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1 Making measurements

In this chapter, you will complete investigations on:

- ◆ **1.1** Measuring length and time
- ◆ **1.4** Density

Overview

Throughout the chapter you will be aiming towards:
- taking accurate readings from a range of measuring devices
- taking a sufficient range of measurements, repeating where necessary, to obtain an average (mean) value
- presenting and analysing data graphically.

Practical investigation 1.1 Estimating measurements

Objective

You probably make estimates of time, distance and space on a daily basis, without realising it. Taking accurate measurements is crucial. A doctor must be accurate in measuring out a volume of medicine to treat a patient correctly. An engineer must measure the forces on a suspension bridge accurately to ensure the bridge will remain firm under a variety of conditions. In these examples, inaccurate measurements could be catastrophic.
In this investigation you will take accurate measurements of mass, weight, temperature, time and distance to compare them with your estimated values.

Equipment

- metre rule
- stopwatch
- thermometer
- top-pan balance
- newton scale
- micrometer screw gauge
- 30 cm rule

Method

1. Look at everything you are going to measure (below). Estimate each value and record your estimates in the table that has been provided.
2. Take measurements of:
   - your partner's height (in cm)
   - how long it takes a student to perform 10 star jumps
   - the length, width and thickness of a glass block (measured with a micrometer screw gauge)
   - the diameter of a piece of wire

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- the temperature of a glass of ice water
- the mass of a bag of sugar
- the diameter of a steel ball bearing (using a micrometer screw gauge).

3 Record your accurate measurements in the table.

Safety considerations

Before you start recording the time for star jumps, check that the surrounding area is clear of obstructions. Check the floor for steel ball bearings in case anyone slips on them. Check with your teacher that your footwear is suitable for this task.

Recording data

1 Record your measurements in the table. Remember to include the appropriate units.

Measurement being taken	Estimated value	Measured value

Analysis

2 Are your estimated and measured values very different? Use the data in your table to compare your answers.

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3 Calculate the volume of the glass block, based on the measurements you have taken.

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4 Using a 30 cm rule, re-measure the glass block. Calculate its volume, based on these measurements. Is there a difference between your two values?

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Evaluation

5 Suggest one reason why your volume measurements for the glass block might be different.

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6 Were the measuring instruments that you chose, suitable in each case? If not, suggest what other instrument you could have used.

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7 List three of the instruments you used and give the precision of these instruments. The precision of an instrument is the smallest scale division on the instrument.

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Practical investigation 1.2 Determining π

Objective

There are relationships between many variables in science. One such is the relationship between the circumference and the diameter of a circle. Engineers use this relationship to balance the blades on a helicopter, mechanics use it when fitting tyres and bakers might use it when baking circular pies.

In this investigation you will use two different measuring methods to determine the relationship between the diameter and circumference of a circle. You will use a graph to show the relationship between the two variables. When you have plotted the points on your graph, you will need to draw a **line of best fit**. It should go through as many of the points as possible, with roughly equal numbers of points above and below it. For this investigation, the line of best fit will be a straight line that shows the trend of the plotted points.

Equipment

- 6 modelling clay balls of varying sizes
- micrometer screw gauge
- string
- ruler

Method

1. Select a ball and measure its diameter across its centre, using the micrometer screw gauge. Take care not to squash the ball out of shape. Record your measurement in the table below.
2. Repeat the measurement in two different places across the ball. Record the measurements in the table and find the average (mean) of all three.
3. Loop a piece of string around the ball snugly. Mark the string where it overlaps, passing once around the ball. Remove the string and use the 30 cm ruler to measure the distance between the marks on the string. Record the value in the table provided.
4. Repeat steps 1–3 for five more balls.

Safety considerations

Take care when handling the modelling clay. To prevent slipping, ensure you do not leave any of the balls on the floor.

Recording data

1. Record your measurements in the table.

   NB When recording your data in the table you do not need to include the units next to every reading, **provided that they are included in the table headings**. Make sure you record all values to the same number of decimal places.

