FLUID MECHANICS WORK PRATICAL

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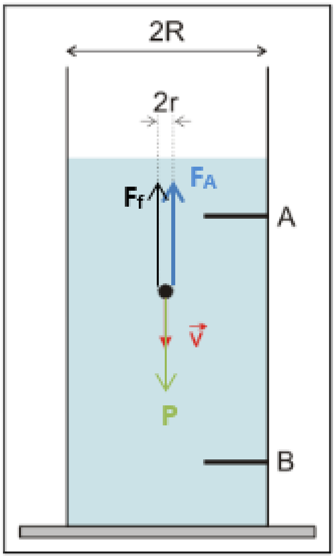
PW-01: Viscosity of a Fluid

I.1.Objectives LW:

The goal of this lab is to apply a classic method for measuring the viscosity of a liquid using a ball viscometer.

I.2. Procedure:

1. **Setup**: Drop a small ball into a viscous fluid (glycerine) contained in a graduated cylinder. The cylinder diameter R is much larger than the ball diameter r (R<<r).
2. **Initial Drop Phase**: As the ball begins to fall, it accelerates due to gravity. We assume that the ball reaches a constant velocity v after passing the first marker A on the cylinder.
3. **Constant Velocity Zone (Between A and B)**: After passing A, the ball falls at a constant speed and its motion is uniform and linear. The sum of forces acting on the ball, namely the buoyant force F_A, the frictional force F_f, and its weight P, is zero ($\sum F=0$).
4. **Measuring Terminal Velocity**: Measure the terminal velocity of the ball by timing its passage between two marked points (A and B) on the cylinder using a stopwatch.
5. **Effect of Ball Size on Viscosity**: To investigate the effect of terminal velocity on viscosity, use balls of different diameters. By comparing the viscosity values calculated with different balls, the consistency and accuracy of the viscosity measurements can be analyzed.



This method allows for calculating the dynamic viscosity of the glycerine by using the known relationship between the forces and the terminal velocity of the ball.

I.2.1. Expression for Dynamic Viscosity:

$$\eta = \frac{2}{9}\frac{g.r^2}{v_{lim}}(\rho_{bille} - \rho_{liq})$$

where:

- **η**: dynamic viscosity of the fluid,

- **v_{lim}**: terminal fall velocity,
- **ρ:**density,
- **r:** radius of the ball.

1. **Measurements and Calculations:**
   Given data:

- Gravitational acceleration g=9.81 m/s^2,
- Liquiddensityd:glycerol = 1.25.
- Ball density d_b=7.8.

The diameters of the steel balls are: r1=1.588 mm, r2=2.381 mm, r3=3.175 mm.

The volume of the ball is given by:

V= $V=4/3\pi r^3$

At 20°C, the dynamic viscosity of glycerol is 1.49.

I.2.2. Conclusion

In this experiment, we successfully measured the dynamic viscosity of a fluid (glycerol) by using the falling ball viscometer method. By observing the terminal velocity of steel balls with varying diameters, we demonstrated how viscosity influences the rate of descent for objects in a viscous medium. Our results showed a consistent relationship between the measured terminal velocities and the calculated viscosity values, validating the theoretical equation. Additionally, the experiment highlighted that larger balls achieve a higher terminal velocity due to increased gravitational force overcoming viscous drag, while smaller balls reached terminal velocity more slowly. Overall, this lab reinforced our understanding of fluid viscosity and demonstrated a practical method for determining this property in various fluids, with good agreement between our measurements and known values for glycerol's viscosity at 20°C

1. **Application:**

Using this formula, the viscosity of glycerol (or the test fluid) can be compared across different ball sizes to evaluate the consistency and accuracy of the results.

Lab Report N°1: Properties of Fluids

Experiment N°1: Free Surface of a Liquid at Rest

I.3. Objective of the Lab:

(Describe the purpose of the experiment, such as understanding the behavior of liquids at rest and the concept of hydrostatic pressure.)

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I.3.1. Observations:

(Note the observations made during the experiment, such as the characteristics of the liquid surface and any phenomena observed when the liquid is disturbed.)

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I.3.2.Conclusion:

(Summarize the findings of the experiment and what can be concluded about the behavior of a liquid at rest.)

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Fluid	Tim (s)	Average Speed (m/s)	Dynamic Viscosity (μ) (Pa·s)	Kinematic Viscosity (ν) (m^2/s)
Glycérine ρ=1260 Kg/m^3				
Oil ρ=920Kg/m^3				

water ρ=1000Kg/m^3				

I.4.Conclusion

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PW-02: Impact of a Water Jet on an Obstacle

The impact of a water jet on an obstacle is a phenomenon commonly studied in fluid mechanics due to its many industrial and environmental applications (e.g., in turbines, dams, or high-pressure cleaning processes). Several factors need to be considered to fully understand this phenomenon:

II.1. Flow Types

- **Laminar flow**: At low velocities, the flow of the jet can remain laminar, with parallel streamlines.
- **Turbulent flow**: At higher velocities, the flow becomes turbulent, causing random fluctuations and greater energy dissipation.

II.2. Jet Characteristics

- **Volumetric flow rate**: The amount of water per unit time affects the force and energy dissipation at the point of impact.
- **Initial velocity**: Higher velocity creates a more intense impact.
- **Angle of incidence**: The angle at which the jet strikes the obstacle influences the distribution of forces and velocities on the impacted surface.

II.3. Pressure Distribution

- At the point of impact, there is a significant increase in pressure due to the deceleration of the jet. The water then spreads radially along the obstacle, leading to a drop in pressure as it disperses.

