Fluid Mechanics Lab(MEP2010)

Lab Project

Measurement of Drag Coefficient of a Falling Object in Water

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Objective: To determine the drag coefficient of a falling object in water using terminal velocity and considering buoyant force.

Materials Required:

1. Falling object (such as a sphere or cylinder) with known dimensions and mass.
2. Transparent water tank or container large enough to accommodate the falling object.
3. Measuring instruments (ruler, calipers, balance).
4. Stopwatch or timer.
5. Depth gauge or marked ruler for measuring water depth.

Methodology:

1. Preparation:
    - Set up the water tank in a stable and level position, ensuring sufficient clearance above and around the tank.
    - Fill the tank with clean water to a depth that allows for complete submersion of the falling object.
    - Measure and record the temperature of the water, as it can affect the fluid properties.
    - Ensure the falling object is clean and free from any contaminants.

2. Measurement of Object Parameters:

- Measure and record the dimensions (diameter, length, etc.) of the falling object using the appropriate measuring instruments.
- Measure and record the mass of the falling object using a balance.

3. Experimental Procedure:

- Hold the falling object stationary at a fixed height above the water surface.
- Release the object and start the stopwatch simultaneously.
- Record the time taken for the object to fall a predetermined distance (e.g., from the water surface to the bottom of the tank).
- Repeat the experiment multiple times to obtain reliable data, ensuring consistent release conditions for each trial.

4. Data Analysis:

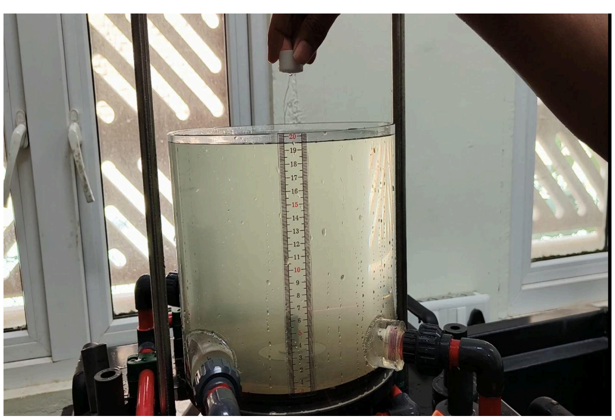
- Plot a graph of distance fallen versus time for each trial.
- Determine the terminal velocity of the falling object by identifying the point where the slope of the distance-time graph becomes constant. This indicates that the object has reached a state of dynamic equilibrium, with gravitational force balancing drag force and buoyant force.
- Use the terminal velocity and the balance of forces (buoyant force and drag force) to calculate the drag coefficient using appropriate equations.

5. Analysis of Results;

- Compare the calculated drag coefficient with theoretical values or literature values for similar objects.
- Discuss any discrepancies or sources of error in the experimental setup or procedure.
- Draw conclusions regarding the drag characteristics of the falling object in water based on the experimental findings.

Schematic/Figures:

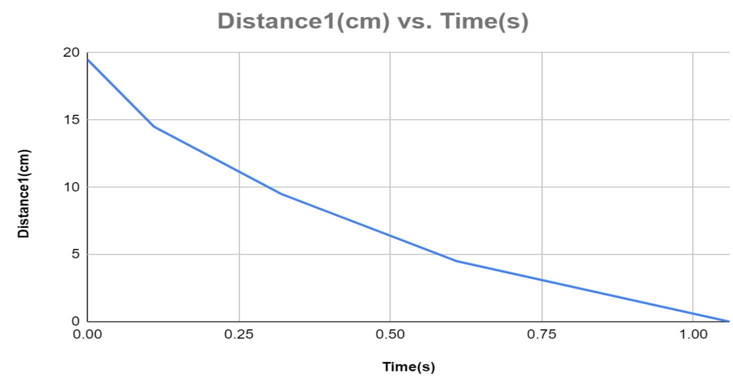
Apparatus Used



Distance v/s Time Plots for 5 Different Observations:

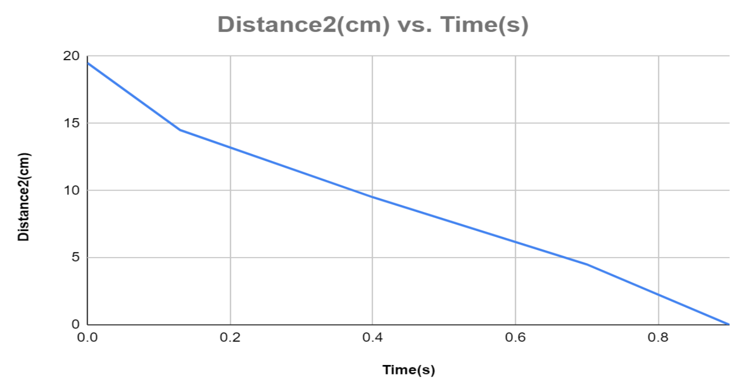
a.

Time(s)	Distance1(cm)
0	19.5
0.11	14.5
0.32	9.5
0.61	4.5
1.06	0



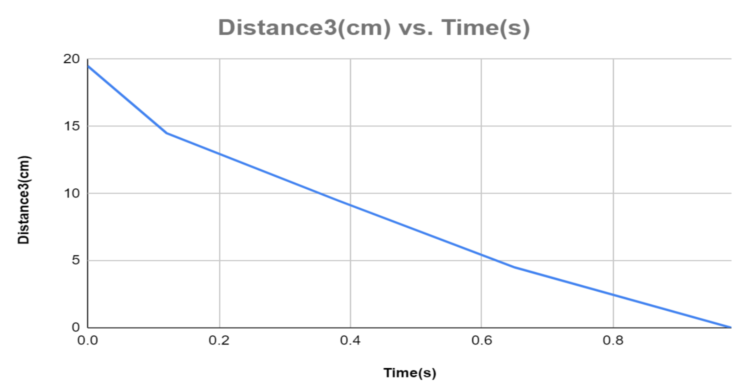
b.

Time(s)	Distance2(cm)
0	19.5
0.13	14.5
0.4	9.5
0.7	4.5
0.9	0



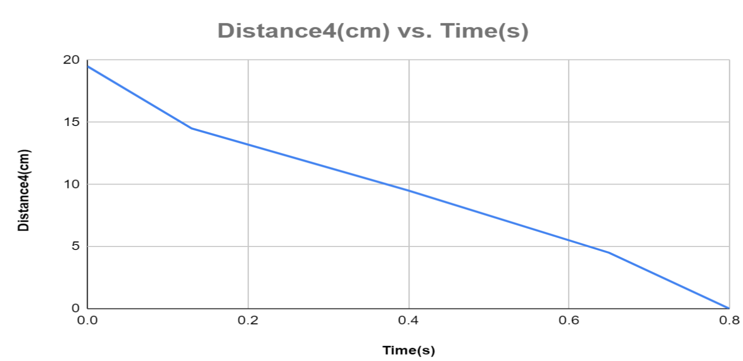
c.

Time(s)	Distance3(cm)
0	19.5
0.12	14.5
0.38	9.5
0.65	4.5
0.98	0



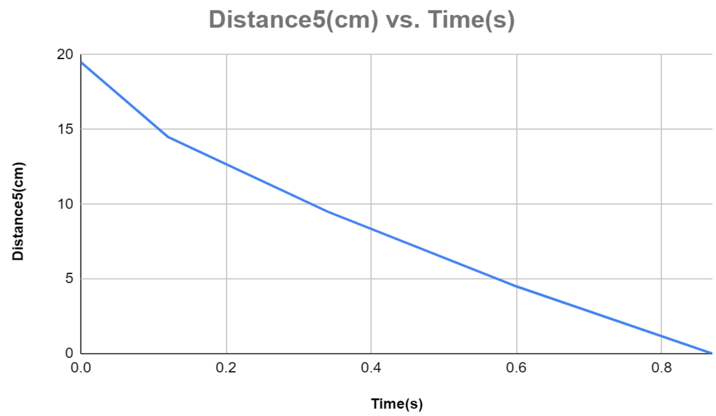
d.

J	K
Time(s)	Distance4(cm)
0	19.5
0.13	14.5
0.4	9.5
0.65	4.5
0.8	0



e.

