# Purposeful Practicals

# Determining density of a regular 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 regularly shaped solid materials using gathered data.

Time taken: 20 minutes

## Introduction

Students will use a ruler to measure the dimensions of some regularly shaped solid objects to calculate the volume of each object. Students will also measure the mass of each object using a mass balance and finally use these measurements to calculate the density of the materials that each object is made from.

## Specification content links

**Physics B 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 |
| --- | --- |
| Hazard symbolDropping heavy objects on feet | Handle heavy objects with care and don’t place them near the edge of the desk. |

## Technician notes

Regular shaped (cuboid) objects made from three different materials are required, for example, wood, plastic and some type of metal or wood and two different types of metal. Objects do not need to be the same size, but they must be cuboid in shape. If the blocks of one the materials have slightly rounded corners or edges, this is useful as a teaching point. The mass balance must have an upper limit that is beyond the mass of the heaviest object to be measured.

## Equipment

Each group will need:

* cuboid block of material 1
* cuboid block of material 2
* cuboid block of material 3
* mass balance
* ruler (with mm marks; long enough to measure longest side of largest cuboid).

*h*

*d*

*w*

Fig 1

## Procedure and procedural understanding

| Procedure | Understanding |
| --- | --- |
| 1. Your teacher will tell you which block is material 1, which is material 2 and which is material 3. |  |
| 1. Measure the height, *h*, width, *w,* and depth, *d*, of one of the blocks with a ruler. These measurements are shown on **Fig. 1**. | The data should be recorded in the table to the resolution of the equipment. So, using the ruler each length should be measured to the nearest 0.1 cm.  Is the block really a cuboid? Does it have sharp edges and corners, or are they rounded? Why is it a good idea to measure each length multiple times in different places? |
| 1. Measure the mass of the block using the mass balance. Record the mass in grams in the table to the resolution of the mass balance. | What is the resolution of the balance?  Is the mass balance showing zero before the cylinder is placed? (Press the ‘tare’ button to zero the balance.) |
| 1. Calculate the volume, *V*, of the block using the equation: | The number of significant figures of a calculated value should be equal to the lowest number of significant figures in the data used.  How many significant figures should your calculated volume have? |
| 1. Calculate the density of the **material** of the block, using the equation: | How many significant figures should your calculated density have?  Would the density be the same if the experiment was repeated with a larger block made from the same material? |
| 1. Repeat steps 2 to 5 using the blocks made from the other two materials. | Will the heaviest block always have the largest density? |

| Block made from | Height of block (cm) | Width of block (cm) | Depth of block (cm) | Volume of block (cm3) | Mass of block (g) | Density of material  (g / cm3) |
| --- | --- | --- | --- | --- | --- | --- |
| Material 1 |  |  |  |  |  |  |
| Material 2 |  |  |  |  |  |  |
| Material 3 |  |  |  |  |  |  |

## Further questions

1. A student can choose which mass balance they use. Four different mass balances are available: A, B, C and D. The table below shows the resolution of each balance (the smallest difference in mass readings that the balance can show) and the capacity of each balance (the largest mass that it can measure).

| Mass balance | Resolution (g) | Capacity (g) |
| --- | --- | --- |
| A | 0.01 | 2000 |
| B | 0.1 | 1000 |
| C | 1 | 2500 |
| D | 0.01 | 500 |

1. The student needs to measure the masses of three blocks with approximate masses of 800 g, 400 g and 150 g. They choose balance B. Explain why balance B is more suitable than balance D. Which balance would be better that B for these blocks?
2. A student needs to measure the mass of a block of approximately 450 g. Why is balance D better than balance B for this measurement?
3. The table below gives some data on two different unknown clear liquids, X and Y that look like water.
4. They use a 15 cm ruler with mm marks. What is the resolution of this measuring instrument?
5. Why is it better to measure each width more than once?
6. The student notices that the edges are slightly rounded. Which of the following actions is sensible?
7. Make a note that this block had rounded edges.
8. Use a 15 cm ruler without mm marks.
9. Measure the width across the middle of the block.
10. Measure the width along the straight part of the edge of the block.