II.4. Flow Structures

- **Waves and splashes**: Depending on the nature of the obstacle (rigid, porous, etc.), various structures such as splashes, waves, or shock waves can form.
- **Cavitation**: If the pressure at the impact point drops below the water's vapor pressure, cavitation bubbles can form and later implode, causing wear on the obstacle.

II.5. Effect of the Obstacle

- **Shape of the obstacle**: The geometry of the obstacle affects how the jet is dispersed or deflected.
- **Rough or smooth surface**: The texture of the obstacle can influence the behavior of the jet, with rough surfaces promoting turbulent flow.

II.6. Thermal and Mechanical Consequences

- **Erosion**: Over time, the impact of the jet can erode the obstacle, especially if turbulent flow or cavitation occurs.
- **Heat transfer**: If the jet is used for cooling the obstacle (as in quenching processes), the flow pattern affects the efficiency of heat transfer.

If you are particularly interested in any of these aspects or working on a specific simulation, I can help you dive deeper with analyses or modeling.

II.7. Technical Report: Impact of a Water Jet on an Obstacle

II.7.1. Introduction

The impact of a water jet on an obstacle is a complex fluid dynamics problem with applications in numerous industries, such as cleaning, cooling, and hydraulic systems. Understanding the forces, flow patterns, and associated phenomena is essential for designing effective systems that use water jets for impact purposes.

II.7.2. Objective

This technical report aims to analyze the fundamental principles governing the impact of a water jet on a solid obstacle. Key factors such as velocity, pressure distribution, cavitation, and surface erosion will be discussed, along with their implications for industrial applications.

II.7.3. Flow Characteristics

II.7.3.1. Laminar vs. Turbulent Flow

The nature of the flow depends primarily on the velocity and the Reynolds number of the jet:

- **Laminar Flow**: At low velocities, the water flows smoothly, with well-defined streamlines. The impact is more predictable with a uniform pressure distribution.
- **Turbulent Flow**: At higher velocities, the flow becomes chaotic, with significant mixing and random fluctuations. Turbulent flow can lead to irregular impact forces and higher energy dissipation.

II.7. 3.2. Reynolds Number

The Reynolds number **Re=ρ×u×D/μ**, where **u** is the velocity, **D** the diameter of the jet, **ρ** the fluid density, and μ\muμ the viscosity, determines the flow regime. For low Reynolds numbers, flow is laminar, and for higher values, it transitions to turbulent flow.

II.7.4. Jet Impact on an Obstacle

II7. 4.1. Velocity and Flow Rate

The velocity of the water jet affects both the magnitude of the impact and the pressure exerted on the obstacle. The kinetic energy of the water jet is converted into pressure energy upon impact. A higher velocity results in a greater force on the surface.

II.7. 4.2. Angle of Incidence

The angle at which the jet strikes the obstacle determines the way the water disperses. Perpendicular impacts result in a direct distribution of force, while oblique angles cause the water to spread in a more complex pattern, influencing the flow dynamics around the obstacle.

II.7. 4.3. Pressure Distribution

At the point of impact, there is a significant pressure spike due to the sudden deceleration of the water jet. The pressure at the impact point can be approximated by Bernoulli’s principle, considering the velocity of the jet and the stagnation point pressure:

$$P = \frac{1}{2}\rho u^2$$

After the initial impact, the water spreads radially, with pressure diminishing as the water moves outward.

II. 8. Phenomena Associated with Impact

II.8..1. Cavitation

Cavitation can occur if the local pressure drops below the vapor pressure of water. Vapor bubbles form in the low-pressure region, which later collapse, potentially causing surface damage due to the high-energy shock waves generated during the collapse.

II.8. 5.2. Splashing and Secondary Flows

Depending on the impact velocity and obstacle shape, splashing may occur, where droplets break off from the main body of water. This leads to secondary flow patterns that influence the behavior of the water after impact.

II. 9. Effects on the Obstacle

II.9.1. Surface Erosion

Repeated impacts can lead to material erosion, especially when cavitation is present or when the flow is highly turbulent. This is of particular concern in hydraulic machinery and surface cleaning systems, where long-term exposure to high-velocity jets can degrade materials.

II.9.2. Heat Transfer

In systems where water jets are used for cooling, such as in metalworking, the heat transfer rate depends on the flow structure and the surface area of contact. Higher impact velocities generally result in more efficient cooling due to increased convective heat transfer.

II.8. Experimental Setup (Example)

An experimental setup for studying the impact of a water jet typically involves a high-pressure water pump, a nozzle to create the jet, and a target obstacle with sensors to measure pressure and temperature. The key parameters to measure are:

- **Jet velocity**
- **Pressure at the impact point**
- **Surface temperature (for heat transfer studies)**
- **Flow patterns using high-speed imaging**

II.8.1. Applications

- **Cleaning Systems**: High-pressure water jets are used to remove dirt, scale, or paint from surfaces. Understanding the impact dynamics helps optimize these systems for efficiency and to avoid surface damage.
- **Cooling Systems**: Water jets are used in quenching processes, where rapid cooling is required. The heat transfer rate is enhanced by understanding how the water impacts the surface.
- **Erosion Studies**: The study of water jet impacts can help predict and mitigate erosion in hydraulic turbines, pipelines, and other infrastructure exposed to high-velocity flows.

II.8.2. Conclusion

The impact of a water jet on an obstacle involves complex interactions between the water's velocity, pressure distribution, and the geometry of the obstacle. Key phenomena such as cavitation, splashing, and erosion are influenced by these factors. Understanding these dynamics is crucial for designing systems that efficiently use water jets while minimizing potential damage to surfaces.

