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Jane Thompson , Jaykishan Sharma
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Chapter 1

Representing values

WHY DO YOU NEED TO REPRESENT VALUES IN PHYSICS?

- In physics, numbers are used to give values to measurable characteristics. We use the word **variable** for such a characteristic. Length, time and mass are just some of the variables whose values help us to describe features of the real world. For example, the time sunlight takes to reach the Earth is 8 minutes and 20 seconds, the mass of the of the moon is 7.3×10^{22} kg, the speed of a bullet train is 500 km/h, the mass of 1 litre of water is 1 kg.
- Each variable has a **unit** linked to it. The unit allows us to understand the size of the variable. Examples of units are: metres, seconds, kilograms and amps.

Maths focus 1: Using units

KEY WORDS

variable: the word used for any measurable quantity; its value can vary or change

unit: a standard used in measuring a variable, for example the metre or the volt

A measured value in physics means nothing without a unit. Scientists have agreed a set of standard units. Wherever you are in the world, scientists use the same set of standard units called SI units (*Système Internationale*). Imagine if you have only numbers in your life, without units. What would your life be like? Does it make sense if you ask a shopkeeper to give you 10 salts?

What maths skills do you need to be able to use units?

1 Choosing the correct unit for a variable	• Identify the variable • Recall the correct unit to match the variable • Use the correct symbol for the unit • Convert units

Maths skills practice

How does using the correct units help when working with equations?

Using the same units means that we can compare the size of variables and calculations very easily. This is why the international SI system was agreed. Table 1.1 shows the basic SI units for some variables. Each unit has a symbol, which makes the unit easier to recognise and write quickly.

Variable	SI unit	SI unit symbol
length (or distance)	metre	m
mass	kilogram	kg
time	second	s

Table 1.1: Units for length, time and mass.

Sometimes you will see different units used (see Table 1.2).

Variable	Unit
length (or distance)	kilometre, millimetre
time	hour

Table 1.2: Different units can be used for the same variable.

The unit metres per second (m/s) for speed is a 'derived unit', which means it is based on a calculation. It is the number of metres travelled in each second. The / symbol is read as 'per' and indicates division.

You can read more about SI units in Chapter 1 of the Coursebook.

Other SI units that you need to be familiar with are shown in Table 1.3.

Variable	SI unit
force	newton (N)
energy	joule (J)
power	watt (W)
temperature	degrees Celsius (°C)
frequency	hertz (Hz)
potential difference	volt (V)
electric current	ampere (A)
resistance	ohm (Ω)
electric charge	coulomb (C)

Table 1.3: SI units.

LOOK OUT

Be careful with units when using equations. For example, when distance and time are measured in metres and seconds, the speed that you calculate will be a value in m/s (metres per second), not in km/h (kilometres per hour).

Maths skill 1: Choosing the correct unit for a variable

In a calculation, the units you use must match (be consistent) with one another. For example, when calculating an area using the equation

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area = length × width

the length and width must have the same units. When the length measurement is in centimetres (cm) and the width is in millimetres (mm), one must be converted so they are consistent.

In Figure 1.1, the width measurement has been converted from millimetres to centimetres.

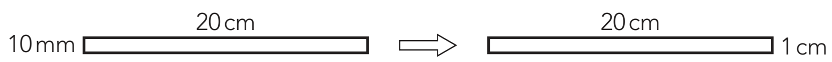

Figure 1.1: Converting millimetres to centimetres.

The area is then 20 cm × 1 cm = 20 cm^2.

See Chapter 6, Maths focus 1, '*Solving problems involving shape*' for more on calculating area.

To convert from cm to m, from cm^2 to m^2, or from cm^3 to m^3, remember:

- there are 100 cm in 1 m
- there are 10 000 cm^2 in 1 m^2
- there are 1 000 000 cm^3 in 1 m^3.

The conversion factors are shown in Table 1.4.

Original unit	New unit	Process	Example
cm	m	Divide by 100	500 cm = 5 m
cm^2	m^2	Divide by 10 000	5000 cm^2 = 0.5 m^2
cm^3	m^3	Divide by 1 000 000	50 000 cm^3 = 0.05 m^3

Table 1.4: Converting units of length, area and volume.

WORKED EXAMPLE 1.1

Find the volume of the block of material in Figure 1.2.

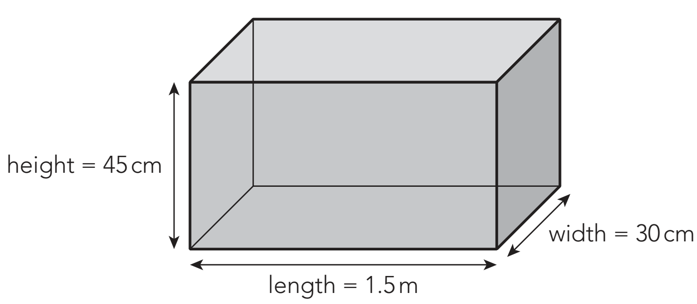

Figure 1.2: Block of material.

