# Purposeful Practicals

# Determining density of an irregular solid

This Practical Pack is part of OCR's Purposeful Practicals. This resource can be used to contribute to PAG P1 and is referenced in the Practical Menu (P1). There are also accompanying Integrated Instructions for students to use.

## Aim

To take appropriate measurements of mass and volume and to calculate the density of irregularly shaped solid materials using gathered data.

Time required for activity: 40 minutes.

## Introduction

Students will accurately measure the volume of an irregular shaped solid using the water displacement method and the mass of the solid using a mass balance. Students will use these measurements to calculate the density of the solid material.

## Specification theory content links

**Physics A J249:** P1.1d, P1.1f, M1a, M1b, M1c, M3c, WS1.2b, WS1.2c, WS1.3c, WS1.3d, WS1.4a, WS1.4b, WS1.4e, WS1.4f, WS2a, WS2b, WS2c, WS2d

## Health and safety

|  |  |
| --- | --- |
| **Hazards** | **Mitigations** |
| Spilling water on the floor creating a slip hazardDanger icon | Make sure water displacement is done slowly and carefully to avoid spillage and immediately clean up any spilled water. |

## Technician notes

Ideally displacement (Eureka) cans are used for this experiment. These are cans with a spout so that the water can run out into a measuring cylinder. The can needs to be large enough to fit the plasticine inside. If these are not available, the students can instead use large beakers that have a volume scale on the side.

The students will need to use a fairly large piece of plasticine for the experiment to work well, they should aim to make an irregular shape with a diameter of at least 6cm, so best to only give them the amount they will need.

Thread or string with a small diameter will work best so that it does not add to the volume measured.

## Equipment

Each group will need:

* mass balance
* measuring cylinder
* access to water
* lump of plasticine
* displacement (Eureka) can or large beaker with volume scale
* string or thread.

## Procedure and procedural understanding

### Method 1 - Using a displacement can

|  |  |
| --- | --- |
| **Procedure** | **Understanding** |
| 1. Use the plasticine to create an irregular shape and trap the end of the string inside the plasticine so that it can be used to lower the plasticine into water.
 |  |
| 1. Measure the mass of the plasticine using the mass balance. Record the result in the table below.
 | What is the resolution of the balance?Is the mass balance showing zero before the plasticine is placed? (Press the ‘tare’ button to zero the balance.)Why is it important that the string is thin and light?Why is it better to measure the mass before the plasticine is placed in water? |
| 1. With the displacement can positioned over a sink, fill the displacement can with water until water starts to pour out of the spout. Position the can on a horizontal surface and wait for the water to stop pouring out.
 | Why is it important to keep the can on a horizontal surface while the water runs out? |
| 1. Position the measuring cylinder under the spout of the displacement can and very slowly lower the plasticine into the can using the string.
 | The plasticine must all be submerged. How would the measurement of volume be affected if some of the plasticine is above the water?How would your volume measurement be affected if you dropped the plasticine in too quickly? |
| 1. Position the measuring cylinder on a horizontal surface and measure the volume of the water at eye level. (1ml = 1cm3.) Record the volume in the table.
 | Why is it important to measure at eye level?Have you read the volume from the bottom of the meniscus of the liquid?Why is it important to have the cylinder on a horizontal surface before measuring?Is this volume exactly equal to the volume of the plasticine? |
| 1. Calculate the density of the plasticine using the equation:

Record the density in the table. |  |

| **Mass of plasticine (g)** | **Volume of plasticine (cm3)** | **Density of plasticine (g / cm3)** |
| --- | --- | --- |
|  |  |  |

### Method 2 – Using a beaker with a volume scale

|  |  |
| --- | --- |
| **Procedure** | **Understanding** |
| 1. Use the plasticine to create an irregular shape and trap the end of the string inside the plasticine so that it can be used to lower the plasticine into water.
 |  |
| 1. Measure the mass of the plasticine using the mass balance. Record the result in the table below.
 | What is the resolution of the balance?Is the mass balance showing zero before the plasticine is placed? (Press the ‘tare’ button to zero the balance.)Why is it important that the string is thin and light?Why is it better to measure the mass before the plasticine is placed in water? |
| 1. Fill the beaker with enough water so that the plasticine shape can easily be fully submerged into the water without the water spilling out of the beaker. Read the initial volume of the water and record it in the table below.
 | Why is it important for the water to completely cover the plasticine when it is submerged?Why is it important that no water spills over the sides when the plasticine is lowered in? |
| 1. Position the beaker on a horizontal surface and very slowly lower the plasticine into the can using the string. Read the final volume of the water and record it in the table.
 | How would your volume measurement be affected if you dropped the plasticine in too quickly?Why is it important to measure at eye level?Have you read the volume from the bottom of the meniscus of the liquid?Why is it important to have the beaker on a horizontal surface before measuring? |
| 1. Calculate the volume of the plasticine by subtracting the initial volume from the final volume of water.
 | Is this volume exactly equal to the volume of the plasticine?What is the resolution of the scale on the beaker. |
| 1. Calculate the density of the plasticine using the equation:

Record the density in the table. |  |

| **Mass of plasticine (g)** | **Initial volume of water (cm3)** | **Final volume of water (cm3)** | **Volume of plasticine (cm3)** | **Density of plasticine (g / cm3)** |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |

## Further questions

1. Describe the sources of error in the experiment.
2. Describe how the experiment could be improved to minimise these errors.
3. Describe a different method that could have been used to determine the volume of the plasticine instead of using the water displacement method.
4. A student suggests that it wouldn’t make a difference to the results if a thicker piece a string were used in this experiment, since both the mass and volume of the string would be increased, so it wouldn’t affect the calculated density of the plasticine. Discuss whether the student is correct.
5. A scientist uses the displacement method to measure the density of three samples of a metal. It is suspected that the three samples are all made from the same metal and so should have the same density. The scientist’s data is shown in the table.

| **Sample of a metal** | **Density of metal (kg / m3)** |
| --- | --- |
| P | 7765 |
| Q | 7738 |
| R | 7791 |

1. The scientist decides to repeat the experiment for each of the samples. Explain why it is important for the scientist to do this.
2. The repeated results are shown in the table below.

|  |  |
| --- | --- |
| **Sample of a metal** | **Density of metal (kg / m3)** |
| P | 7767 |
| Q | 7741 |
| R | 7725 |

The scientist decides that the experiment should be repeated once more for one of the samples. Explain which sample density should be repeated.

