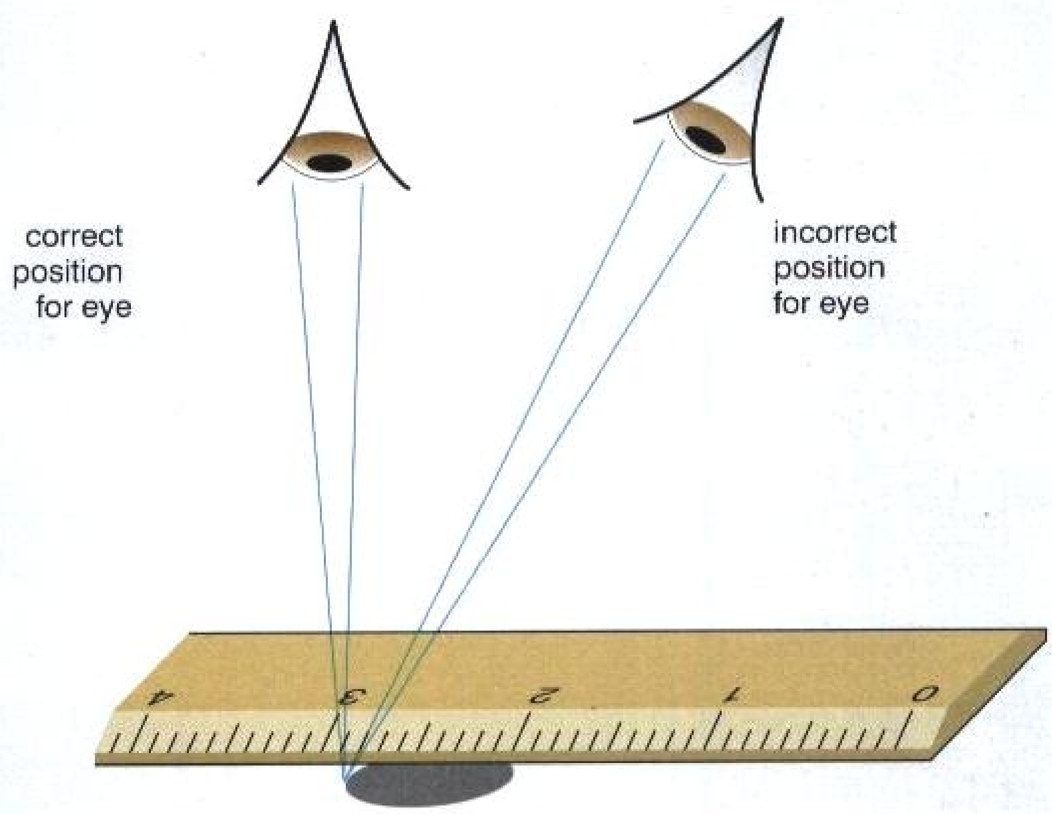
# 1 LENGTH AND TIME

This train runs for 30 km between Shanghai and Pudong Airport, and completes the journey in 7 minutes, reaching a top speed of 430 km/h. The train uses magnets to hover 10 mm above the track. The track must be placed within a few mm of the planned route, and this requires great accuracy in all measurements.

Making measurements is very important in physics. Without numerical measurements physicists would have to rely on descriptions, which could lead to inaccurate comparisons. Imagine trying to build a house if the only instructions were 'big' and 'small'.

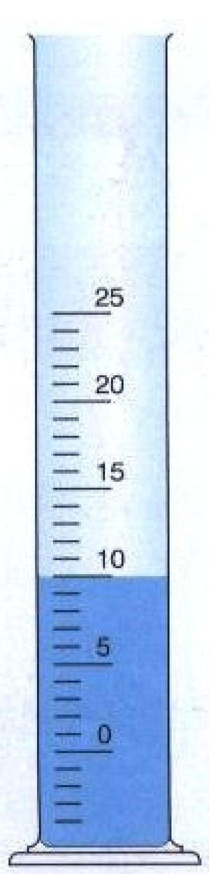
When making measurements, physicists use different instruments, such as rules to measure lengths, measuring cylinders to measure volume and clocks to measure time.

A physicist will always take care to make the measurements as accurate as possible. If she is using a rule she will place the rule along the object to be measured, and will read off the scale the positions of the beginning and the end of the object. The length is, of course, the difference between these two readings. If the rule is nearer to her eye than the object being measured, the reading will appear to change as she moves her eye. The correct reading is obtained when her eye is directly above the point being measured.




To improve accuracy further, she may take several readings, and use the average of these readings as a better result.

