CHAPTER

1 Measurement of Physical Quantities

PHYSICS WATCH

Scan this page to watch a clip about physical measurements of a baby.

QUESTIONS

- What is the average head circumference of a newborn in centimetres?
- Other than head circumference, what are two other important measurements taken to monitor a baby's growth pattern?
- What are some other physical quantities that are commonly used as measurements in daily life?

From the day you were born, you are subjected to measurements. You wouldn't remember, but your parents probably took you to the clinic several times to have you measured. The measurements taken were then plotted to monitor your growth pattern.

Head circumference is an important measurement to monitor during the first two years of a baby's life. The average head circumference of a newborn is about 13 inches. By monitoring the baby's head circumference, we can detect if the baby's head and the brain inside it are growing normally.

1.1 Physical Quantities

In this section, you will learn the following:
- Describe the use of rulers and measuring cylinders to find a length or a volume.
- Describe how to measure a variety of time intervals using clocks and digital timers.
- Determine an average value for a small distance and for a short interval of time by measuring multiples.

Physics is the study of our natural world — from the very large (e.g. the solar system) to the very small (e.g. the atom). The study of physics are related to two main ideas: matter and energy. The knowledge we have gained in the field of physics is the result of the work of many scientists. These scientists have conducted many experiments to verify their ideas on matter and energy. When they carry out experiments, they need to make accurate measurements in order to obtain reliable results.

WORD ALERT

Magnitude: size

Figure 1.1 *The sign warns drivers on the clearance limit to pass underneath the bridge. In which other places can you find similar signs?*

What are physical quantities?

Look at the sign in Figure 1.1. You may have noticed similar signs along bridges where vehicles can pass underneath. In physics, height is a physical quantity — '3.8' is the numerical magnitude and 'm' is the unit.

A **physical quantity** is a quantity that can be measured. It consists of a numerical magnitude and a unit.

There are altogether seven basic physical quantities, or base quantities. Table 1.1 shows the seven base quantities and their corresponding SI units. **SI units** are the units of measurement in the widely used International System of Units (abbreviated SI from French: *Système International d'Unités*).

Table 1.1 *The seven base quantities and their SI units*

Base quantity	SI unit	Symbol for SI unit
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

ENRICHMENT INFO

Do you know?
1 The length from your wrist to your elbow is the same as the length of your foot.
2 Your mouth produces 1 *l* of saliva a day.
3 Breathing generates about 0.6 g of carbon dioxide every minute.
4 On average, people can hold their breath for about one minute. The world record is 21 min 29 s.

Other common physical quantities such as area, volume and speed are derived from the seven base quantities. They are called *derived quantities*. For example, speed is derived from length (i.e. distance travelled) and time. Table 1.2 gives examples of how some common physical quantities are derived from the base quantities.

Table 1.2 *Some common derived quantities and their SI units*

Physical quantity	How it is derived from base quantities	Symbol for SI unit
Area	Length × width	m^2
Volume	Length × width × height	m^3
Speed	$\frac{\text{Length}}{\text{Time}}$	m/s

PHYSICS WATCH

Scan this page to watch a clip about how unit errors can cause a disaster.

In the past, people used parts of their bodies and things around them as units of measurement. That was how measuring terms such as the foot, yard and horsepower came about. Unfortunately, such methods of measurement created much confusion because the measurement varied from individual to individual. It was not until 1968 that scientists agreed to adopt one universal set of units — the SI units.

Prefixes for SI units

Using decimal notation, the distance between air molecules can be expressed as 0.000 000 01 m. If we need to mention this quantity a number of times, it would be tedious to use this type of notation. Instead of using decimal notation, it is more convenient to use prefixes to represent the quantity. For example, when measuring short distances such as $\frac{1}{1\,000\,000}$ of a metre, we simply express it as one micrometre.

