# Teacher packs in Experimental Science

PHY Pack 9

# Determination of the density of liquids

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***Curriculum areas covered:*** Density and relative density

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**Title**: Determination of the density of liquids

***Target group:*** Diploma in Basic Education Students

***Also suitable for:*** B.Ed Primary Education

***Duration of Activity:*** 50 minutes plus discussion time

***Learning outcomes:***

By 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 a liquid. |
| | CS2 | Identify the appropriate apparatus for measuring various quantities involved in determining density. |
| | CS3 | Relate density to relative density. |
| | CS4 | Relate density to daily activities. |
| **3. Key Skills (KS)** | KS1 | Use the measuring cylinder to measure volume. |
| | KS2 | Weigh the liquid on a balance. |
| | KS3 | Determine the density of liquids. |
| **4. Practical Skills (PS)** | PS1 | Make and record observations/measurements |



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# A. Teacher's Guide

**Overview**
Students are asked to find the mass of 100 $cm^3$ each of three given liquids. The students are then asked to determine the density of the liquids using the recorded mass and volume.

**Aim**
This experiment is to enable students use experimental data to establish relationship between two measured quantities. The established relationship can be used to make predictions outside the range of direct measurements.

**Practical Skills developed**
1. Application of scientific methods including observations, measurements, collecting, and tabulating data.
2. Use of significant figures
3. Team work and oral communication.

**Advice to Tutors**
1. Measured quantities should be repeated and averaged.
2. Encourage students to use different types of non-volatile liquids.
3. Students should be taught to record their readings systematically.
4. The reading of the liquid level should be taken at the bottom of the meniscus.
5. Teacher should find time to discuss the Physics principle behind the experiment. The Tutor should also make the students to know that density can be a function of pressure and temperature.

**Sample Assessment Questions with Answers**
1. What is the difference between density and relative density of a material? (CS3)
**Answer:** Relative density is dimensionless whereas density has dimensions.

2. What are the SI units of density? (KN2)
**Answer:** kg/ $m^{-3}$

3. Why is that when two immiscible liquids are shaken together in the same container they separate after sometime? (CS3)
**Answer:** The less dense liquid will float on top of the denser one.

4. How is density useful in our daily activities? (CS4)
**Answer:** An example of real life application of density is "ice floating on water." Ice floats on water because it is less dense than water. Things that are less dense float on top of things that are denser because molecules in ice are further apart than molecules in water.



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## B. Student Guide

You are provided with a measuring cylinder, a beaker, a lever balance and the liquid whose density is to be determined. You need to make a table in which your readings can be recorded. Since the mass of the liquid cannot be measured directly on the balance, you have to pour it into an empty dry beaker before weighing.

**Aim:**
The aim of the experiment is to determine the density of a liquid using the materials provided. You are expected to use the measuring cylinder and the chemical balance for this experiment

### Background to the Experiment
Density is regarded as the degree of compactness of a material or substance. Density is a physical property of matter used in characterizing substances. If a body is very compact, it has a higher density and when less compact, it has a lower density. Density, $\rho$ can be defined as

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

A substance denser than water sinks in water and one less dense than water floats on it. This property is very important in the construction of ships, canoes, boats and other marine vessels. The experimental task is to determine the density of a liquid. This experiment can be performed with *density bottles* but we are using the measuring cylinder because it is readily available and also less expensive.

**Relative Density**

$$\textit{relative density } (RD) = \frac{\text{density of the substance}}{\text{densiy of the water}} = \frac{\rho_{subs\tan ce}}{\rho_{water}}$$

**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


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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 = 1 μs = $10^{-6}$s

**Eg.** To convert 1cm$^3$ to m$^3$ you follow the steps below:
**Solution:** Given that: 1 centimeter = 1cm = $10^{-2}$ m
$(1cm)^3 = (10^{-2}\ m)^3$ , $\therefore$ $1cm^3 = 10^{-6}m^3$