To use a measuring cylinder, she will firstly make sure that the cylinder is standing on a level table. Then she will make sure that her eye is at the same level as the liquid inside the cylinder. The surface of most liquids will bend up or down near the walls of the measuring cylinder. This bent shape is known as a meniscus. However, most of the surface is flat, and measurements are made to this flat surface.




Warning: Some measuring cylinders have unusual scales, and one division may represent an unexpected quantity, perhaps 2 $cm^3$ or 0.5 $cm^3$. Check carefully.

In this book, volumes will usually be measured in $cm^3$ (or perhaps in $m^3$). In other places, such as on some measuring cylinders, you will see the millilitre.

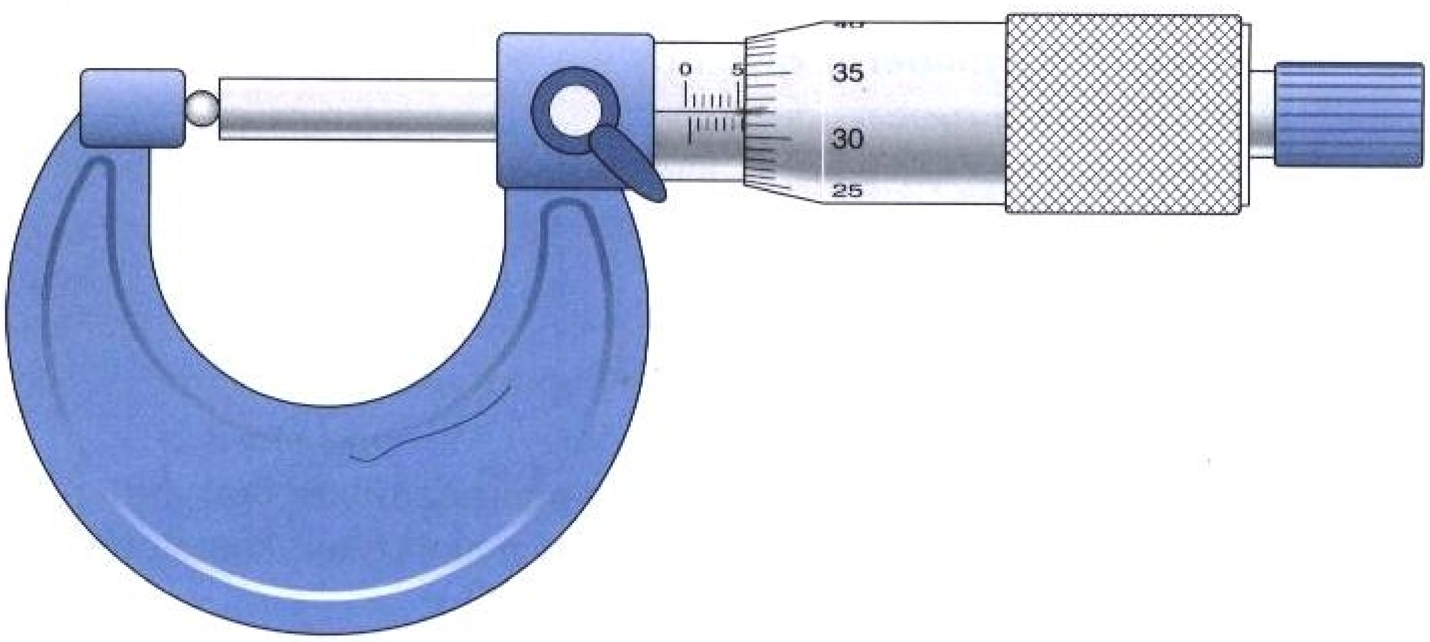
A volume of 1 mL is the same as a volume of 1 $cm^3$.
1000 $cm^3$ = 1000 mL = 1 L

For measuring large volumes we also use the cubic metre.
1 m$^3$ = 1000 L = 1000 000 cm$^3$

You may need to use specialised measuring equipment. For example, the micrometer is used to measure small distances, such as the diameter of a piece of wire.

The micrometer is designed so that the gap between the jaws changes by 0.5 mm for every complete turn of the thimble. By measuring the exact position of the thimble when an object is being held, the thickness of the object can be measured very accurately. A physicist will always check that the jaws of the micrometer are clean, and will then check that the reading is 0 mm when the jaws are closed gently. Most micrometers allow the zero reading to be reset, but this may need to be done by a trained person. Most micrometers also have a special ratchet fitted onto the end of the thimble, which slips and emits a clicking sound when sufficient force has been applied, but extra care should be taken if the micrometer does not have one of these.