II.8.3. References

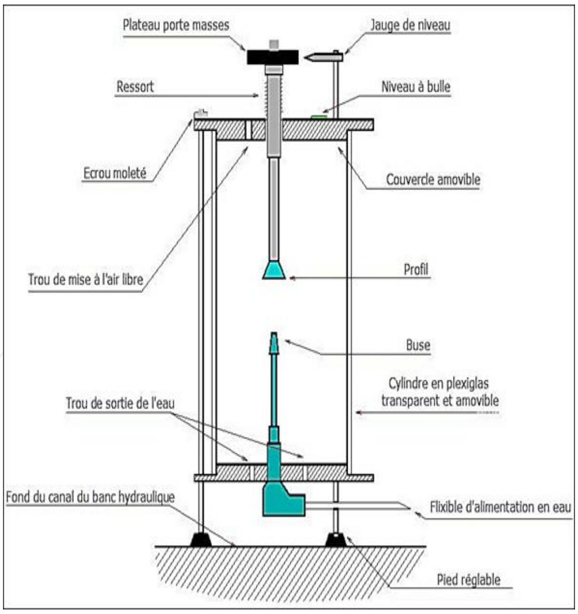
- [1] White, F. M. (2006). *Fluid Mechanics*. McGraw-Hill.
- [2] Schlichting, H. (2016). *Boundary-Layer Theory*. Springer.
- [3] Brennen, C. E. (1995). *Cavitation and Bubble Dynamics*. Oxford University Press.

II.9. Objective of the Experiment:

Through the direct measurement of the force exerted by a water jet on an obstacle, the theorem of momentum is studied experimentally. This is achieved by measuring the impact force on plates of different shapes (flat, hemispherical, and conical).

II.10. Measurement Device Characteristics

A vertical pipe, supplied by the hydraulic bench, ends with a nozzle that produces a water jet with variable flow. This jet reflects off an obstacle and exits at an angle α relative to the direction of the incident jet. The nozzle and the obstacle are enclosed in a transparent cylinder, with a hole at the base to drain the water into the balance. The various dimensions are as follows:



- Jet diameter: 8 mm.
- Impact surface diameter: 40 mm.
- Impact surfaces :
  - Hemispherical surface at 180°.
  - Curved surface at 120°.
  - Flat surface at 90°.
- Set of weights: 5, 10, 50, and 100 grams.

II.10.1. Theory

Consider a water jet striking an obstacle. If we neglect friction and head losses, the only external force is the force exerted by the obstacle, denoted as F. The application of Euler's theorem allows us to calculate the theoretical forces for the different surfaces:

- **Flat Plate** :

$$F_A = \rho Q^2 / S$$

- **Curved Surface (α=120°)**:

$$F_A = \frac{3}{2}\rho Q^2 / S$$

- **Hemispherical Surface (α=180°)**:

$$F_A = 2\rho Q^2 / S$$

Where :

- F_A is the theoretical force,
- ρ is the water density,
- Q is the flow rate,
- S is the cross-sectional area of the jet.

II.10.2. Experimental Procedure

1. Connect the device to the hydraulic bench and level it using the adjustable feet.
2. Mount one of the obstacles on the device and set the cursor to zero.
3. Place a mass on the plate and adjust the flow rate to bring the cursor back to zero.
4. Record the flow rate and the value of the mass.
5. Repeat the cycle for the other two obstacles.

II.10.4. Results and Calculations

The results can be recorded in the following tables:

II.10.4.1. Impact Surface: Flat Plate 90°

Surface d'impact : Plaque plane 90º

Poids (Kg)	F_e (N)	V (m^3)	T (sec)	Q (m^3/s)	Q^2	F_A (N)	Err %

Surface d'impact : Hémisphère 180º

Poids (Kg)	F_e (N)	V (m^3)	T (sec)	Q (m^3/s)	Q^2	F_A (N)	Err%

Surface d'impact : Plaque conique 120º

Poids (Kg)	F_e (N)	V (m^3)	T (sec)	Q (m^3/s)	Q^2	F_A (N)	Err%

II.10.4.2. Task:

1. Complete the tables above with the experimental data.

2. Analyze and comment on the forces in the system using a graph.

II.10.4.3. Interpretation of the results

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II.10.4.4.Conclusion……………………………………………………………………

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PW-03: Study of the Center of Buoyancy

III.1. Study of the Center of Buoyancy

The **center of buoyancy** is the point through which the buoyant force acts on an object submerged in a fluid. This point is crucial in determining an object's stability in the fluid, as it impacts whether an object will remain upright or tip over.