Thus, 0.000 000 01 m can be expressed as 0.01 μm (micrometre), where μ represents the submultiple 10^{-6}. The prefixes listed in Table 1.3 are useful for expressing physical quantities that are either very big or very small.

Table 1.3 *Some common prefixes and their symbols*

	Factor	Prefix	Symbol
Multiples	10^9	giga-	G
	10^6	mega-	M
	10^3	kilo-	k
Submultiples	10^{-1}	deci-	d
	10^{-2}	centi-	c
	10^{-3}	milli-	m
	10^{-6}	micro-	μ
	10^{-9}	nano-	n

Standard form

Another convenient and acceptable way of expressing physical quantities is to use the **standard form**. Standard form is a way of writing numbers, in which one integer (1 to 9) is multiplied by an appropriate power of 10. For example, 0.005 67 and 16 800 will be expressed in standard form as 5.67×10^{-3} and 1.68×10^4. In the case of 0.01 μm, it can also be expressed as 1×10^{-8} m. Some other common quantities expressed in standard form are shown below:

- One kilometre (km) is 1×10^3 m.
- One milliampere (mA) is 1×10^{-3} A.
- Three megajoules (MJ) is 3×10^6 J.
- Six microcoulombs (μC) is 6×10^{-6} C.
- Eight nanoseconds (ns) is 8×10^{-9} s.

How do we measure length?

In physics, length is an important quantity that is often used. For example, we measure length to find out how far an object has moved, how much space an object occupies (i.e. the object's volume) and how far apart two objects are.

The SI unit for **length** is the **metre (m)**. There is a wide range of lengths in this world from the width of a human hair to the radius of the Earth. It is necessary to use the appropriate instruments and methods to measure different types of length.

The metre rule and measuring tape

The metre rule and measuring tape (Figure 1.2) are instruments that are commonly used to measure length.

A metre rule can measure lengths of up to one metre. A steel measuring tape is suitable for measuring straight distances longer than a metre, while a cloth measuring tape is suitable for measuring the length along a curved surface, such as a person's waist.

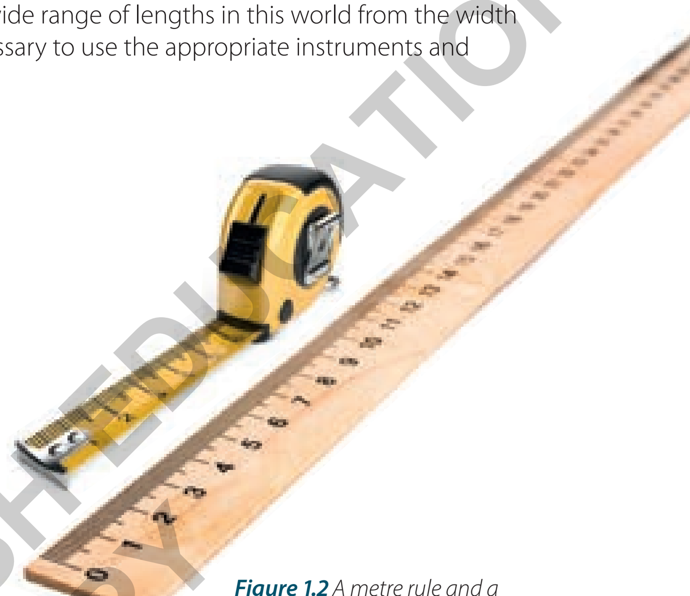


Figure 1.2 A metre rule and a retractable steel measuring tape are used to measure lengths.

What is the precision of an instrument?
The smallest unit an instrument can measure is known as its **precision**. What is the smallest unit on a metre rule? It is 0.1 cm or 1 mm. Therefore, the precision of a metre rule is 1 mm.

The thickness of a piece of paper is less than the precision of a metre rule (i.e. 1 mm). Therefore, you cannot measure the paper's thickness directly using a metre rule. You will have to estimate its thickness.