To measure the thickness of an object, open the jaws of the micrometer and close them gently onto the object in question. A scale on the barrel will show by how many complete turns the jaws have been opened, with every two turns indicating another millimetre. The scale round the edge of the thimble is calibrated from 0 to 50. So a reading of 40 indicates that a further 0.40 mm must be added to the thickness. But be careful, a reading of 5, say, indicates that only 0.05 mm is to be added.



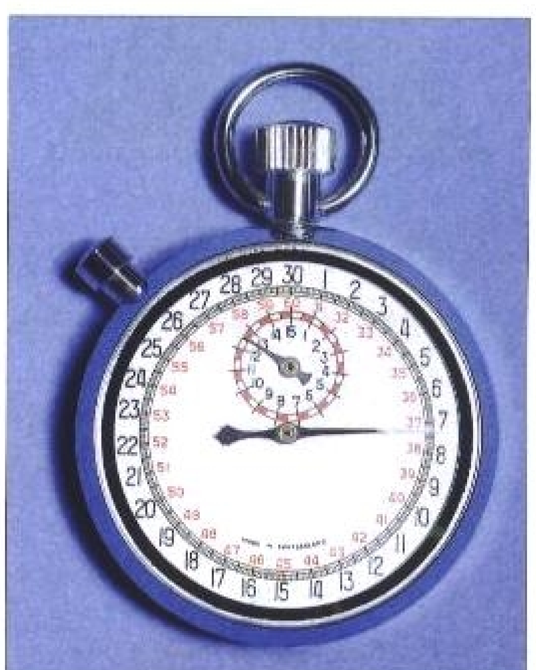

The marks along the top of the line along the barrel show that the jaws have been opened to 5 mm, and the fact that an additional mark has become visible below the line shows that they are opened beyond 5.5 mm. Therefore you know that the answer must be between 5.5 mm and 6.0 mm. Next you look at the scale on the thimble. The reading of 32 shows that you must add 0.32 mm to the reading. So the final answer is 5.82 mm.

Times are measured by using a stopwatch or stopclock.

Hand-operated stopwatches have an accuracy that is limited by the delay between your eye seeing the moment to start, your brain issuing the command to start the watch and your finger pressing the start button. The total delay is typically around 0.2 s. This delay is known as your 'reaction time', and it increases the danger of some tasks, such as driving a car.

For applications where accuracy is critical, such as in athletics, the clock has to be started and stopped automatically by the athlete breaking a light beam that shines across the track.

If you are measuring the time of an oscillation, such as the swing of a pendulum, it is very easy to improve the accuracy of the measurement by timing a number of swings, perhaps 10 or 20.



The reaction time of the person using the stopwatch will affect the accuracy of the timing.

It is important to count correctly. Let the swing go, count zero and start the stopwatch as the pendulum crosses a mark at the bottom of the swing (we call this the fiducial mark). The next time the pendulum crosses the fiducial mark going in the same direction count one, and so on. In this way the count will be correct.

After measuring the time for 20 swings, say, divide the total time by 20 to give the period of one oscillation of the pendulum.

## REVIEW QUESTIONS

**Q1** Rules that are 30 cm long are often made of wood or plastic that is thicker in the middle, and thinner along the edges where the scale is printed. Explain why the user is less likely to make an error if the rule is thinner at the edge, and suggest reasons why the rule is thicker in the middle.

**Q2** A plastic measuring cylinder is filled with water to the 100 $cm^3$ mark, and a student measures the column of water in the cylinder and finds that it is 20 cm high.

**a** The student pours 10 $cm^3$ of the water out of the cylinder. How high will the column of water be now?

**b** The student then refills the cylinder back to the 100 $cm^3$ mark by holding it under a dripping tap. She finds that it takes 180 drops of water. What is the volume of one of these drops?

**c** What is the cross-sectional area of the cylinder? Hint: The volume of a cylinder is given by the equation: volume = cross-sectional area × length.

**d** So from answer (c) what is the internal diameter of the tube used to make the measuring cylinder?

**Q3** A student tries to measure the period of a pendulum that is already swinging left and right. At the moment when the pendulum is fully to the left, she counts 'One' and starts a stopwatch. She counts successive swings each time that the pendulum returns to the left. When she counts 'Ten' she stops the stopwatch, and sees that it reads 12.0 s.

**a** What was her mistake?

**b** What is the period of swing of this pendulum?

**c** In this particular experiment, explain the likely effect of her reaction time on her answer.

More questions on the CD ROM

Examination questions are on page 50.