Teacher packs in Experimental Science

PHY Pack 8

Determination of the density of solids

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Curriculum areas covered: Density and relative density

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Title: Determination of the density of solids

Target group: Diploma in Basic Education Students

Also suitable for: B.Ed. Basic Education

Duration of Activity: 50 minutes plus discussion time

Learning outcomes: At the end of the lesson the student should be able to

1. Knowledge and Understanding (KN)	KN1	Define density
	KN2	State the SI units of density
2. Cognitive Skills (CS)	CS1	Explain how the measuring cylinder is used for measuring the volume of an irregular object.
3. Key Skills (KS)	KS1	Use the measuring cylinder to measure volume.
	KS2	Identify the appropriate instrument for measuring various quantities involved in determining density.
	KS3	Determine the density of solid objects.
4. Practical Skills (PS)	PS1	Make and record observations/ measurements.
	PS2	Report results accurately.

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A. Teacher's Guide

Overview

Students are provided with a measuring cylinder, a solid object, lever balance, water, an irregular object whose density is to be determined. Ensure object does not dissolve in water and use a sinker, if necessary. Students need to prepare a table of observations in which their readings can be recorded. Since the volume of the object cannot be measured directly, students have to use the displacement method to determine the volume.

Instructions

(i) Students should be working in small groups to determine the density of an irregular solid object.
(ii) Students should use the lever balance to find and record the mass (say m) of the irregular solid object.
(iii) Should pour water into the measuring cylinder to about a third of its depth
(iv) Students should record the initial volume of water in cylinder as V_1
(v) Students should attach to the solid object a piece of thread
(vi) Students should lower solid object gently into the water to avoid splashing
(vii) Students should record final volume of the water plus the volume of the solid object as V_2
(viii) Students can now empty the contents of the cylinder
(ix) Students should repeat procedures (i) to (viii) using different values of V_1
(x) Students should find the average value of $(V_2 – V_1)$ cm^3
(xi) Students can now proceed to calculate the density by converting the volume in cm^3 to m^3 and the mass from g to kg.

Reflection on the experiment

In place of the measuring cylinder, you can use an eureka can in the determination of the density.

Sample Assessment Questions with Answers

1. Explain the term density. (KN1)

Answer: Density is regarded as the degree of compactness of a material or substance. If a body is very compact it has a higher density and when less compact it has a lower density. Density, ρ can be defined as

$$\rho = \frac{\text{mass of the substance}}{\text{volume of the substance}} = \frac{m}{V}$$

2. How would you measure the volume of an irregular solid object by using a uniform graduated cylinder? (KS1)

Answer:

a. Pour water into the measuring cylinder to about a third of its depth
b. Record volume of water in cylinder, V_1

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c. Attach the object to a piece of thread
d. Lower solid gently into liquid, avoiding splashing
e. Record volume of the water plus solid, V_2
f. The volume V of the object is given by

$$V = V_2 - V_1$$

3. If a "sinker" (a known weight with known volume used to hold down the floating solid) is attached to the irregular object, how would you determine the density of the irregular object? (KS2)

Answer:

a. Find the mass of the object m and record it.
b. Pour water into the measuring cylinder about a third of its depth
c. Record volume of water in cylinder V_1
d. Attach the object to the sinker on a piece of thread
e. Lower the object and sinker gently into liquid, avoiding splashing
f. Record the new volume V_2
g. Let the volume of the sinker be V_s
h. The volume V of the object is given by

$$V = V_2 - V_1 - V_s$$

Therefore $\rho = \frac{\text{mass of the substance}}{\text{volume of the substance}} = \frac{m}{V}$

4. How would you improve the precision of your measurements? (PS1)

Answer: The eye direction should be horizontal to the figure to be read on the measuring cylinder.

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B. Student's Guide

Purpose/Aim: To determine the density of an irregular object (a solid material) using a measuring cylinder

Background to Experiment

The experimental task is to determine the density of an irregular solid object. Since the volume of an irregular object cannot be determined directly we use indirect means by employing a measuring cylinder method (displacement method).

Density

Density is regarded as the degree of compactness of a material or substance. If a body is very compact, it has a higher density and when less compact, it has a lower density. Density, ρ can be defined as

$$\rho = \frac{\text{mass of the substance}}{\text{volume of the substance}} = \frac{m}{V}$$

Units and standard Prefixes

In physics we sometimes deal with numbers that are very small and other times we deal with numbers which are very large. It gets cumbersome to write numbers in the conventional decimal notation. Once the fundamental units are defined, it now becomes easy to introduce larger and smaller units for the same physical quantities. In the metric system of measurement, additional units always relate to the fundamental units by multiples of 10 or $\frac{1}{10}$. The multiplicative factors are most conveniently expressed in exponential notation; thus $10000 = 10^4$, $\frac{1}{100} = 10^{-2}$ etc. The names of the additional units are always derived by adding a prefix to the name of the fundamental units.

The following are a few examples of the use of the multiples of ten and their prefixes.