1. The scientist calculates a mean density for each of the samples. Explain why calculating a mean density from a series of repeat measurements is better than just using a single measurement.
2. The scientist determines the density of a fourth sample (sample S). The density measurement is repeated three times. The density measurements are shown in the table below.

| **Sample of a metal** | **Density measurement 1** **(kg / m3)** | **Density measurement 2****(kg / m3)** | **Density measurement 3** **(****kg / m3)** | **Mean density of metal****(kg / m3)** |
| --- | --- | --- | --- | --- |
| S | 7742 | 7797 | 7738 |  |

The scientist decides to omit repeat 2 when calculating the mean density for this sample.

1. Explain why the scientist does this.
2. Calculate the mean density (omitting measurement 2).
3. Describe what the scientist should have done, instead of just omitting measurement 2, to improve the quality of the data.

### Answers

1. Some water may not run into measuring cylinder / not waiting long enough for water to stop dripping out of displacement can / volume scale not read at eye level / mass and volume of string will be included in measurements / pieces of plasticine may fall off when it is handled between measurements / water volume read when cylinder is not on a horizontal surface / water splashed out of container when plasticine lowered in / resolution of balance and measuring cylinder.
2. Wait until all the water has run into measuring cylinder / make sure measuring cylinder is on a horizontal surface and the scale is at eye level, measuring at the meniscus / use a very thin light thread instead of string / do not touch the plasticine with your hands, move it around very carefully using the thread that is attached to avoid pieces falling off / lower the plasticine into the water very slowly / use measuring instruments with a higher resolution / repeat the experiment and calculate an average density.
3. Plasticine could be moulded into a regular shape such as a cuboid or a sphere and the volume be found by directly measuring the dimensions. This method would likely lead to a less accurate value of density since it would be difficult to create a uniform shape.
4. The student is wrong. The string would add to both the mass and the volume measurement, but the density of the string is not the same as the density of the plasticine and so the ratio of the mass to the volume of the string is not the same as the ratio for the plasticine.
5. Repeat readings show whether the experiment is repeatable. If the same person using the same equipment obtains several repeat readings that are all close to each other, then the measurement is repeatable.

If one reading stands out as very different from the others, this can be checked (with a further repeat).

An average of the repeat readings is often used - this is likely to reduce the effect of any random errors that occurred.

1. The two results for metal R are quite far apart, so the density measurement should be repeated for R. It could be that the readings have a larger random error, or it could be that one of the readings was anomalous.
2. An average of the repeat readings is likely to reduce the effect of any random errors that occurred.
3. Because measurement 2 is very different from measurement 1 and 3. Measurement 1 and 3 are close together, so it is best to treat measurement 2 as anomalous and omit it.
4. 7740 kg/m3
5. The scientist should have repeated measurement 2 again and maybe even done further repeats to check if those repeats were close to 7740 kg/m3.

## Practical skills, apparatus and techniques assessed

|  |  |  |
| --- | --- | --- |
| a | **Reference** | **Description of skill/technique** |
|  | 1aiii | Measure **mass** of irregular solid with a mass balance. |
|  | 1av | Measure **volume** of displaced water with a measuring cylinder. |
|  | 1bi | Use of measurements to determine the density of a solid. |

## Scientific and practical understanding

### Anomalous data

A result that is very different from the other readings in a set of repeats is anomalous. An anomalous result can be ignored if it is considered to be a mistake.

### Density

Calculated by dividing the mass of the plasticine by its volume.

### Mass

Measured using the mass balance.

### Mass balance

A mass balance is used to measure the mass of the plasticine. For this activity, the resolution of the mass balance might be 1 g or 0.1 g.

### Mean

A type of average where all the numbers are added together and then the sum total is divided by the number of values added.

### Measurement error

Minimise errors during measurement by carefully reading the measuring cylinder and correctly using the mass balance.

### Measuring cylinder

Used to measure the volume of the displaced water.

### Meniscus

Ensuring the volume is read at the bottom of the meniscus to increase accuracy when using the measuring cylinder.

### Resolution

The smallest measurement that can be made by the measuring instrument. In this experiment it is the smallest scale division on the measuring cylinder and the smallest mass change that can be measured on the mass balance. The resolution of a beaker is much worse than the resolution of a measuring cylinder, so the uncertainty will generally be better if a measuring cylinder is used to measure the volume of displaced water.

### Tare

Setting the mass balance to zero before measuring the mass.

### Volume

In this activity, the volume of the plasticine is measured by measuring the volume of the water it displaces.

### Practical understanding

Students are able to:

* follow written instructions
* take measurements of mass
* take measurements of volume using a displacement method
* comment on the errors in the experiment
* comment on the importance of repeating and averaging

### Scientific understanding

* calculate density using measurements

Notes and references

Health and safety should always be considered by a centre before undertaking any practical work. A full risk assessment of any activity should be undertaken including checking the [CLEAPSS](https://science.cleapss.org.uk/) website.

Centres should trial experiments in advance of giving them to students.

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