How do we avoid errors in measurement?
When you use a metre rule, your eyes should be positioned such that your line of sight is perpendicular to the rule (Figure 1.4(a)). If this is not done, an error will be introduced into the measurement (Figure 1.4(b)). This type of error is called **parallax error**.

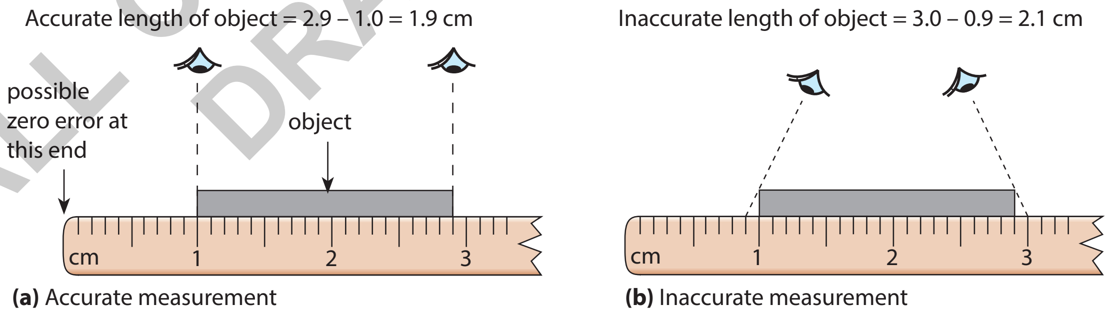


Figure 1.4 How to take accurate readings by avoiding parallax errors

A metre rule may have its zero mark at the very end of the rule. It may no longer be suitable for measuring if the zero-mark end is worn. The worn end of the rule may introduce errors into the readings. Hence, it is better to measure from another point and subtract it from the final reading (Figure 1.4(a)). Taking several readings and calculating the **average** also minimises errors.

ENRICHMENT THINK

A stack of paper is shown in Figure 1.3. How would you estimate the thickness of a sheet of paper in the stack?

Figure 1.3 A stack of paper

QUICK CHECK

When using a metre rule to measure length, I must be careful to avoid parallax error.

True or false?

Let's Review

Section A: Multiple-choice Questions

1 In a particular experiment, you are required to measure the distance between two points. The two points are between 0.7 m and 0.8 m apart. Which of the following instruments should you use to obtain a reading that has a precision of 0.001 m?

A A half-metre rule
B A metre rule
C A ten-metre measuring tape
D A metre rule and a pair of vernier calipers

2 Figure 1.28 shows two vernier scales. The top vernier scale shows the reading when the vernier calipers are closed. The bottom vernier scale shows the reading when the diameter of a steel ball bearing is being measured.

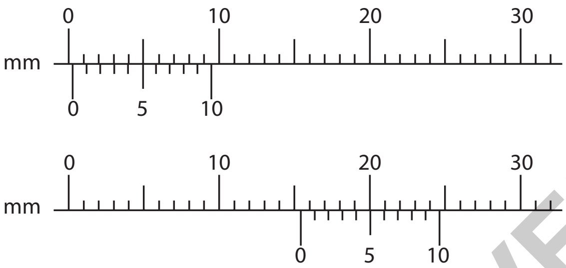


Figure 1.28

What is the diameter of the ball bearing?

A 1.49 cm **B** 1.50 cm
C 1.59 cm **D** 1.61 cm

3 When using a measuring cylinder, one precaution to take is to

A check for zero error.
B look at the meniscus from below the level of the water surface.
C obtain more readings by looking from more than one direction.
D position the eye in line with the base of the meniscus.

4 Figure 1.29 shows a simple pendulum.

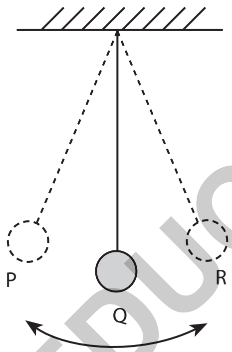


Figure 1.29

Which of the following statements about the period of the pendulum is/are **not** true?