III.2. Key Concepts

1. **Definition of Center of Buoyancy**:
   - The center of buoyancy is the centroid (or geometric center) of the displaced fluid volume by the submerged part of the object.
   - It is the point at which the buoyant force, or upward force exerted by the fluid, acts.
2. **BuoyantForce**:
   - According to Archimedes' principle, the buoyant force F_b is equal to the weight of the fluid displaced by the object.
   - $Fb=\rho_{fluid}Vg$.
     - ρ_{fluid} is the density of the fluid,
     - V is the volume of the displaced fluid,
     - g is the acceleration due to gravity.
3. **Calculation of the Center of Buoyancy**:
   - For an object with uniform density and simple geometry (such as a cylinder, sphere, or rectangular prism), the center of buoyancy is located at the center of the submerged volume.
   - For more complex shapes, the center of buoyancy is found by determining the centroid of the submerged portion of the object, using integral calculus or geometric decomposition.
4. **Relation Between Center of Buoyancy and Center of Gravity**:
   - The **center of gravity** of an object is the point where its weight is concentrated and acts downward.
   - The relative positions of the center of gravity and the center of buoyancy determine the object's stability in the fluid:
     - If the center of buoyancy is directly below the center of gravity, the object tends to tip and become unstable.
     - If the center of buoyancy is directly above or well-aligned with the center of gravity, the object tends to remain upright and stable.
5. **Stability in Fluids**:
   - When the center of buoyancy shifts in response to the tilting of an object, it can create a **restoring moment** that tends to bring the object back to its original position. This moment is crucial for the stability of ships and floating structures.
   - **Metacentric Height**: The distance between the center of gravity and the metacenter (a point related to the center of buoyancy that changes position as the object tilts) indicates stability:
     - A large metacentric height indicates good stability.
     - A small metacentric height or the absence of one leads to poor stability.

III.3. Applications of the Center of Buoyancy Study

- **Shipbuilding and Marine Engineering**: Ensures that boats and ships are designed with stable buoyancy characteristics.
- **Submarine and Underwater Craft Design**: Determines the depth at which a vessel floats or sinks based on its weight and the buoyant force.
- **Floating Structures**: Used in the design of oil rigs, floating platforms, and buoys for stability in water.
- **Aerospace Engineering**: In atmospheric studies, buoyancy principles apply to balloons and airships.

III.3.1. Example Calculation

Consider a uniform cylindrical object partially submerged in water. The center of buoyancy can be calculated by determining the submerged volume's centroid based on its height in the water.

III.3.2. For a cylindrical object

- If the cylinder floats upright, the center of buoyancy is at the center of the submerged portion.
- If the cylinder tips, the submerged portion's geometry changes, altering the center of buoyancy and, consequently, the stability of the object.

The study of the center of buoyancy is essential in various engineering disciplines, particularly for any structure or vehicle that interacts with fluids. Understanding the center of buoyancy allows engineers to ensure stability, design safer structures, and manage fluid mechanics effectively.

III.4. Objective

The objective of this practical study is to understand and experimentally verify the concept of the center of buoyancy. By examining different shapes and orientations of objects submerged in water, we will observe how the position of the center of buoyancy affects stability.

III.4.1 MaterialsNeeded

- Water tank or large transparent container
- Set of different floating objects (e.g., cylindrical, cubic, and irregularly shaped)
- Measuringruler
- Small weights (to adjust center of gravity)
- Marker or small flag (to mark the position of the center of buoyancy)
- Data recordingsheet

IIII.4.2. Procedure

1. **Preparation**:
   - Fill the tank with water and ensure it is stable and level.
   - Select an object (such as a cylinder) and attach small weights to adjust the center of gravity as needed. Mark the object's center of gravity if possible.
2. **Initial Observation**:
   - Gently place the object in the water. Observe whether it floats upright, tilts, or submerges.
   - Record the initial depth of submersion and the object's orientation in the water.
3. **Center of BuoyancyIdentification**:

   - Observe the position where the buoyant force (upward) acts. Place a marker or small flag at this point. This point is the **center of buoyancy**.
4. **StabilityTesting**:
   - Push the object slightly to tilt it and observe how it returns to its original position.
   - If the object returns to its original orientation, it is stable. If it flips or tilts further, it is unstable.
   - For stable objects, measure the distance between the center of buoyancy and the center of gravity (the **metacentric height**).
5. **Effect of Shape**:
   - Repeat the experiment with objects of different shapes (e.g., cube, irregular shape) and observe how the center of buoyancy and stability change.
   - Record the depth of submersion for each shape and note any differences in stability.
6. **Data Collection**:
   - For eachshape, record:
     - Depth of submersion
     - Position of the center of buoyancy
     - Stability observation (whether it returns to the initial position)
     - Distance between the center of buoyancy and the center of gravity.

III.4.3. Analysis

1. **Comparison of Shapes**:
   - Analyze how different shapes affect the location of the center of buoyancy and the overall stability.
   - For objects with large metacentric heights (larger distance between the center of buoyancy and center of gravity), stability should be higher.
2. **Influence of the Center of Gravity**:
   - Observe the impact of adding weights at different points on the object. Higher weights (further from the center of buoyancy) should increase instability.
3. **StabilityAssessment**:
   - Based on the observations, determine which shapes and weight distributions provide better stability.

III.4.4. Conclusion:

Summarize how the location of the center of buoyancy affects stability and how different shapes and weight adjustments influence an object's balance in water. This experiment should demonstrate the principle that an object with a higher center of buoyancy, aligned above or closer to the center of gravity, will tend to have greater stability when submerged in a fluid. Understanding these principles is critical in fields like naval engineering, where buoyancy and stability are essential for the safety and performance of vessels and floating structures.

III.5. Objective of the Experiment:

- Determination of pressure force.
- Determination of the center of pressure.

III.5.1Description of the Experimental Apparatus:

The apparatus (see Figure 1) consists of a transparent plastic tank mounted on a worktable, with adjustable screws that also allow for leveling using a bubble level to check the device's horizontality. The tank is open at the top, allowing for filling with water and installation of the experimental accessories. It is equipped with a drainage valve.

The surface on which the hydrostatic pressure acts is made up of a plunger shaped like a quarter of a ring. At the opposite end, there is a mechanism that enables balancing the vertical surface upon which the hydrostatic pressure acts, according to the water level in the tank. The entire setup can rotate around a horizontal axis.