Time(s)	Distance5(cm)
0	19.5
0.12	14.5
0.34	9.5
0.6	4.5
0.87	0



Results:

Formula used to calculate terminal velocity (Vt) = $\frac{\Delta y}{\Delta x}$ = $\frac{\Delta s}{\Delta t}$

For Example we used the following values from Graph a to find terminal velocity

a. $Vt_1 = \frac{\Delta s}{\Delta t} = \frac{14.5 - 4.5}{0.61 - 0.11}$ = 20 cm/s = 0.2 m/s

Similarly we have used other readings from the graphs to find the terminal velocities Vt_2, Vt_3 ,Vt_4 ,Vt_5 And then took the average value of terminal velocity shown below.

$$Vt = \frac{Vt_1 + Vt_2 + Vt_3 +, Vt_4 +, Vt_5}{5} = \frac{0.2 + 0.17 + 0.18 + 0.19 + 0.193}{5} = 0.19 \text{ m/s}$$

Now using this formula to calculate drag coefficient

$$C_d = \frac{2 * (m - \rho * V_s)g}{\rho A V_t^2}$$

Where:

m is the mass of the falling object,
g is the acceleration due to gravity,
ϱ is the density of water,
Vs is the volume of water displaced by the falling object,

A is the reference area (such as the cross-sectional area of the falling object), and
vt is the terminal velocity of the falling object.

Using diameter of object = 2.3cm
Height of the object = 1.3cm

$$C_d = \frac{2*(0.00613 - 1000*3.14*(0.0115)^2*0.013)*9.8}{1000*3.14*(0.0115)^2*(0.19)^2} = 0.95$$

Error Analysis

C_d calculate (Measured Value) = 0.95

C_d (True value for short cylinder) = 1.15

Percentage Error = $\frac{1.15 - 0.95}{1.15} * 100 = 17.39\,\%$

Discussion:

The experiment successfully determined the drag coefficient of a falling object in water using terminal velocity and distance-time plots. Terminal velocity was identified by observing the slope in the distance-time plot, indicating equilibrium between gravitational, drag, and buoyant forces. By considering buoyant force, the analysis accounted for the upward force exerted by displaced water, leading to a more accurate determination of terminal velocity and drag coefficient. Discrepancies between experimental and theoretical values were discussed. Assumptions made during the analysis were evaluated for their impact on accuracy, with suggestions for improvement provided.

Conclusion:

In conclusion, the experiment provided valuable insights into drag coefficient determination in fluid dynamics. By employing terminal velocity and distance-time plots, a thorough understanding of drag forces acting on falling objects in water was achieved. The findings contribute to the broader understanding of fluid mechanics principles and offer practical applications in various engineering and scientific fields. Further research can explore the effects of different object shapes and environmental conditions on drag coefficient to enhance predictive accuracy and real-world applicability.

Shortcoming For this experiment to perform in Air

1. **Lack of Buoyant Force**: Unlike water, air does not exert a significant buoyant force on objects. This absence of buoyancy can affect the equilibrium state of the falling object and may lead to inaccurate measurements of terminal velocity and drag coefficient.

2. **Lower Density**: Air has a much lower density compared to water. As a result, the drag forces experienced by the falling object in air are typically much smaller than those experienced in water. This can make it challenging to accurately measure and analyze the effects of drag on the falling object.

3. **Shorter Terminal Distance**: In air, objects typically reach terminal velocity over shorter distances compared to water due to lower drag forces. This shorter terminal distance may limit the accuracy and precision of measurements, especially if the experimental setup does not allow for sufficient distance for the object to reach terminal velocity.

4. **Need for Controlled Environment**: Conducting experiments in air often requires a wind tunnel or other controlled environment to minimize external disturbances and ensure consistent airflow around the falling object. Without proper apparatus to control airflow and environmental conditions, it can be challenging to isolate the effects of drag and accurately measure terminal velocity.

5. **Variable Density and Viscosity**: Air density and viscosity can vary significantly with factors such as altitude, temperature, and humidity. These variations can introduce additional complexity and uncertainty into the experiment, making it difficult to control experimental conditions and obtain reliable results.

****************************END OF REPORT**********************************