PROJECT REPORT

ME303 THERMO – FLUID LAB

- Study of Metacenter and Metacentric Height
- Design of Floating Body with Adjustable Volume Fraction Underwater

By Group Monday G4

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Part 1 : Metacentre and Metacentric Height

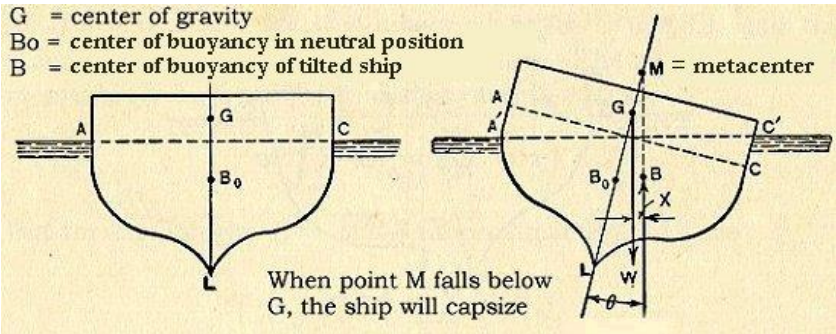
1. Introduction

This experiment investigates the stability of floating bodies by examining buoyancy, the metacenter, metacentric height, and the center of gravity. These parameters are essential in determining whether a body will remain stable or become unstable when subjected to external forces or disturbances. The results provide insights into how design adjustments impact stability, which is crucial in marine and civil engineering applications.

2. Objectives

- To understand the concept of buoyancy and its role in the stability of floating bodies.
- To measure and locate the metacentre (M) and centre of gravity (G) of a floating body.
- To calculate the metacentric height (GM) and determine its influence on stability.

3. Theoretical Background



Buoyancy: According to Archimedes' Principle, a floating body displaces a volume of water equal to its submerged volume, resulting in an upward buoyant force equal to the weight of the displaced water.

Metacenter (M): The metacenter is the point where the line of action of the buoyant force intersects the centerline of the body when it tilts. As the body tilts, the buoyant force shifts, and the metacenter's location helps determine stability.

Metacentric Height (GM): The metacentric height is the distance between the center of gravity (G) and the metacenter (M). It is a key parameter for stability.

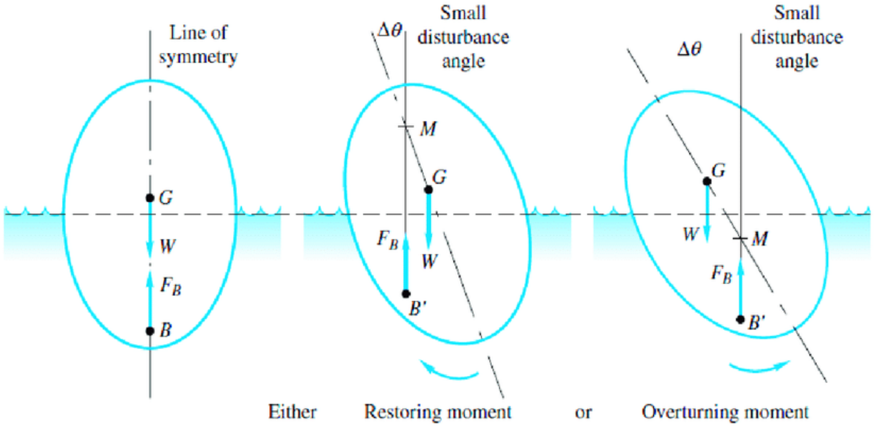
Positive GM (M above G) indicates stability.

Negative GM (M below G) suggests instability.

Center of Gravity (G): The center of gravity is the point where the body's mass is considered to be concentrated. It influences how the body reacts to external forces and tilting.