3. The table below contains the dimensions of two blocks of iron measured with a 15 cm ruler with mm marks and their mass measured with a mass balance with a resolution of 1 g. All measurements were taken at room temperature.

|  | Height of block (cm) | Width of block (cm) | Depth of block (cm) | Volume of block (cm3) | Mass of block (g) | Density of material  (g / cm3) |
| --- | --- | --- | --- | --- | --- | --- |
| Large block of iron | 5.2 | 14.5 | 9.4 |  | 5472 |  |
| Small block of iron | 1.7 | 2.1 | 1,2 |  | 32 |  |

1. Calculate the density of iron using the data from each block of iron.
2. The true value for the density of iron is 7.9g / cm3 at room temperature. Give a reason why the density calculated from the large block is closer to the true value than the density calculated from the small block.
3. The resolution of the equipment used to measure each block is the same. The resolution of the mass balance is 1 g, which is why the mass is measured to the nearest gram. This means there is an uncertainty in each mass measurement of ± 0.5g. Calculate the percentage uncertainty of each mass using this equation:
4. The height, width and depth were all measured with a ruler whose resolution was 0.1 cm. If the estimated uncertainty in any length measurement is ± 0.1 cm, calculate the percentage uncertainty in the smallest length measurement of each material.
5. Use your answers to part c) and part d) to explain why the error in the calculated density for the small block is larger than the error in the calculated density for the large block.

## Answers



a) The capacity of balance D is too small for the 800 g block; this means it is not suitable for measuring the mass of this block. The capacity of B is more than the mass of the 800 g block, so it is suitable.

Balance A would be better than B for these three blocks. Its capacity is large enough for each of the three blocks (so it is suitable), and its resolution (0.01 g) is better than the resolution of balance B (0.1 g).

1. Both balances (B and D) have a large enough capacity, so both would be suitable. Balance D has a resolution of 0.01 g; this is better than the (0.1 g) resolution of balance B.
2. Errors in measurements – e.g. ruler only measures to nearest mm / mass balance only measures to nearest 0.1 g / edges of block may be worn so measurements are not accurate.
3. The percentage difference gives an idea of accuracy, the smaller the number the closer the calculated density is to the actual value. However, the percentage difference only gives us a valid measure of accuracy if the uncertainty in the calculated value is low. If there is error in the calculated value then the percentage difference value isn’t as valid as the magnitude of the calculated value isn’t definitely known.

a) The resolution is 0.1 cm or 1 mm.

b) Measuring more than once will help to show that the density measurement is repeatable. If the student makes a mistake in reading the ruler or in writing the value down, the repeat readings may help them notice the mistake. If the block is not actually a cuboid, its width might vary, e.g. it might be narrower at one end than at the other.

3.

a) Large block = 7.7 g / cm3 Small block = 7.5 g / cm3

b) Greater error in the small block measurements.

c) Large block = 0.0091% (or 0.009%, as uncertainty is only given to one significant figure)

Small block = 1.6% (or 2%, as uncertainty is only given to one significant figure)

d) Large block, percentage uncertainty = (0.1 ÷ 5.2) × 100% = 1.9% (or 2%, to one significant figure)

Small block, percentage uncertainty = (0.1 ÷ 1.2) × 100% = 8.3% (or 8%, to one significant figure)

e) The percentage uncertainty in the mass measurement is bigger for the small block (than it is for the large block). The percentage uncertainty in the length measurements is bigger for the small block (than it is for the large block). The largest percentage uncertainty is in length measurements for the small block. As the mass and length measurements of the small block have the bigger percentage uncertainties than the measurements of the large block, the percentage uncertainty in the density will be bigger for the small block.

### Practical skills, apparatus and techniques assessed

| a | Reference | Description of skill/technique |
| --- | --- | --- |
|  | 1ai | Measure **length** (height, width and depth) of blocks with a ruler. |
|  | 1aiii | Measure **mass** with a mass balance. |
|  | 1bi | Use of measurements to determine the density of a solid. |

## Scientific and practical understanding

### Accuracy

How close a measured or calculated value is to the true value.

### Density

Calculated by dividing the mass of the solid by its volume:

Dimensions

The measurements of the solid's length, width, and height.

Mass

Measured using the mass balance.

Mass balance

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

Measurement error

Measurement errors can be minimised by carefully using the ruler and mass balance.

## Percentage uncertainty

Instruments with better resolution can help to keep the percentage uncertainty small. If percentage uncertainties are large, then the calculate value may not be accurate**.**

Resolution

For a measuring instrument, resolution is the smallest difference that the instrument can detect or show. For a ruler with millimetre marks, the resolution is 1 mm or 0.1 cm. If the resolution is poor, then the percentage uncertainty will be larger.

### Ruler

Used to measure the dimensions (length, width, height) of the solid.

### Volume

Calculated by multiplying the measured dimensions of the cuboid solid   
(volume = height × width × depth).

### Practical understanding

Students are able to:

* follow written instructions
* take measurements of mass
* take measurements of length dimensions to calculate volume
* calculate the percentage difference
* comment on the accuracy of the calculated density
* comment on the errors in the experiment
* consider the percentage uncertainty of measurements.

### 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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