1 It is independent of the mass of the bob.
2 It increases as the length of the pendulum increases.
3 It is the time taken for the bob to swing from Q to P and back to Q.

A 1 and 2 only **B** 1 and 3 only
C 2 and 3 only **D** 3 only

5 Ⓢ Figure 1.30 shows two forces acting at right angle to each other.

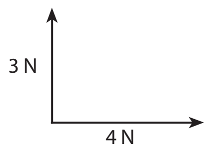
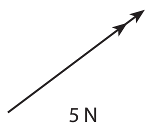


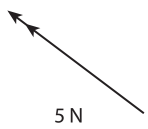
Figure 1.30

Which of the following shows the resultant force?

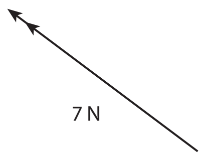
A



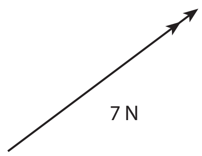
B



C



D



Let's Review

Section B: Short-answer and Structured Questions

1 Identify the physical quantity, numerical magnitude and unit in the following statements:

(a) The length of a table is found to be five metres.

(b) The time the pendulum takes to complete a single oscillation is two seconds.

(c) A typical car has a mass of one thousand kilograms.

2 A student measures the width of a glass slide using a pair of vernier calipers.

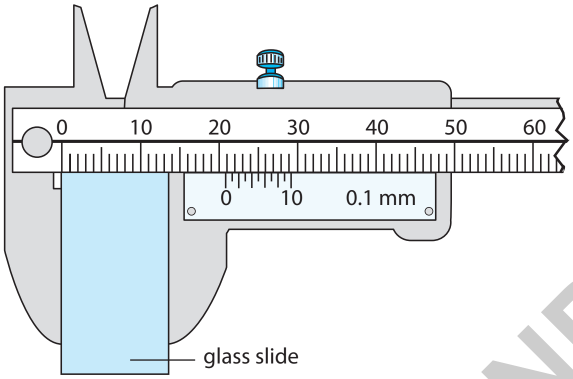


Figure 1.31

(a) In Figure 1.31, what is the measurement of the width of the glass slide?

(b) List the precision of the following measuring instruments: vernier calipers and metre rule.

(c) Explain why the method shown in Figure 1.31 will not yield an accurate measurement.

How would you obtain a more accurate measurement of the width of the glass slide?

3 Describe the method you would use to find the volume of the following:

(a) a matchbox

(b) the cork stopper of a bottle

(c) some liquid perfume in a very small bottle

4 A student conducted an experiment to measure the acceleration due to gravity g of a simple pendulum.

The data obtained were tabulated in Table 1.7.

Table 1.7

Length of thread l/m	0.35	0.65	1.00	1.45	1.95
Time for 20 oscillations t/s	24.1	32.4	40.1	47.5	56.3

The relation between the period T, the length l of the pendulum and the acceleration due to gravity g is

$T = 2\pi\sqrt{\frac{l}{g}}$. Find the value of g using the graphical method.

5 Figure 1.32 shows a lorry that is stuck in muddy ground being pulled by two jeeps. Each jeep exerts a force of 3000 N at an angle of 45° to the horizontal. Using a vector diagram, determine the resultant force on the lorry.

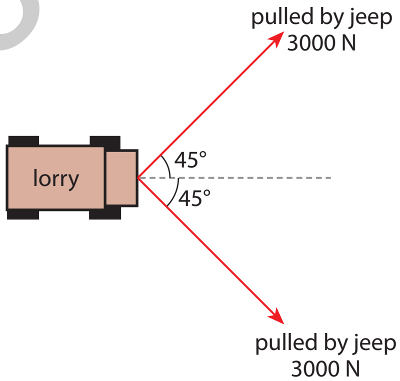


Figure 1.32