4. Experimental Setup and Procedure

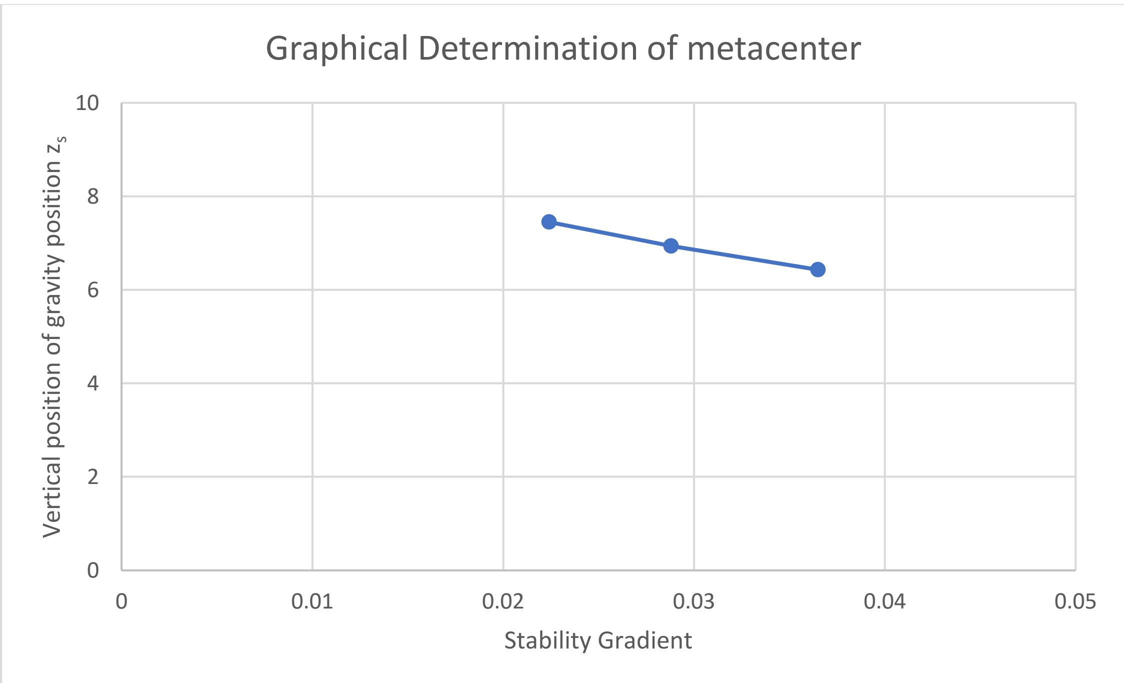
- A model floating body was used, along with equipment to measure tilting angles and calculate the metacentric height.
- Determine the Center of Gravity: The body was initially weighted to identify G's location. Adjustments were made to measure the effect of different mass distributions on G.
- Tilt Experiment: The body was gradually tilted, and measurements were taken at various angles to observe changes in the buoyant force's line of action and the position of M.
- Calculation of Metacentric Height: Using the tilt data, the metacentric height GM was calculated from the distance between G and M.



5. Observations and Results

Position of Horizontal sliding weight x = 8 cm			
Height of Vertical Sliding Weight z	3 cm	6cm	9cm
Angle α	12.5°	16°	20.5°

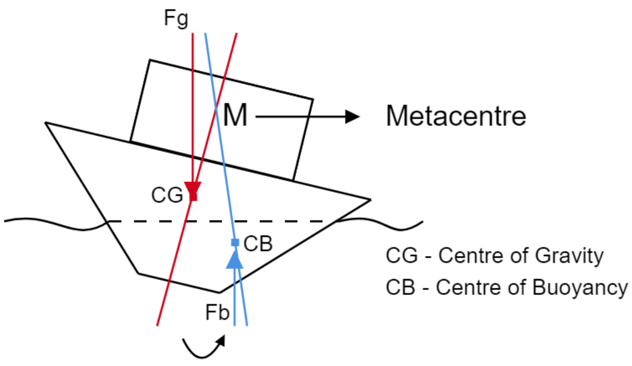
Horizontal Position of Centre of gravity x_s= 0.46 cm			
Height of vertical sliding weight z	3cm	6cm	9cm
Centre of Gravity position z_s	6.43 cm	6.94 cm	7.45 cm
Angle α	12.5°	16°	20.5°
$\frac{dx_s}{d\alpha}$	0.0368	0.0288	0.0224



6. Analysis

Stable Condition: When M was above G, any tilting motion caused the buoyant force to act as a restoring force, pushing the body back to equilibrium. The positive metacentric height reinforced stability, preventing capsizing.