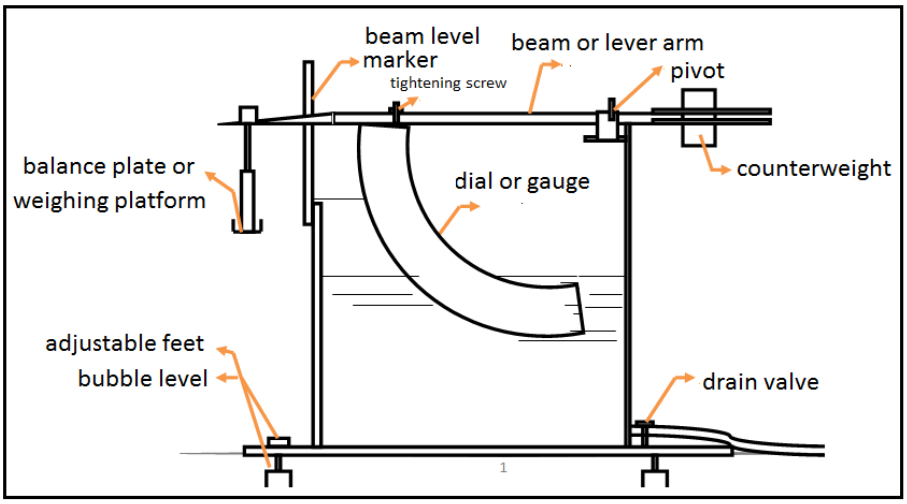
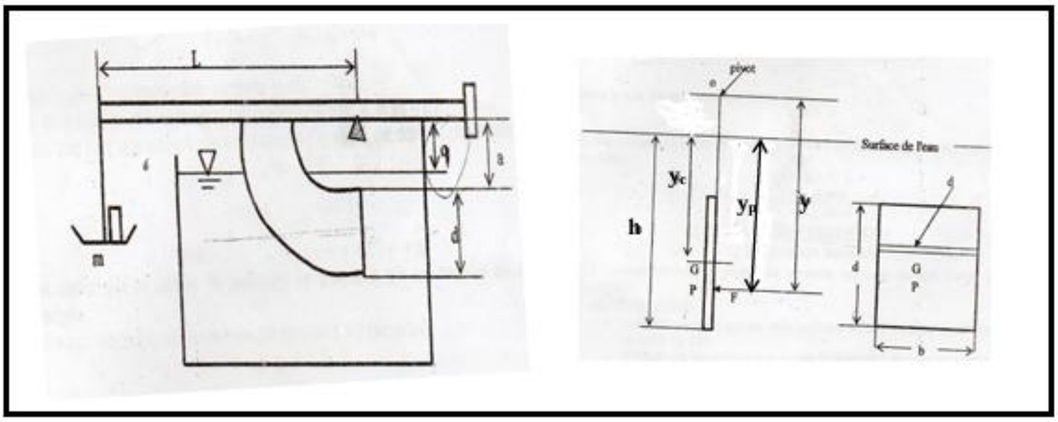


Figure 1. Experimental device

Partial or total immersion of the surface causes a change in the value of the buoyant force as well as its point of application, which leads to an imbalance in the position of the quarter-ring-shaped plunger. The correct position of the rod is achieved by placing an appropriate mass on the balance plate. Graduations marked on the plunger allow for various tests at different water levels in cases of partial or full immersion of the flat surface. This device directly measures the moment due to the buoyant force exerted by a liquid on a fully or partially submerged vertical plane, allowing comparison with calculated results. The moment of the force exerted by hydrostatic pressure is measured using calibrated masses



III.5.2. Theoretical Background: Archimedes' Principle:

Anybody submerged in a fluid experiences an upward vertical force (buoyant force) exerted by the fluid. The magnitude of this force is equal to the weight of the fluid displaced, which corresponds to the submerged volume of the body.

$$F_{buoyancy} = \rho_{fluid} V_{immersed} g$$

where:

- $F_{buoyancy}$ is the buoyant force,
- ρ_{fluid} is the density of the fluid,
- $V_{immerse}$ is the volume of the body that is submerged,
- g is the acceleration due to gravity.

III.5.3.1. Experimental calculations

a. The pressure force:

$$F = \rho g y_c A, \qquad y_c = \frac{h}{2} \qquad A = h.b \Rightarrow \rho g y_c A = \frac{1}{2}\rho g b h^3$$

A:is the immersed surface

b. The center of thrust:

The thrust moment relative to the pivot axis is given by:

$$\sum M_0 = yF = PL \Rightarrow yF = mgL$$

$$\Rightarrow y = \frac{mgL}{F} y_p = a + d - \frac{h}{3}$$

Where (m) is the mass placed in the balance pan (L): is the distance between the axis of the balance and the axis of the pivot.

