1 Making measurements

In this chapter, you will find out

- How to make measurements of length, volume and time
- How to increase the precision of measurements of length and time
- How to determine the densities of solids and liquids

Contents

1.1 Measuring length and volume

Measuring lengths with a ruler is a familiar task. But when you use a ruler, it is worth thinking about the task and just how reliable your measurements may be. Consider measuring the length of a piece of wire.

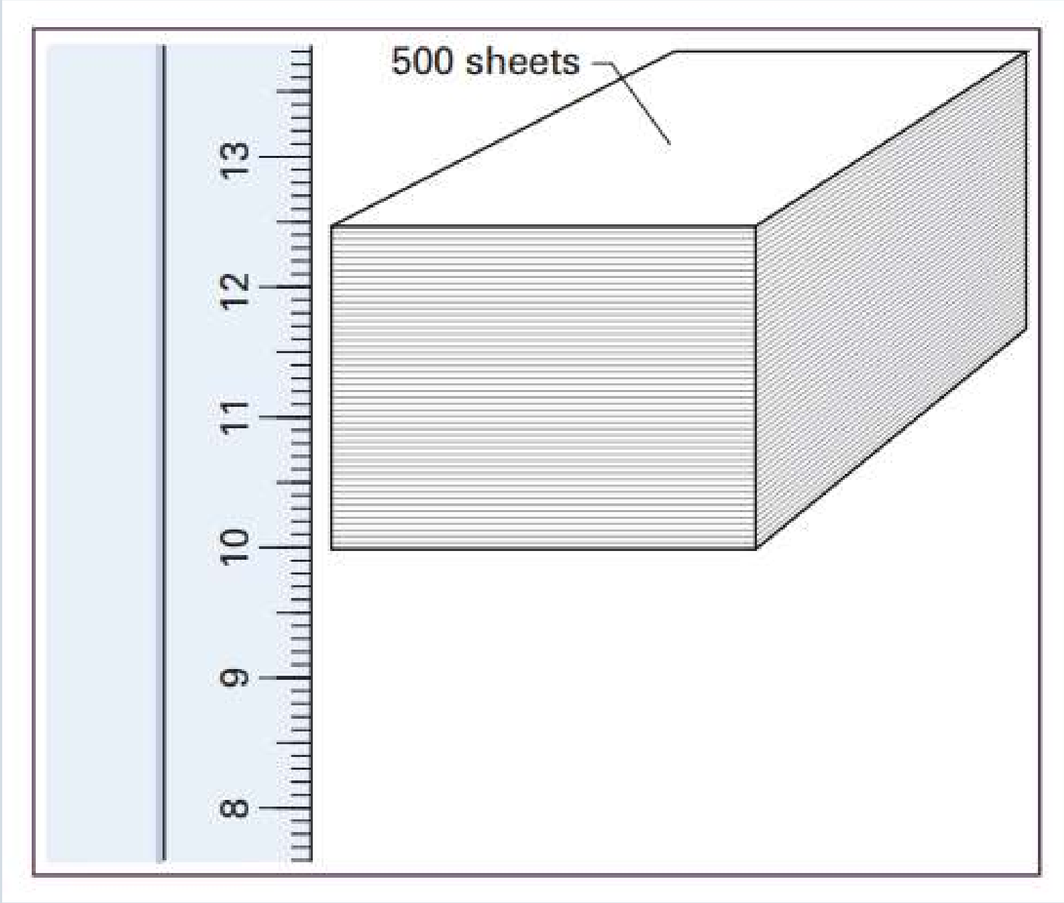
- The objest your measuring **must be straight**, and laid closely alongside the rule.
- Look at the ends of the wire. Are they cut neatly, or are they ragged?
- Look at the markings on the ruler. Line one end of the wire up against the zero of the scale.
- Look at the other end of the wire and read the scale.

You can probably determine the length of the wire to within a millimetre. But there is something else to think about – **the ruler itself**. Are the marks at the ends of a metre ruler separated by exactly one metre? Any error in this will lead to a small inaccuracy in your result.

More measurement techniques

If you have to measure a small length, such as the thickness of a wire, it may be better to measure **several thicknesses** and then **calculate the average**.

For some measurements of length, such as **curved lines**, it can help to lay a thread along the line. Mark the thread at either end of the line and then lay it along a rule to find the length. This technique can also be used for measuring the circumference of a cylindrical object such as a wooden rod or a measuring cylinder



Measuring volumes

Shape is regular

For a regularly shaped object, such as a rectangular block, measure the lengths of the three different sides and multiply them together.