1 nanometer = 1nm = 10^{-9} m
1 micrometer = 1μm = 10^{-6} m
1 millimeter = 1mm = 10^{-3} m
1 centimeter = 1cm = 10^{-2} m
1 kilometer = 1km = 10^{3} m
1 milligram = 1mg = 10^{-6}kg
1 gram = 1g = 10^{-3} kg
1 nanosecond = 1ns = 10^{-9} s
1 microsecond = 1μs =10^{-6} s

Eg. To convert 1cm^3 to m^3 you follow the steps below:

Given that: 1 centimeter = 1cm = 10^{-2} m

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$(1\text{cm})^3 = (10^{-2}\ \text{m})^3$
$\therefore 1\text{cm}^3 = 10^{-6}\text{m}^3$

SI standard units
By international agreement, a small number of physical quantities such as length, time and mass (called Fundamental quantities) have been assigned standard units. We can define all other physical quantities in terms of these fundamental quantities. The units of these fundamental quantities are standard units and are both accessible and invariable. The SI unit of density is the kg m^{-3} but in 'cgs' units density is measured in g/cm^3.

E.g. Convert 1g/ cm^3 to kg/m^3.
Solution
$1g = 10^{-3}$ kg
$1cm^3 = 10^{-6}m^3$

$$\Rightarrow 1\frac{g}{cm^3} = \frac{10^{-3}kg}{10^{-6}m^3} = \frac{10^3 kg}{m^3} = 10^3\ kg/m^3$$

Equipment/ Materials/Apparatus
Measuring cylinder, lever balance, water, an irregular object which does not dissolve in water and whose density is to be determined. A sinker should be used if necessary.

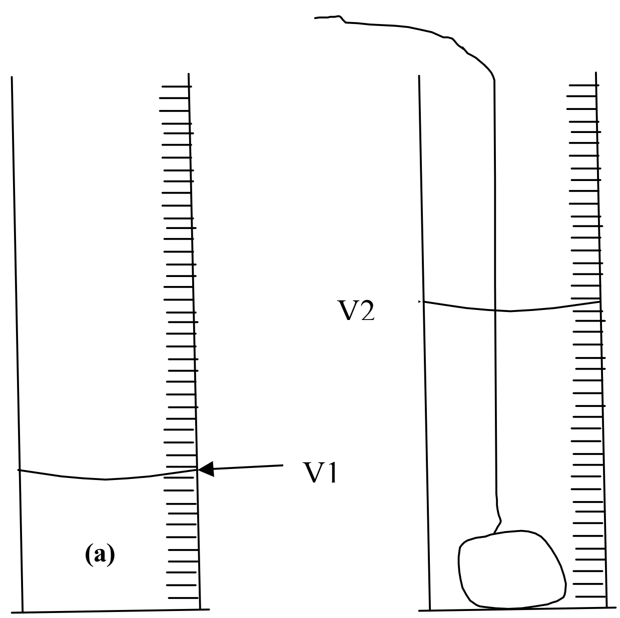

Figure 1 **(a)** initial level of water V1 **(b)** final level of water, V2 after immersion of object

Other requirements
If the solid floats in water, a suitable "sinker" (a known weight to hold down the floating solid) of known volume must be attached to it.

Procedure

(i) Find and record the mass, m, of the object.
(ii) Pour water into the measuring cylinder about a third of its depth
(iii) Record volume V_1, of water in cylinder
(iv) Attach the object to a piece of thread
(v) Lower solid gently into liquid, avoiding splashing
(vi) Record volume V_2, of the water plus solid
(vii) Empty the contents of the cylinder
(viii) Repeat procedure (i) to (vii), using different values of V_1

Results and Calculations
Tabulate your results as shown Table 1 .

Table 1: Table of Results

	V_1/cm^3	V_2/cm^3	$(V_2-V_1)\ /cm^3$
1st recording			
2nd recording			
3rd recording			

Therefore average value of $(V_2 – V_1)$ cm^3=….. cm^3

Theory
The volume of the displaced water = $(V_2 – V_1)$ cm^3
Therefore the volume of the solid = $(V_2 – V_1)$ cm^3
Mass of the solid =…….. (g)

$$density = \frac{mass}{volume}$$

Density of irregular solid = $\dfrac{mass\ of\ \text{solid}\ m\ \text{(g)}}{average\ \text{value of}\ (V_2 - V_1)cm^3}$

Conclusion
The density of the solid = …….kg/m^3

Reflection on the experiment
In place of the measuring cylinder, you can use an eureka can in the determination of the density.

C. Assessment – Student's sheet

On completion of the experiment, you should answer the following questions:

1. Explain the term density. (KN1)

2. How would you measure the volume of an irregular solid object by using a uniform graduated cylinder? (KS1)

3. If a "sinker" (a known weight with known volume used to hold down the floating solid) is attached to the irregular object, how you would determine the density of the irregular object. (KS2)

4. How would you improve the precision of your measurements? (PS1)

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D. References and Other Useful Links

1. Abbot A. F. (1980), *Ordinary Level Physics*, 3rd Edition, Heinemann Books International, London.
2. Moss G. L. (1963), *Ordinary Level Practical Physics*, Heinemann Books International, London.
3. *www.take_home.physics.org*

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