VII: Buoyancy and Buoyant Force

1: Buoyancy

- The phenomenon that keeps a body swim or suspended is known as Buoyancy.
- The force a fluid exerts on a body immersed is known as Buoyant Force(F_B)

2: Buoyant Force

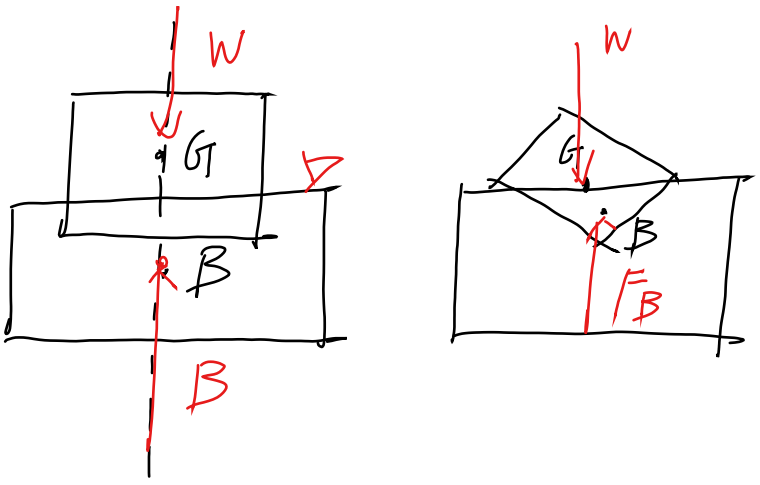
- According to the 2^{nd} law of hydrostatic: Pressure in a fluid at rest is constant over any surface normal to the field of a body force.
- The resultant horizontal force has been canceled out, so the buoyant force acts in the vertical direction.
- The resultant force is the buoyant force acts vertically upward and is equal to the weight of the displaced fluid.
- Archimedes'law:

$$F_B = \rho V g$$

- This formula can be induced by calculating the resultant force of the both sides of a submerged project.

3: Floating body

- For a floating body, its weight is equal to the buoyant force.
- $W = m_{floatingbody}g$
- $F_B = m_{displacedliquid}g$
- $W = F_B$
- i.e.$m_{floatingbody} = m_{displacedfluid}$

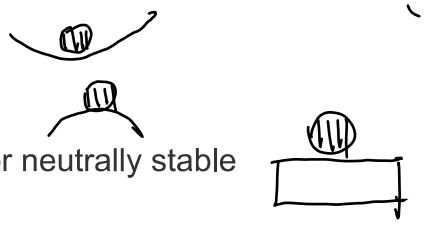


VIII: Stability

1: Stability

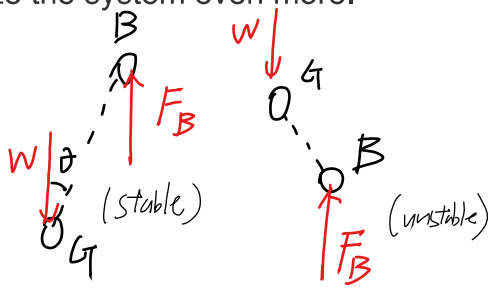
- The buoyant force acts through the centroid of the displaced fluid volume.
- The point B is called the centre of the buoyancy.

- For equilibrium body, there is no moments.
- If the F and W are not in the same line, there will be a rotational moment.
- According to the action of the moment, the types of the equilibrium can be distinguished into 3 parts:
  - Stable
  - Unstable
  - Neutral or neutrally stable



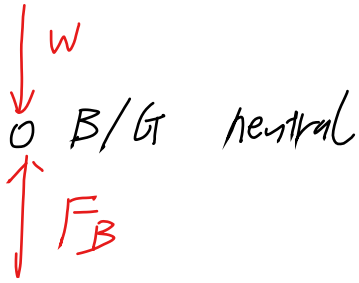
2: Submerged Bodies

- For wholly immersed body, the condition for stable equilibrium is that G is under the B.
- If the weight and buoyant force isn not in the same line, then they produce rotational momentum.
  - If G is blow B,the momentum tends to restore stability.
  - If B is below G then the resultant momentum tends to destabilize the system even more.
  - If the G and B coincide then neutral stability is obtained.



3: Stability of the submerged bodies

- When B is above the G, the body is in the equilibrium of the stable.
  - The stable equilibrium case has a righting couple, namely $W \times BG \times \sin\theta$ (anti-clockwise),which si try to restore the tilt(clockwise).
- When B is below G, the body is in unstable equilibrium.
  - The case of unstable equilibrium the couple (anticlockwise) tends to increase the angle of tilt.(anti-clockwise).
- If the B and G are coincident then body is in neutral equilibrium.