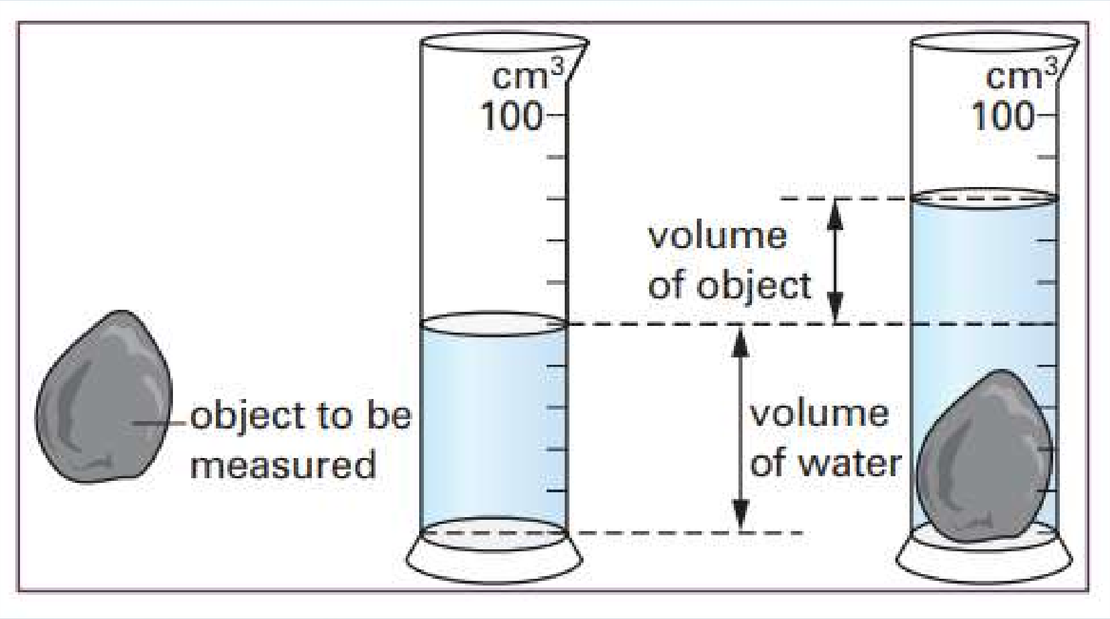
Shape is not regular

For objects of other regular shapes, such as spheres or cylinders, you may have to make one or two measurements and then look up the formula for the volume.

For liquids, measuring cylinders can be used.

Measuring volume by displacement

Most objects do not have a regular shape, so we cannot find their volumes simply by measuring the lengths of their sides. The technique is known as **measuring volume by displacement**.



- Select a measuring cylinder that is about **three or four times larger** than the object. Partially **fill it with water**, enough to cover the object. Note the volume of the water.
- Immerse the object in the water. The level of water in the cylinder will increase. Th e increase in its volume is equal to the volume of the object.

Units of length and volume

Quantity	Units
Length	metre (m)
	1 decimetre (dm) = 0.1 m
	1 centimetre (cm) = 0.01 m
	1 millimetre (mm) = 0.001 m
	1 micrometre (μm) = 0.000 001 m
	1 kilometre (km) = 1000 m
Volume	cubic metre (m^3)
	1 cubic centimetre (cm^3) = 0.000 001 m^3
	1 cubic decimetre (dm^3) = 0.001 m^3

1.2 Improving precision in measurements

Vernier calipers

Th ecalipers have two scales, the main scale and the vernier scale. Together, these scales give a measurement of the distance between the two inner faces of the jaws.

- Close the calipers so that the jaws touch lightly but fi rmly on the sides of the object being measured
- Look at the zero on the vernier scale. Read the main scale, just to the left of the zero. Th is tells you the length in millimetres.