III.5.3.2. Theoretical calculations:

a. Center of thrust:

$$y_p = y_c + \frac{I_x}{y_c A}$$

$$I_x = \frac{bh^3}{12}, A = bh$$

I_x : represents the moment of inertia of the surface

For a rectangular surface: we have $y_p = y_c + \frac{I_x}{y_c A} = \frac{h}{2} + \frac{\frac{bh^3}{12}}{\frac{bh^2}{2}} = \frac{h}{2} + \frac{h}{6} = \frac{2h}{3}$

Where : $y_p = \frac{2h}{3}$

b. Pressure force :

$$y = d + a - (h - y_p)$$

$$F = \frac{mgL}{y}$$

III. 6. Total immersion

III.6.1. Experimentalcalculations

a. The pressure force

$$F = \rho g y_c A, \qquad y_c = h - \frac{d}{2} \qquad A = b.d$$

A:is the immersed surface

b. The center of thrust:

The thrust moment relative to the pivot axis is given by:

$$\sum M_0 = yF = PL \Longrightarrow yF = mgL$$

$$\Longrightarrow y = \frac{mgL}{F} y_p = y - a$$

For a rectangular surface: we have $y_p = y_c + \frac{I_x}{y_c A} = y_c + \frac{\frac{bd^3}{12}}{bdy_c} = y_c + \frac{d^2}{12y_c}$

c. Pressure force :

$y = a + \frac{d}{2} - (y_p - y_c)$ and $F = \frac{mgL}{y}$

- **F**: pressure force (N)
- **ρ**: density of water (ρ=1000 kg/m^3)
- **h**: water height (mm)
- **m**: mass (g)
- **yc**: center of gravity
- **g**: gravitational acceleration (g=9.81 m/s^2)
- **A**: wetted surface area (m^2)
- **y**: point of application of the pressure force (m)
- **yp**: center of pressure (m)
- **Ix**: moment of inertia of the wall

Given dimensions : L=275 mm, a=100 mm, b=75mm, d=100 mm.

III.6.2. Procedure:

- Place the plunger on the two knife edges and attach it to the balance arm using the central screw.
- Level the plexiglass tank using its adjustable feet.
- Balance the arms of the scale by moving the counterweights.
- Add water to the tank until the water level reaches the bottom of the plunger.
- Place a mass on the balance (which will now be unbalanced).
- Add more water to the tank until the balance is restored, and record the water height using the measurement scale.

- Repeat the operation multiple times, adding masses.

In this experiment, two cases are considered:

- **Partial immersionTotal immersion**

Mass (g)	Partial imm(h) (mm)		Mass (g)	Partial total(h) (mm)
50			**300**	
100			**350**	
150			**400**	
200			**450**	
250				

III.7. TaskRequirements

1. Complete tables **2.1** and **2.2** with experimental calculations for both partial and total immersion cases.
2. Complete tables **2.3** and **2.4** with theoretical calculations for both partial and total immersion cases.
3. Plot the graphs $y_{theoreticaly}$ and $y_{experimental}$=f(h) as well as $F_{theoretical}$ and $F_{experimental}$=f(h).
4. Compare the results and provide conclusions.

III.7.1. Experimental calculation

Table 2.1 Partial immersion

M(Kg)	h(m)	Y_c (m)	A(m^2)	F(N)	Y(m)	Y_p(m)

Table 2.2 Total immersion

M(Kg)	h(m)	Y_c (m)	A(m^2)	F(N)	Y(m)	Y_p(m)

III.7.2. Theoretical calculation

Table 2.1 Partial immersion

M(Kg)	h(m)	Y_c (m)	A(m^2)	F(N)	Y(m)	Y_P(m)

Table 2.2 Total immersion

M(Kg)	h(m)	Y_c (m)	A(m^2)	F(N)	Y(m)	Y_P(m)

III.8. Conclusion

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PW-04: Experimental Verification of Bernoulli's Theorem

The experimental verification of Bernoulli's theorem can be carried out through simple experiments using common laboratory equipment. Here is how it can be done

IV.1. Required Equipment

- Venturi tube or channel with varying cross-section
- Manometers or Pitot tubes to measure pressure
- Pump or water source to generate flow
- Ruler or heightmeasurementtool
- Reservoir to maintain a constant flow

IV.1.2. Principle of the Experiment

Bernoulli's theorem states that for an incompressible, non-viscous fluid in steady flow, the sum of the static pressure, kinetic energy per unit volume, and potential energy per unit volume remains constant along a streamline. The equation is expressed as:

$$P + \rho g h + \frac{1}{2}\rho v^2 = constant$$

where:

- P is the static pressure,
- ρ is the density of the fluid,
- v is the fluid velocity,
- g is the acceleration due to gravity,
- his the height.

IV.1.3. Experimental Procedure

1. **Set up the apparatus**: Install a Venturi tube or a channel with variable cross-section and connect manometers at different points to measure pressure.
2. **Circulate the fluid**: Start the pump to create a steady flow of water in the tube.
3. **Measure pressures**: Record the pressure readings at different sections of the tube using the manometers.
4. **Measure velocity**: Calculate the velocity at each section using the continuity equation $(A_1 v_2 = A_2 v_2)$ and compare pressure readings.
5. **Verify Bernoulli's equation**: Confirm that the sum of the terms $P + \rho g h + \frac{1}{2}\rho v^2$remains constant across the measured points.

IV.1.4. Analysis of Results

Compare the experimental values of pressure and velocity with the theoretical predictions of Bernoulli's theorem. Differences may be observed due to losses from viscosity and turbulence, which are not considered in Bernoulli's ideal assumptions.

IV.1.5. Factors to Consider

- **Viscosity effects**: Although Bernoulli's theorem assumes a perfect fluid, energy losses can occur due to friction.
- **Turbulence**: If the flow is turbulent, results may deviate from theoretical expectations.

This experiment demonstrates the validity of Bernoulli's theorem under conditions that approximate those of an ideal fluid while highlighting real-world limitations such as viscosity and turbulence.