Ball	Diameter of ball / cm				Circumference / cm
	1	2	3	Average	
1					
2					
3					
4					
5					
6					

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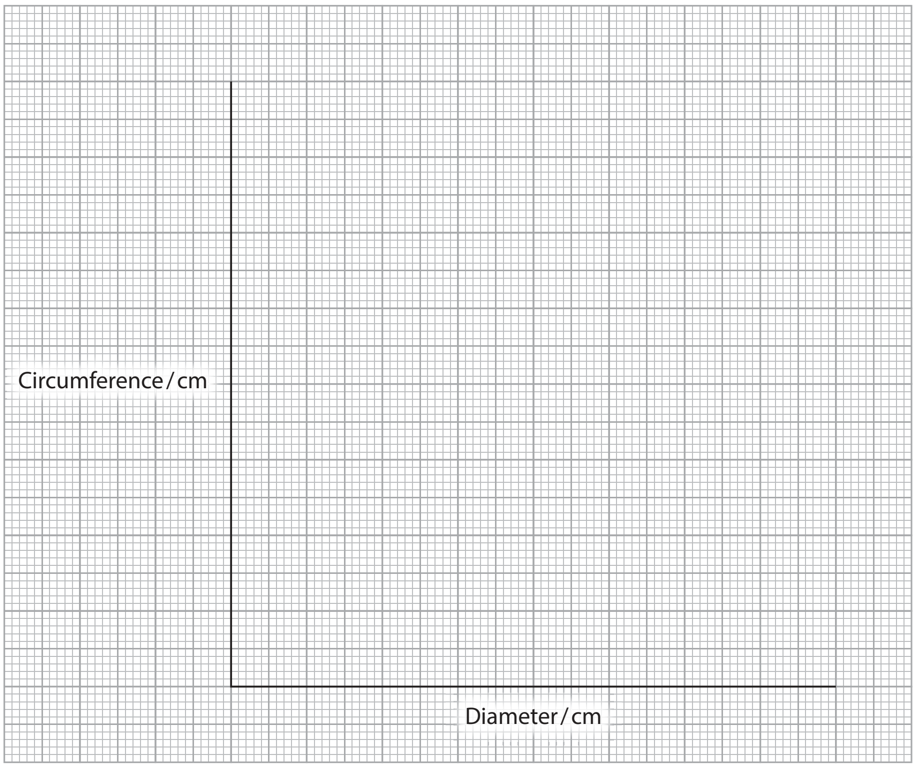
Handling data

2 Plot a graph of your results on the axes below.

NB You will need to choose a suitable scale, so that your plot is laid out across the grid clearly. As a general rule it is best to use scales that are easy to follow. For example, choose a scale in which each square represents multiples of 2, 5 or 10. Always label the axis beyond your highest values, for example, if the highest value is 38, number the axis to at least 40.



3 Draw the line of best fit on your graph.

Analysis

4 Now look at the line of best fit. Describe its appearance and state any key points through which it passes.

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5 The circumference and diameter of a circle are directly proportional. On a graph, this is represented by a straight line through the origin. Does your graph support this relationship? Give reasons for your answer.

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6 Calculate the gradient of your graph.

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7 The equation for the circumference, C, of a circle is:
$C = \pi d$
where π is a constant of approximate value 3.14 and d represents the diameter of the circle.
Do your results agree with this equation?
Use the gradient of your graph to help support your answer.

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Evaluation

8 State another way in which you could have measured the circumference of the ball.

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9 Which of these methods is more accurate? Give reasons for your answer.

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10 Explain why you needed to take three measurements across each ball.

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11 The gradient of your line should be close to 3.14. Suggest one reason why your value might differ from this and from those of other students.

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Practical investigation 1.3 The simple pendulum

Objective

Pendulums are used in everyday life, for example, in clocks and metronomes, to help us keep time, and in construction to protect buildings from damage during earthquakes. A swing in the park is an example of a pendulum. Do you think you would swing more quickly if the swing was shorter in length? In this investigation you will test whether the length of the pendulum affects the time period of oscillation.