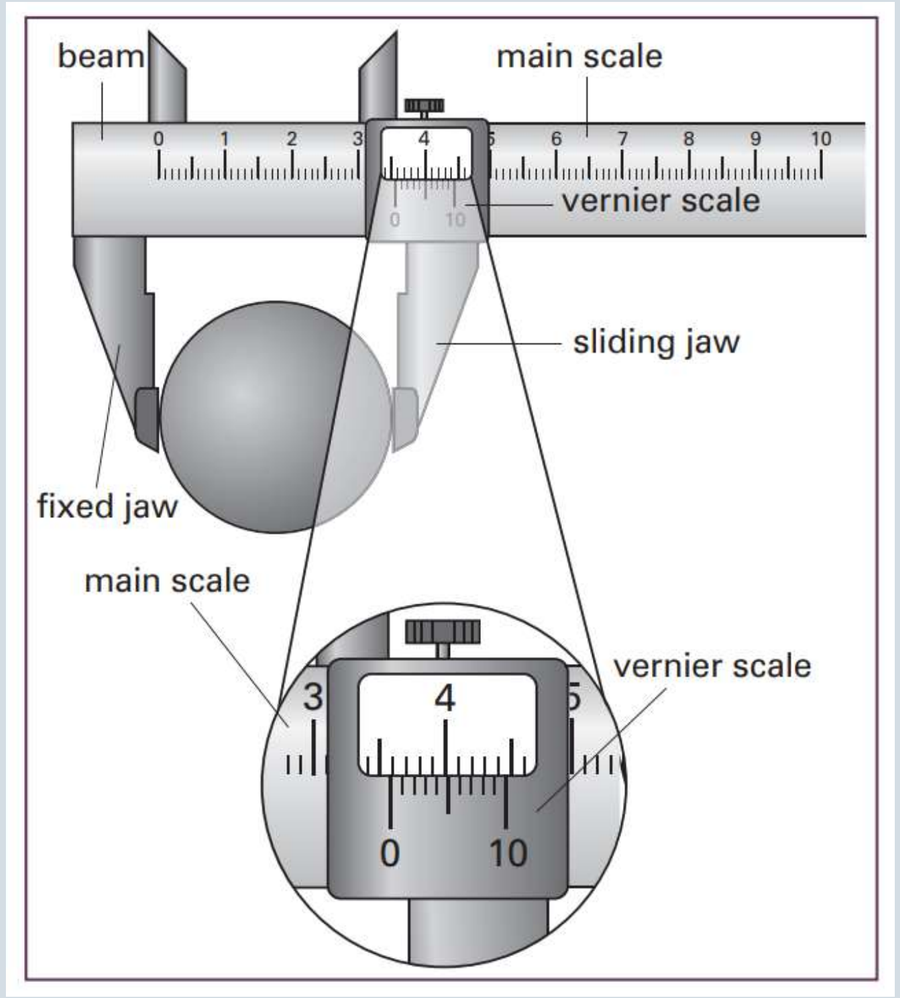
Vernier calipers

Now look at the vernier scale. Find the point where one of its markings is exactly aligned with one of the markings on the main scale. Read the value on the vernier scale. This tells you the fraction of a millimetre that you must add to the main scale reading.

= main scale reading + vernier reading

= 35 mm + 0.7 mm

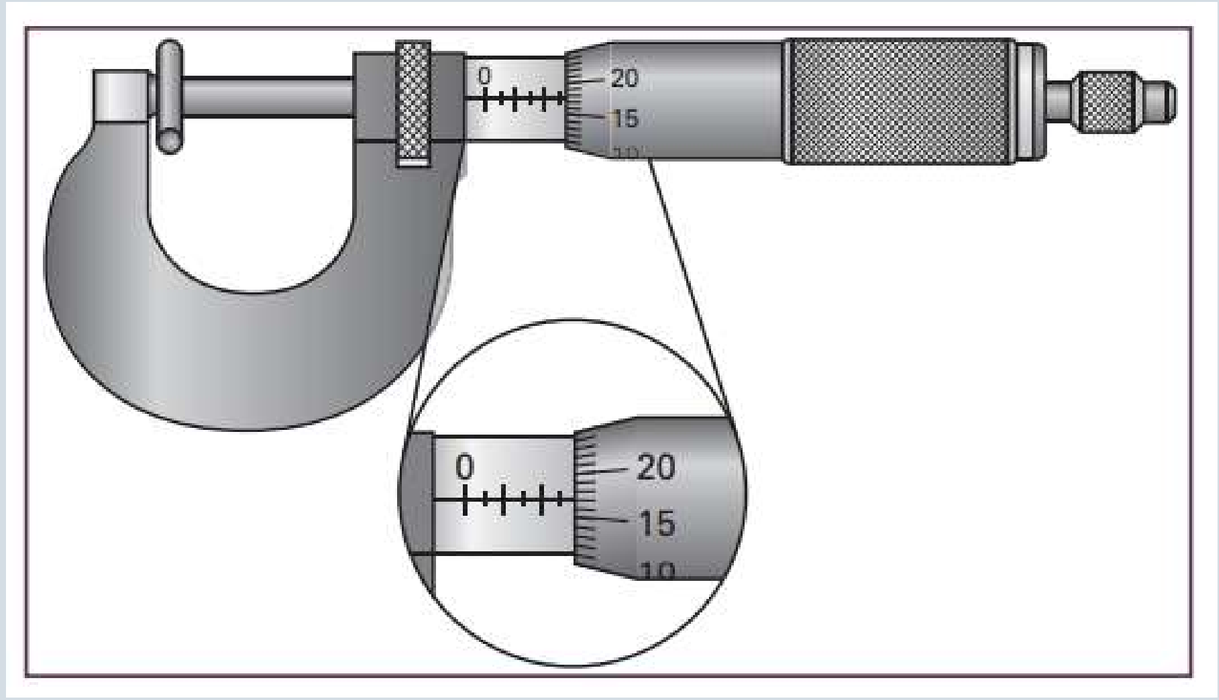
= 35.7 mm



Micrometer screw gauge

The main scale is on the shaft , and the fractional scale is on the rotating barrel. Th e fractional scale **has 50 divisions**, so that one complete turn represents **0.50 mm**.

