)




IF YOU CANA T EXPLAIN
IT SIMPLY. YOU DONA T
UNDERSTAND IT WELL
ENOUGH.
ALBERT EINSTEIN


SEE YOU
next week
Have a Great Week!