IV.2. Experimental Verification of Bernoulli's Theorem

Objective: To experimentally verify Bernoulli's theorem by measuring the relationship between pressure,

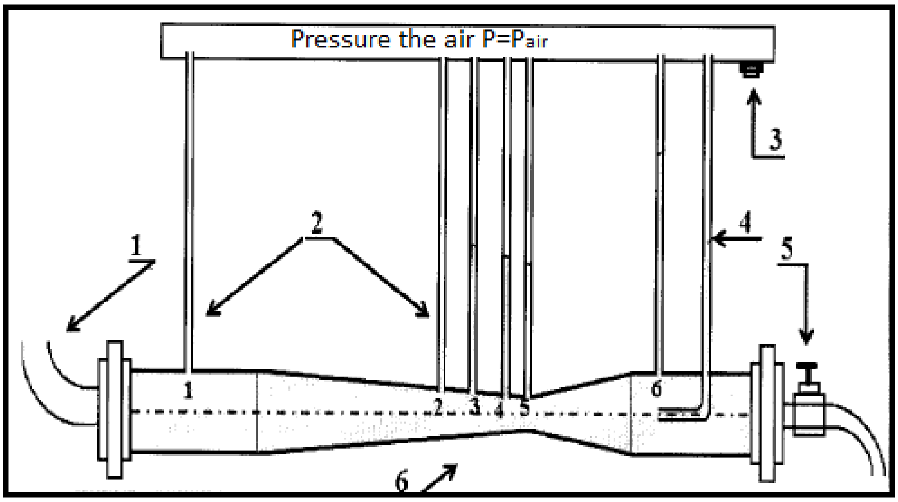

Figure IV.1. Schematic of the installation

1. Supply	2. Static pressure ports	3. Control valve
4. Purge valve	5. Total pressure port	6. Convergent-divergent

The apparatus consists of a "convergent-divergent" test duct made from a very smooth material (friction losses are negligible). The duct is attached to the rest of the setup with two flanges and is equipped with 7 manometers, including an adjustable total pressure port (manometer no. 4, figure IV.1).

IV.2.1. Procedure

1. **Setup**: Connect a Venturi tube to a water source and arrange manometers at various points along the tube to measure pressure. Ensure the apparatus is level and securely mounted.
2. **Initiate Flow**: Start the water pump to generate a steady flow through the tube. Adjust the flow rate as needed to maintain a consistent stream.
3. **Record Measurements**:
   - Observe and record the pressure readings at the manometer points.
   - Measure the water height at each manometer, if applicable.
4. **CalculateVelocity**:
   - Use the continuity equation $A_1 v_2 = A_2 v_2$ to calculate the velocity at different cross-sections of the tube, where AAA is the cross-sectional area.
5. **VerifyBernoulli's Equation** :
   - For each measurement point, calculate $P + \rho g h + \frac{1}{2}\rho v^2$and verify if the sum is approximately constant.

IV.2.2. Theory

Daniel Bernoulli's theorem states that the total mechanical energy of a flowing fluid remains constant in the absence of energy losses due to friction. In other words, this can be expressed analytically as follows (see figure IV.1.):

$$\frac{P_1}{\rho g} + z_1 + \frac{v_1^2}{2g} = \frac{P_i}{\rho g} + z_i + \frac{v_i^2}{2g} \quad with\ i = 2, \dots., 6 \quad (IV.1.)$$

In the current experiment, we have (see figures. IV.1. & IV.2.):

$$\frac{P_i}{\rho g} = h_i + \frac{P_{air}}{\rho_{air} g} \quad with\ i = 1, \dots, 6 \ \ (IV.2.)$$

By substituting equation (IV.1.) into (IV.2.) and taking the horizontal reference at the level of the pipe axis (i.e., $Z_I = 0$) we obtain:

$$h_{Tth\ i} = h_i + \frac{v_i^2}{2g} = const \quad with\ \ 1, \dots, 6 \quad (IV.3.)$$

$$v_i = \frac{4Q}{\pi d_i^2}$$

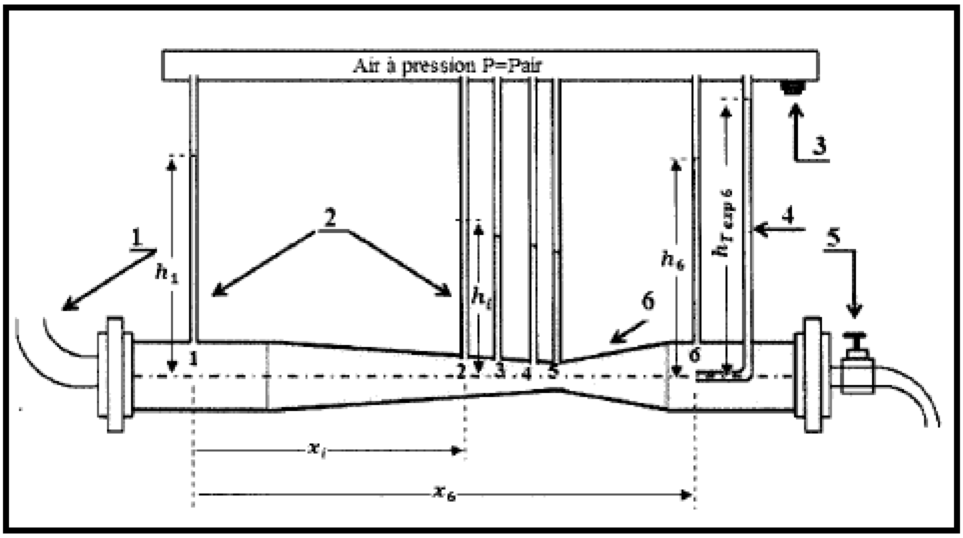

Figure.IV.2. Flow in a convergent-divergent.