Unstable Condition: In configurations where G was above M, the buoyant force acted in a direction that increased tilting, leading to a higher risk of capsizing. This is a characteristic of negative GM and is undesirable in practical applications.



7. Conclusion

This experiment demonstrated the crucial role of the metacentric height in determining the stability of floating bodies. By maintaining a positive GM, the floating body remained stable under small disturbances, proving that a higher metacenter relative to the center of gravity promotes stability. The findings underline the importance of strategic weight distribution and design considerations to enhance the stability of floating structures.

PART 2A : Design of Floating Body with Adjustable Volume Fraction Underwater

INTRODUCTION :

This project demonstrates the design and functionality of a floating body capable of maintaining a specified fraction of its volume submerged in water, with an adjustable submersion level that can be altered at any point during the experiment. The floating body is engineered to allow precise control of buoyancy through a dual-pump system that adjusts water levels within the body's hollow compartment. This setup enables real-time modifications in submersion, showcasing potential applications in marine devices and research equipment where buoyancy control is essential. Results from testing confirmed that the design meets stability requirements across various submersion levels, providing insights for further applications in controlled buoyancy systems.

Objective

- To design a floating body with adjustable buoyancy, allowing a specified fraction of its volume to remain submerged, with real-time adjustment capability. This design has applications in underwater monitoring, marine biology, and remote sensing.
- This experiment designs a prototype that can submerge between 10% and 90% of its volume, with real-time adjustment via a water-pumping system, ensuring stability across submersion levels in still water.

Background

Buoyancy, governed by Archimedes' Principle, is the upward force exerted by a fluid that opposes the weight of a submerged object. The extent to which an object floats or sinks depends on the balance between its weight and the displaced water's buoyant force. This project applies these principles to design a floating body with adjustable buoyancy through controlled water intake and drainage.

Design and Methodology

- **Materials and Components**:
  - **Floating Body**: Constructed from lightweight, waterproof materials to ensure durability and buoyancy. A hollow internal compartment allows for water intake.
  - **Pumps**: Two small pumps were used for controlling water levels within the body, one for water intake and the other for draining.

    Floating Body Material-
    - **PVC Pipe** – Length = 27 cm, Diameter = 16 cm
    - **Acrylic sheets** – 2 circular acrylic sheets of dia = 16cm
    - **Aradlite Adhesive** – For joining the sheets and other components

    Pumps used –

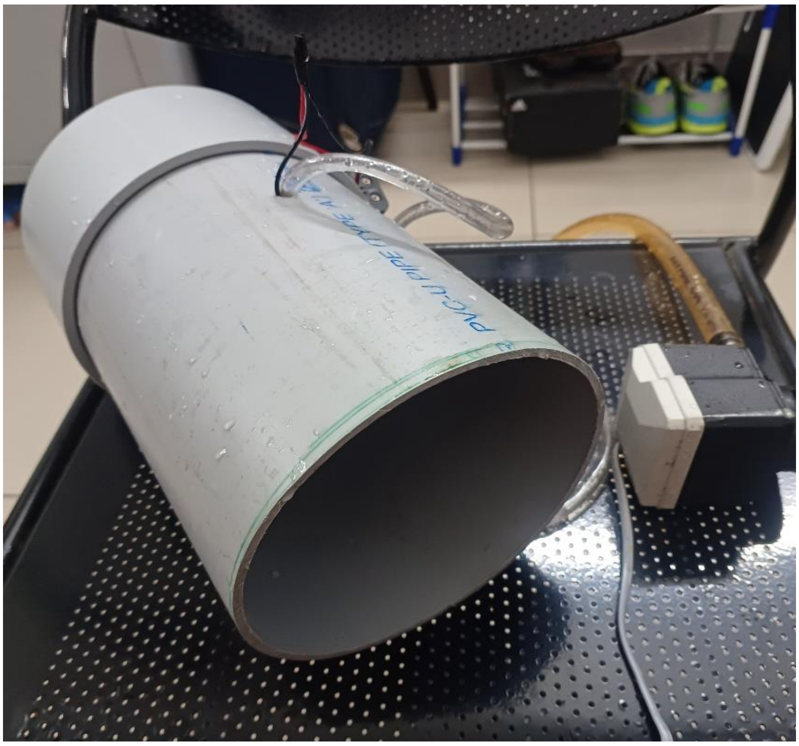
    Two pumps used
    - **Water inlet pump**
    - **Water outlet pump**

- **Design Considerations**:
  - **Buoyancy Control**: The floating body is designed to maintain equilibrium with an adjustable amount of water within, allowing control over the fraction of volume submerged.