**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$^3$

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

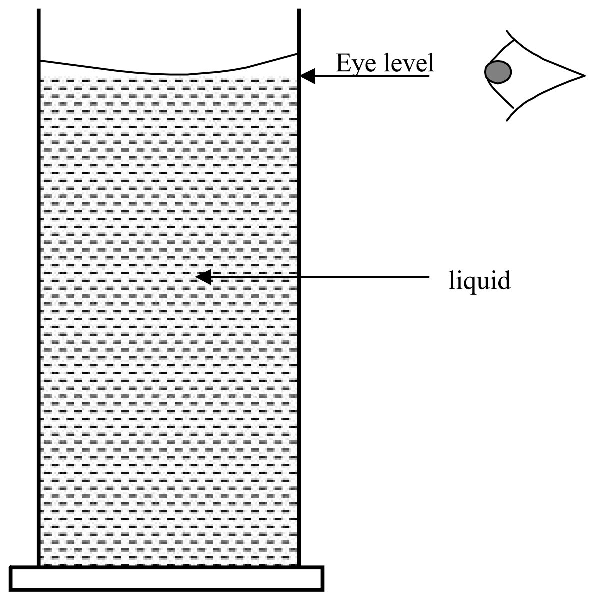
**Equipment/ Materials Needed**
Measuring cylinder, lever balance, a beaker, the liquid whose density is to be determined.

**Instructions**
You will be working in small groups to determine the density of three liquids (ie. Cooking oil, glycerine and water).

1. Place a dry empty beaker on a balance and find its mass.
2. Use the measuring cylinder to measure exactly 100 cm$^3$ of the given liquid and pour all into the beaker.
3. Now, weigh the beaker with the liquid in it and find the mass.
4. Work out the difference in readings to find the mass of the liquid.
5. Record the results and calculate the density of the liquid.
6. The experiment should be repeated by using the two other liquids provided.
7. Use the density of water to find the relative densities of the cooking oil and the glycerine.

**Procedure**

1. Place a dry empty beaker on a balance and find its mass.
2. Use a measuring cylinder to pour exactly 100cm$^3$ of the given liquid into the beaker.
3. Weigh the beaker with the liquid in it and find the mass.
4. Work out the difference in readings to find the mass of the liquid.
5. Record the results and find the density of the liquid.
6. Repeat the experiment by using two or more liquids (eg. Tap Water, sea water, cooking oil, etc.).




Measuring cylinder

**Results and Calculations**

| | $m_1$ /g | $m_2$/g | ($m_1$- $m_2$ ) /g |
|---|---|---|---|
| Liquid 1 | | | |
| Liquid 2 | | | |
| Water | | | |

**Theory**
Mass of the empty beaker, $m_1$ =
Mass of 100 $cm^3$ of liquid and beaker $m_2$ =
Mass of 100 $cm^3$ of liquid only ($m_2 - m_1$) =

$$Density = \frac{mass}{volume} = \frac{m_2 - m_1}{100}\, g/cm^3 = (\ldots)\, kg/m^3$$

**Discussion**
Compare the densities of the liquids used. Use the density of water to find the relative densities of the other liquids.

**Reflection on the experiment**
Other liquids such as engine oil, vegetable oil can be used to perform the experiment.

# C. Assessment – Student's sheet

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

1. What is the difference between density and relative density of a material? (CS3)

2. What are the SI units of density? (KN2)

3. When two immiscible liquids are shaken together in the same container they separate after sometime. Why is this so? (CS3)

4. How is density useful in our daily activities? (CS4)

## D. Extensions to experiment

1. Use density bottles to perform the same experiment and compare your results with what you have just done.

2. Did you get anything different from your previous results?

3. If the two results did not tally, then find out what might have accounted for it.

## E. References and Other Useful Links

1. Abbot A. F. (1980), *Ordinary Level Physics*, 3rd Edition, Heinemann Books International, London.

2. Nelkon M. and Parker P., (1987), Advanced Level Physics, Heinemann Educational Publishers, London.

3. http://wiki.answers.com/

## F. Health and Safety

1. Care should be taken when transferring the liquid from the measuring cylinder into the beaker to avoid splashing on the ground.

2. Oil can support burning so make sure no fire comes close to the area of the experiment.

3. Wash hands with soap and water after the experiments.