Pre-Lab Questions 5

Topic: Archimedes' Principle

Objective: To enable the students to describe, state and derive the terms and expressions relevant in carrying out experiment 5 meaningfully.

After successfully answering these questions, the students will be able to

1. describe the meaning of a buoyant force.
2. state Archimedes' Principle.
3. derive the equation $F_b = \rho Vg$.
4. state the conditions for an object to sink or float in a fluid.

PRE-LAB QUESTIONS 5

Answer the following questions and submit your group answers to the instructor.

1. What is a buoyant force, F_b?

2. State Archimedes' principle.

3. Is Archimedes' principle valid for liquid only, gas only or both liquid and gas?

4. The weight of an object in air is W_{air}, while its weight when fully immersed in a liquid is W_{liquid}. The weight of the liquid displaced by the object is $W_{displaced\ liquid}$. Write down the relationship

   a) between F_b, W_{air} and W_{liquid}
   b) between F_b and $W_{displaced\ liquid}$

5. Referring to the conditions in question 4, show that $F_b = \rho Vg$ where ρ and V is the density and volume of the displaced liquid, while g is the acceleration due to gravity.

6. State the conditions on densities that determine whether an object will sink or float in a fluid.

Experiment 5

Topic: Archimedes' Principle

Objective: 1. To determine the density of a metal block
2. To determine the density of paraffin

Apparatus: Newton's balance, string, metal block, paraffin, beaker and electronic balance

Learning Outcomes of Experiment 5

After doing the experiment, the students will be able to

1. experimentally determine the density of a solid and a liquid by using equations derived from Archimedes' Principle.
2. calculate the uncertainties in the results of the experiments.
3. write a report on the experiment.
4. state the appropriate and reasonable sources of error or factors that contributed to the uncertainties in the results.

Introduction

When an object is partially or fully submerged in a fluid, the magnitude of the buoyant force acting on the object equals to the weight of the fluid displaced by the object.

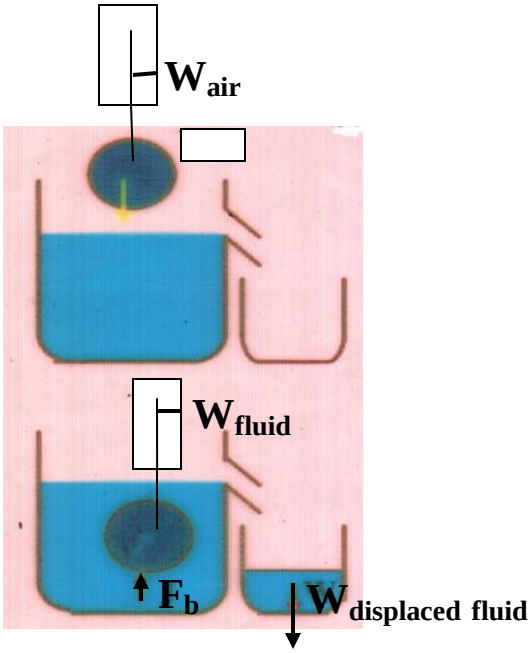
Hence, the buoyant force is acting in an opposite direction to the weight of the object, as such the weight of an object submerged in a fluid is less than its weight in air.

The difference between the weight of the object in air and the weight when it is submerged in a fluid equals to the buoyant force of the fluid acting on the object.

For an object totally submerged in a fluid, the volume of the object equals to the volume of the displaced fluid. If the object is partially submerged, the volume of submerged part of the object only is equal to the volume of the displaced fluid.

Fig. 1 summarizes the relationship between various parameters for an object fully submerged in a fluid.

Fig. 1

Physical conditions	Relations between parameters
Object fully submerged in a fluid 	$F_b = W_{displaced\ fluid}$ **(Archimedes' Principle)** [$V_{object} = V_{displaced\ fluid}$] $F_b = W_{air} - W_{fluid}$ W_{air} = reading of newton balance when the object is weight in air W_{fluid} = reading of newton balance when the object is totally submerged in a fluid $W_{df} = m_{df}\,g$ $= \rho_{df} V_{df}\,g$ (df stands for displaced fluid)

The direction of motion of an object submerged in a fluid is determined only by the densities of the object and the fluid.

If the density of the object is less than the density of the fluid, the downward gravitational force is less than the upward buoyant force and the unsupported object accelerate upwards.

If the density of the object is greater than the density of the fluid, the downward gravitational force is more than the upward buoyant force and the unsupported object sinks.

Instructions

To determine the density of a given metal block.

1. Using $\rho = \frac{m}{V}$, carry out an experiment to determine the density of a given metal block, where m is determined by an electronic balance and V is determined from Archimedes' principle.

2. Compute the density of the metal block by direct measurement of volume (V) by using a vernier caliper and the equation $\rho = \frac{m}{V}$.

3. Determine the uncertainty in your results of step 1 and step 2.

4. Calculate the percent difference between the results of step 1 and step 2.

5. State your conclusions.

To determine the density of paraffin.

1. Carry out an experiment to determine the density of paraffin by using Archimedes' principle.

2. Determine the uncertainty in your results.

3. Calculate the percent error between your experimental results to the standard density of paraffin given in Table 1 in the Post-Lab Questions section.

4. State your conclusions.

Format of the Laboratory Report

1. *Objective* : State the objective of the experiment.
2. *Apparatus* : State the instruments used.
3. *Theory* : State the physics and related equations underlying your investigation.
4. *Procedures* : Describe the steps that you take to perform the experiment.
5. *Data* : Present the data appropriately. Organize the data in tables if possible. Use a correct and consistent significant figures. State the units and uncertainties of each quantity.
6. *Results* : Show the relevant calculations.
7. *Conclusions* : Indicate what is measured, the uncertainties and the sources of uncertainties.

Post Laboratory Questions

1. Comparing the experimental results of the density of the metal block, to densities of some metals given in Table 1, can you determine the material of the metal block?

   Table 1: Densities of some substances at STP

Metals	ρ *(kg/m^3)*
Air	1.29
Paraffin	792
Aluminium	2.70×10^3
Copper	8.92×10^3
Fresh water	1.00×10^3
Iron	7.86×10^3
Lead	11.3×10^3

2. How will the string that tie the block to the Newton's balance effect the experimental results using Archimedes' principle?

3. What is the advantage of using Archimedes' principle to determine the density of substance over the direct method of using $\rho = \frac{m}{V}$?

4. Explain how a submarine is caused to submerge and surface without the use of its propulsion propeller and fins?

References

Wilson, J.D. and Hernández-Hall, A.C. (2010). Physics Laboratory Experiments. 7th Edition. Brooks/Dale Cengage Learning. Boston, MA.

Jewett, J.W. and Serway, R.A. (2008). Physics for Scientists and Engineers. 8th Edition. Brooks/Dale Cengage Learning. Boston, MA.