- **Structure and Stability**: The design maintains low centre of gravity and balanced mass distribution to prevent tilting or instability during submersion adjustments.

- **Body specifications**
  Volume of the cylindrical body **= pi * R^2 * L**
  So, Volume **= 3.14 *.08*.08*.27 = .0054 m^3 = 5.4 lt**
  Density of pvc material = 1330 kg/m^3

- **Mechanism for Adjusting Submersion**:
  - **Water Intake and Drainage**: Water intake increases the submersion level, and drainage reduces it. The system is manually regulated by a to initiate the appropriate pump based on the target submersion fraction.
- **Control Mechanism**:
  - The control system uses a user interface to specify target submersion fractions. We are manually giving the input and activates the pumps to adjust the water volume in the floating body until the target is reached.



Experiment Setup and Procedure

- **Setup**: The experiment was conducted in a controlled water tank. The floating body was placed in the water, and manual controls were set up to operate the pumps for water intake and drainage.
- **Procedure**:
  Cylinder Filling and Emptying Timings Analysis
  To understand the dynamics of filling and emptying a cylindrical structure, we analyzed the time taken for the cylinder to reach specific fractions of its volume capacity. These times provide insights into the efficiency of the system at different levels of submersion or drainage, potentially assisting in optimizing control mechanisms for similar setups.

1. **Cylinder Filling Timings**
   The filling process was observed at incremental volume capacities. Each percentage represents the submerged portion relative to the cylinder's full diameter. The recorded times are as follows:

Fraction of Diameter(P)	**Submerged level (%)**	**Time Taken(sec)**
25	25	6
50	50	9.12
75	75	6.17
100	100	2.71

   These timings indicate a nonlinear filling pattern, with time intervals increasing till 50% then decreases as the cylinder approaches full capacity. This may be due to the pressure dynamics or other resistances that impact flow as the cylinder fills.

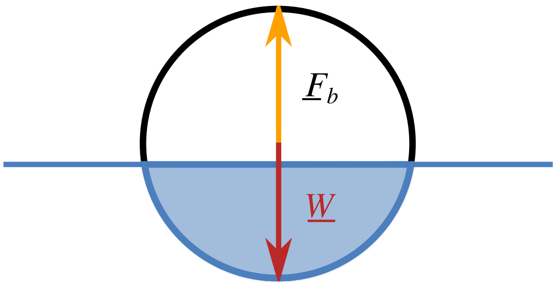
2. **Cylinder Emptying Timings**

The emptying process was timed as the cylinder's water level dropped through similar volume capacities. Here, each entry reflects the time taken to reach a specific fraction of remaining capacity:

Initial Submerged level (%)	**Final Submerged Level (%)**	**Time Taken (sec)**
100	75	60
75	50	70
50	25	85
25	2.5 cm from bottom	45

The emptying pattern shows a gradual increase in the time required to lower the water level, likely due to similar flow dynamics impacting discharge efficiency.

3. **Buoyancy Force Calculations** –



Volume of Fluid Displaced = V =πh^2(3R−h)/3

where h is the height of the submerged part of the sphere, and R is the radius of the sphere.

Weight of Displaced Fluid = Wf = ρVg

density ρ of the fluid and gravitational acceleration g.

The buoyant force Fb is equal to the weight of the displaced fluid:

The Buoyant Force = Fb = Wf = ρVg

The weight of the acrylic PVC pipe is approximately 4.40 Newtons. To float due to its weight, it will need to displace about 448.61 cm^3 of water, which corresponds to the partially submerged volume necessary for equilibrium.

CONCLUSION

This project successfully demonstrated the design and functionality of a floating body capable of maintaining and adjusting its submersion fraction. The ability to dynamically control submersion levels with high precision and stability showcases the potential of this design for applications requiring controlled buoyancy. Future iterations could improve pump efficiency and enhance control accuracy, expanding the design's applicability in marine and research settings.