Prediction

Physicists often make predictions or hypotheses, based on the information they have. They then use this as a basis for their investigation. An example of a prediction for this experiment could be:

The length of a pendulum has no effect on the time period of a pendulum.'

Write your own prediction for this investigation.

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Equipment

- pendulum bob
- string
- 2 small rectangular pieces of wood or corkboard
- clamp stand
- clamp
- boss
- stopwatch
- ruler
- C clamp

Method

1. Hang the pendulum from the clamp stand and wait for it to come to rest.
2. Use the ruler to measure the length of the pendulum from the pendulum's point of suspension to the center of mass of its bob.
3. Keeping the string taut, move the pendulum bob to one side and release it, allowing it to swing at a steady pace. Use the stopwatch to time 10 complete oscillations.
4. Repeat twice more and take an average of the results.
5. Repeat for four different lengths of pendulum.

Safety considerations

Clamp the stand to the bench to ensure it is stable and cannot fall over and cause injury.
Release the pendulum through small angles from the vertical, to prevent injury.

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Recording data

1 Record your measurements in the table.

Length of pendulum / cm	Time taken for 10 oscillations / s				Time taken for 1 oscillation / s
	1	2	3	Average (mean)	

Analysis

2 Sketch a graph of length against time period.

3 Using your results, state and explain whether the length of the pendulum has an effect on the time period of an oscillation.

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Evaluation

4 Suggest another variable that might affect the time period of an oscillation.

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5 Another student conducts the same investigation but finds it difficult to count the oscillations accurately. How could she improve your method to ensure that she counts the oscillations correctly?

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6 She also decided to time ten oscillations. Why is it more accurate to record the time taken for ten oscillations than just for one?

Practical investigation 1.4 Calculating the density of liquids

Objective

Knowing the density of materials can be very useful in engineering, architecture – and even in predicting the weather! Density plays an important role in buoyancy. Substances with a lower density float on substances with a greater density. For example, warmer air floats on top of cooler, more dense air. This drives weather systems. In this investigation you will determine the densities of three common fluids.

Equipment

- 100 ml measuring cylinder
- oil
- salt-water solution
- water
- balance

Method

1 Place the measuring cylinder on the balance and set it to zero.
2 Add 50 ml of water to the measuring cylinder. Record the mass and volume in the table below.
3 Repeat for 10 ml increments of water, up to a maximum of 100 ml. Record the mass and volume of the water in the table below.
4 Empty and dry the measuring cylinder. Now repeat the above procedure for the salt-water solution and the oil.

Safety considerations

Wear goggles to ensure no oil or salt-water solution gets into your eyes. Rinse immediately if this occurs.
Clear any spillages immediately to prevent slipping.