4: Floating Bodies

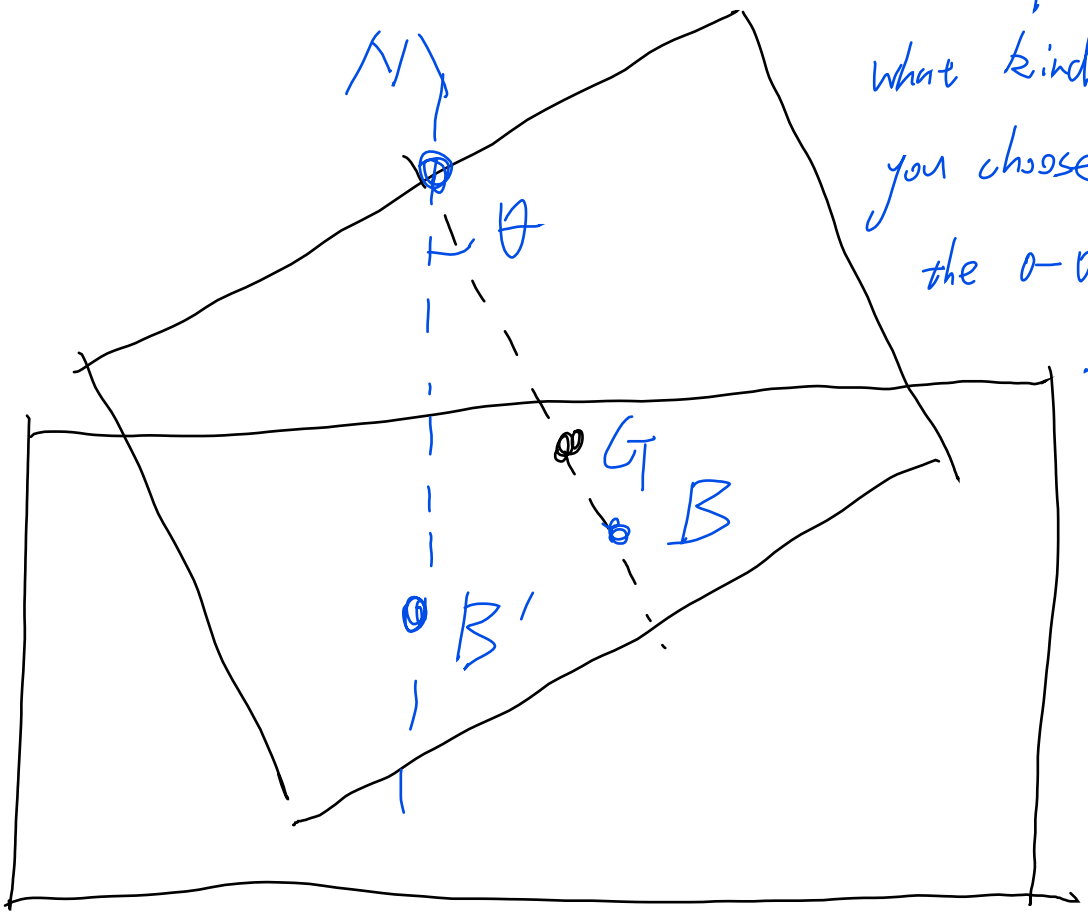
- It is not necessary that G is under the B.
- The body undergoes an angular displacement will change the immersed volume so that change the buoyancy (B).
- The new centre of B is $B\prime$ and the new buoyant force is $F_B\prime$.
- We define the metacenter as the point where a vertical through the new centre of buoyancy intersects the continuation of the line BG.
- The distance between the metacenter (M)and centroid (G) is called the metacenter height.
- If the V is he volume of displaced liquid and $\overline{MB}$ is the distance of MB, I is the second order moment of area of the water line:

$$\overline{MB} = \frac{I}{V}$$

$$\overline{MG} = \overline{MB} \pm \overline{GB} = \frac{I}{V}\overline{GB}$$

- Minus if G is above B and Plus if G is below B.

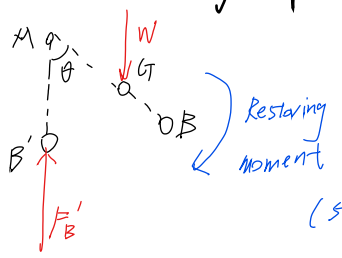
I depends on what kind of axis you choose, normally the o-o, sometimes x-x or y-y.



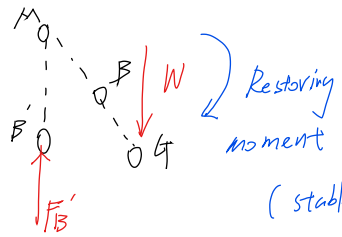
$$\overline{MG} = \frac{I}{V} + \overline{GB} \quad (G \text{ is below } B)$$

$$\overline{MG} = \frac{I}{V} - \overline{GB} \quad (G \text{ is above } B)$$

- The stability of floating bodies

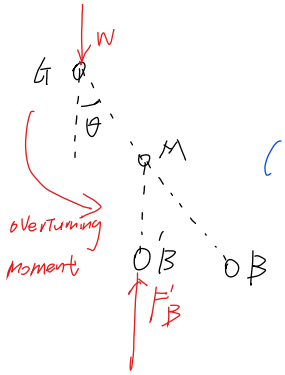


(stable case)



(stable case)

- For stability of floating bodies, the metacentric height has to be positive (M has to above the G)



(unstable case)

- The restoring moment

$= W \cdot \overline{MG} \cdot \sin\theta$

if it is minus, it 'll become the overturning moment