1. **Analysis**: Compare the experimental results with the theoretical expectations. If differences are observed, discuss potential sources such as:

- **Viscous losses**: Energy losses due to fluid friction.
- **Turbulence**: Non-laminar flow can disrupt the ideal behavior assumed in Bernoulli's theorem.

IV.2.3. Observations and Results

Create a table to record pressure, calculated velocity, and energy values for different points along the flow path. Analyze the data for consistency with the theorem.

1. **Conclusions**: Summarize the findings and discuss whether the experimental results align with Bernoulli's theorem. Include observations of any deviations and their potential causes, such as friction or turbulence.

IV.2.4. SafetyPrecautions:

- Ensure the apparatus is stable to prevent water spillage.
- Handle water and electrical equipment carefully to avoid any risk of electric shock.

1. **Further Work**: Suggest improvements to minimize errors, such as using smoother tubing or increasing the accuracy of pressure measurements.

IV.2.5. Operating Procedure

1. Adjust the apparatus in the horizontal plane on the hydraulic bench.
2. Connect the apparatus to the supply and fill the manometers with water to remove all air bubbles.
3. Close the supply valve and the control valve, and lower the water level in the manometers, if necessary, using the hand pump.
4. Set the maximum flow rate according to the maximum reading in the manometers by adjusting the supply and control valves.

5. Record the flow rate, the water levels in the six manometers, and the water level in manometer no. 7 for the 6 sections and enter the values in Table IV.1. below.
6. Repeat step (5) for different flow rates by adjusting the control valve.

Flow rate Q(l/s)	**Section**	**Diameter *d (mm)***	**Static socket reading *h (mm)***	**Stop socket reading hT_{ext}(mm)**
	1			
	2			
	3			
	4			
	5			
	6			
	1			
	2			
	3			
	4			
	5			
	6			
	1			
	2			
	3			
	4			
	5			
	6			

IV.3. Calculations and Results

1. Complete the table below.
2. Plot *hTth(x)* and *hTexp*on the same graph.
3. Determine if the theoretical total head is the same for each section as that measured experimentally by manometer no. 7, *hTexp(x)*. If the theoretical and experimental estimates differ, explain why.
4. Discuss the validity of Bernoulli's equation for:
   a. Convergent section
   b. Divergent section.

(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(5+8)**
Q(l/s)	*Section*	*X* *(mm)*	*D* *(mm)*	*h* *(mm)*	hT_{ext} *(mm)*	*Vreal* *(m/s)*	$V^2/2g$ *(m)*	h_{Tth} *(m)*
	1							
	2							
	3							

	4							
	5							
	6							
	1							
	2							
	3							
	4							
	5							
	6							
	1							
	2							
	3							
	4							
	5							
	6							

IV.4. Conclusion

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Control of Practical Work Fluid Mechanics

QCM: Fluid Mechanics

1. What are the units of dynamic viscosity (μ)?

☐ a) kg\cdotpm/s
☐ b) Pa\cdotps.
☐ c) N\cdotps/m2.

2. In a venturi tube, the measured pressure difference corresponds to:

☐ a) Dynamic pressure
☐ b) Static pressure
☐ c) Total pressure
☐ d) Pressure loss

3. What is the purpose of a Venturi meter in a fluid mechanics lab?

☐ a) To measure the fluid viscosity
☐ b) To determine flow rate
☐ c) To calculate pipe roughness
☐ d) To measure pressure losses

4. Which instrument is used to measure the velocity of fluid flow in aImpact of a Water Jet on an Obstacle?

☐ a) Manometer
☐ b) Pitot tube
☐ c) U-tube
☐ d) Bourdon gauge

5. In a Bernoulli experiment, which of the following remains constant along a streamline?

☐ a) Velocity
☐ b) Pressure
☐ c) Total energy
☐ d) Flow rate

6. In an open channel flow experiment, the flow rate is determined using:

☐ a) Venturi meter
☐ b) Orifice plate
☐ c) Weir or flume
☐ d) Pitot tube

***7.* During a pipe flow experiment, what does the friction factor depend on?**

☐ *a) Fluid density only*
☐ b) Pipe material and diameter only
☐ c) Reynolds number and relative roughness
☐ d) Flow rate and temperature

8. In a practical fluid dynamics experiment, you are measuring the pressure drop across a pipe with a given flow. If the flow is turbulent, which of the following will increase the pressure drop?

☐ a) Increasing the pipe length.

☐ b) Decreasing the fluid velocity.

☐ c) Reducing the pipe roughness.

☐ d) Increasing the pipe diameter.

9. When performing a forced convection experiment, you measure the heat transfer rate from a heated surface. Which of the following factors will increase the heat transfer rate?

☐ a) Decreasing the fluid velocity.
☐ b) Decreasing the fluid temperature.
☐ c) Increasing the surface roughness of the heat transfer surface.
☐ d) Increasing the fluid velocity.

10. During a fluid flow experiment through a Venturi tube, the pressure decreases at the narrowest part of the tube. What can we infer about the flow?

☐ a) The velocity at the narrowest section is lower.
☐ b) The flow rate at the narrowest section is higher.
☐ c) The velocity at the narrowest section is higher.
☐ d) The density of the fluid is increasing.

11. In an experiment where a fluid flows over a flat plate, which of the following is true about the boundary layer?

☐ a) The boundary layer velocity profile is constant along the plate.
☐ b) The boundary layer thickness decreases with increasing velocity.
☐ c) The boundary layer is thin and does not affect the flow significantly.
☐ d) The flow within the boundary layer is governed by viscous forces.