- Turn the barrel until the jaws just tighten on the object. Using the friction clutch ensures just the right pressure.
- Read the main scale to the nearest 0.5 mm.
- Read the additional fraction of a millimetre from the fractional scale.



= main scale reading + fractional scale reading = 2.5 mm + 0.17 mm = 2.67 mm

1.3 Density

The mass of an object is the amount of matter it is made of. Mass is measured in kilograms. But density is a property of a material. It tells us how concentrated its mass is.

density – the ratio of mass to volume for a substance.

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

$$\rho = \frac{M}{V}$$

Unit of mass	Unit of volume	Unit of density	Density of water
kilogram, kg	cubic metre, m^3	kilograms per cubic metre	1000 kg/m^3
kilogram, kg	cubic decimetre, dm^3	kilograms per cubic decimetre	1.0 kg/dm^3
gram, g	cubic centimetre, cm^3	grams per cubic centimetre	1.0 g/cm^3

Values of density

	Material	Density / kg / m³
Gases	air	1.29
	hydrogen	0.09
	helium	0.18
	carbon dioxide	1.98
Liquids	water	1000
	alcohol (ethanol)	790
	mercury	13 600
Solids	ice	920
	wood	400–1200
	polythene	910–970
	glass	2500–4200
	steel	7500–8100
	lead	11 340
	silver	10 500
	gold	19 300

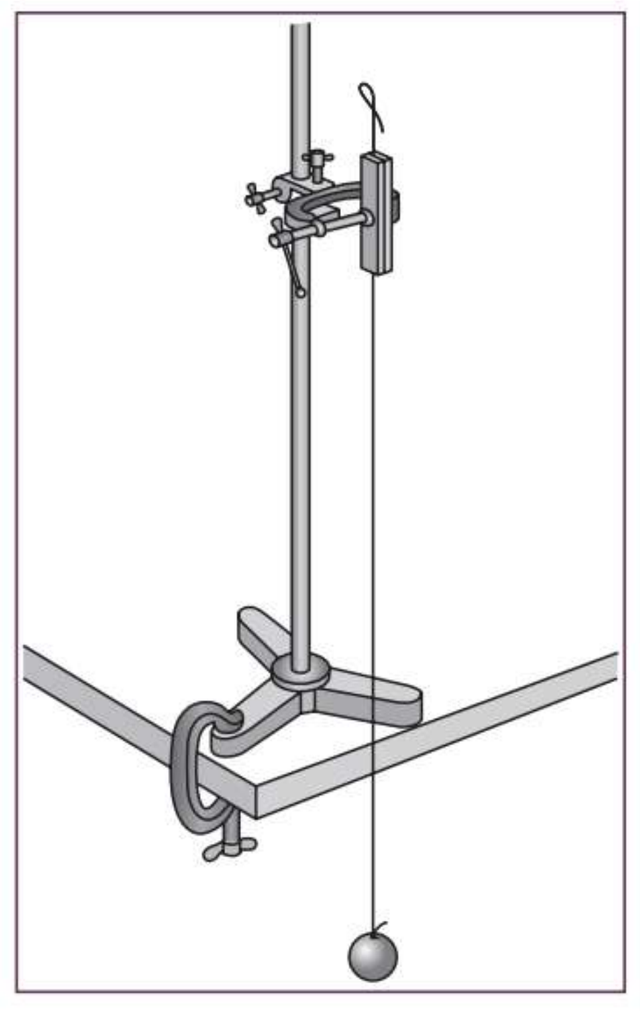
- Density is the key to floating. Ice is less dense than water. This explains why icebergs float in the sea, rather than sinking to the bottom.
- Many materials have a range of densities. Some types of wood have less dense and some have more dense.
- Gold is denser than silver. Pure gold is a soft metal, so jewellers add silver to make it harder. The amount of silver added can be judged by measuring the density.
- It is useful to remember that the density of water is 1000 kg/m3 , 1 kg/dm3 or 1.0 g/cm3 .

1.4 Measuring time

An analogue clock is like a traditional clock whose hands move round the clock's face.

A digital clock is one that gives a direct reading of the time in numerals.

Measuring short intervals of time



The time for one swing of a pendulum (from left to right and back again) is called its **period**. A single period is usually too short a time to measure accurately. However, because a pendulum swings **at a steady rate**, you can use a stopwatch to measure the time for a **large number of swings**, and calculate the average time per swing. Any inaccuracy in the time at which the stopwatch is started and stopped will be much **less significant** if you measure the total time for a large number of swings.

After this chapter you should know

- How to measure length, volume, mass and time
- How to measure small quantities
- That special instruments are available to measure with greater precision
- All about density.