Recording data

1 Record your measurements in the tables.

Water

Mass / g	Volume / cm^3

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Salt-water solution

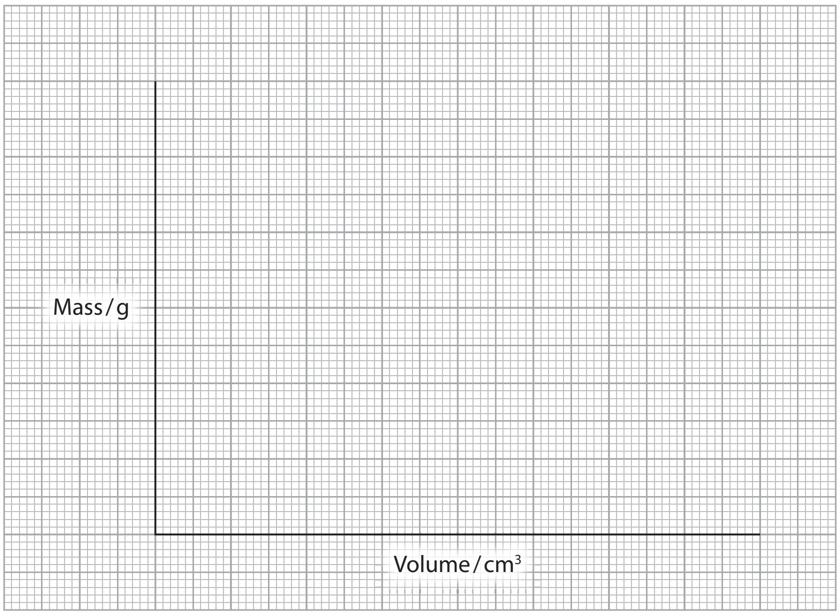
Mass / g	Volume / cm^3

Oil

Mass / g	Volume / cm^3

Handling data

2 Use your results to plot a graph of volume against mass for each of the liquids you have measured. Plot all three graphs on the grid below.
When you draw the graph, label each axis and include the appropriate unit. For this graph, plot the volume along the horizontal axis and the mass up the vertical axis.
Remember to choose an appropriate scale for your each axis.



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Analysis

3 Draw a line of best fit for each of the liquids you have tested. Label them clearly.

4 The gradient of the line of best fit in each graph is equal to the density of the fluid. By looking at your graph, can you predict which has the highest density? In the space below, explain how you can make this assumption by sight alone.

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5 Now calculate the gradient of each of the lines of best fit. Do your values support your answer to question **4**?

<u>Water</u>

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<u>Oil</u>

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<u>Salt-water solution</u>

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6 Fluids that are less dense float on top of more dense substances. In the measuring beaker in Figure 1.1, draw in the order in which the fluids would settle, labelling each one clearly.

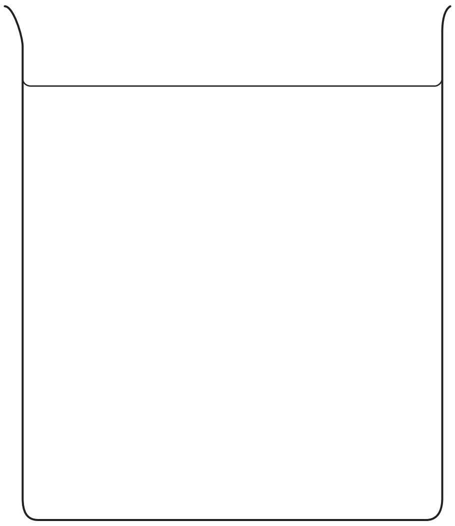

Figure 1.1

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Evaluation

7 Your teacher will give you the actual values of density for the fluids you have tested. How do your results compare? Suggest two reasons why your results may be different.

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8 An oil spill occurs out at sea. A student suggests that a clean-up operation would be impossible because the two substances would mix. Do you think the student is correct? Comment on the student's statement, relating it to the experiment you have conducted here.

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Exam-style questions

A student has been asked to determine the material from which a key is made (Figure 1.2).

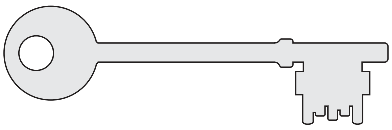

Figure 1.2

The student has been given the table below, which lists the densities of a variety of common metals based on measurements taken from 1 cm^3 metal blocks found in the laboratory.

Type of metal	Density / g/cm^3
aluminium	2.7
iron	7.9
lead	11.4
steel	8.4

The student fills a measuring cylinder with water and carefully adds the key, using another measuring cylinder to collect the water that is displaced. The displaced water collected in the measuring cylinder is displayed in Figure 1.3.

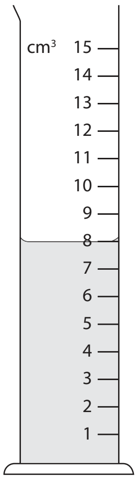

Figure 1.3

1 Show clearly on the diagram the line of sight you would use to obtain an accurate reading. [2]

2 State the volume of the key. [1]

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3 The student then takes the key, dries it and uses a balance to measure its mass. The mass of the key is 65.01 g. Calculate the density of the material from which the key is made. [3]

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4 Refer to the table above to determine the metal from which the key is most likely to be made. [1]

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