CONTINUED

Step 1: Remind yourself of the equation for volume.

Volume = length × width × height

Step 2: List each variable with its units.

Length = 1.5 m

Width = 30 cm

Height = 45 cm

Volume = ?

Step 3: Check for consistency and decide which unit you are going work in. Here we will work in metres (remember that 1 cm = 0.01 m).

Length = 1.5 m

Width = 0.3 m

Height = 0.45 m

Volume = ?

Step 4: Substitute the values and units into the equation and find the volume.

Volume = 1.5 m × 0.3 m × 0.45 m

Volume = 0.20 m^3

Questions

1 **a** A student releases a trolley down a long ramp, as shown in Figure 1.3. As the front of the trolley passes marker 1, she starts a stopwatch and stops it as the trolley reaches marker 2.

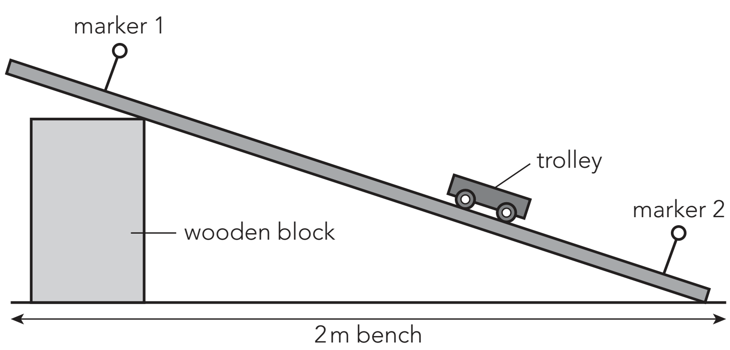

Figure 1.3: Trolley rolling down a ramp.

Write down suitable units, in symbols, for the following variables:

i The time taken to travel down the ramp is measured in ……………………..

ii The length of the ramp is measured in …………………………………………

iii The mass of the trolley is measured in …………………………………………

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b The distance between marker 1 and marker 2 is 1.6 m and it takes 2 s to cover this distance. Calculate the speed of the trolley. Give your answer in m/s.

....

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....

2

Figure 1.4: Horizontal cylinder.

A horizontal cylinder has a cross-sectional area of 30 cm^2 and a length of 3 m. What is its volume?

Use the equation volume = cross-sectional area × length

....

....

....

Do you need to convert the units? Why? Discuss with your classmate.

Maths focus 2: Using symbols for variables

A *variable* is a measurable characteristic. It has a value, expressed as a number with a unit. Scientists use symbols instead of the variable names and units to help find and work with relationships between variables. Then they can express the relationship as a mathematical equation.

What maths skills do you need to use symbols for variables?

1 Using the symbol for each variable and its unit	• Learn the symbol for each variable • Know that the symbol stands for the variable and its unit

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Maths skills practice

How does using symbols for variables help you to learn and use equations in physics?

Look at this equation that shows the relationship between the mass of an object, the gravitational field strength and its weight:

weight (in N) = mass (in kg) × gravitational field strength (in N/kg)

Writing equations like this is slow and inefficient. Using symbols, this becomes faster and much easier:

$W = mg$

W stands for 'weight in N'. For example the value of W might be 10 N. The symbol includes the numerical value *and* the unit.

In symbol equations, the multiplication sign is often omitted: $mg = m \times g$

Maths skill 1: Using the symbol for each variable and its unit

Most variables in physics have symbols, which are single letters. You need to learn them. A few variables, such as a moment, have no symbol.

Practise your knowledge of symbols. Make yourself a set of flash cards with the variable name and symbol on one side, and the unit name and symbol on the other (Figure 1.5). Practise until you know them all.

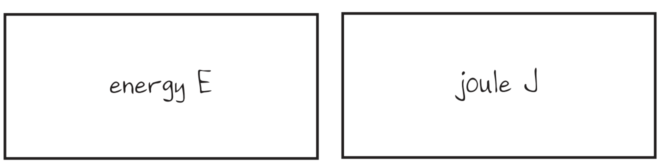

Figure 1.5: Each side of one flashcard, used to help you remember variable symbols and units.

There are only 26 letters in the alphabet, so sometimes the same letter is used more than once.

- Sometimes lower case (small) letters are used and sometimes upper case (CAPITALS):
  - m represents both metre and milli (the prefix for 10^{-3}); m represents mass.
  - V represents volt; V represents both volume and potential difference.
- In print, *italic* single letters are always variables; units are shown in ordinary type. For example, A means area but A means amp.
- Sometimes Greek letters are used. For example, θ for temperature in °C.

WORKED EXAMPLE 1.2

Read this paragraph about heating water and fill the gaps by writing the correct symbols after each **bold** term.

A 1 **kilogram** .... mass of water is heated from a temperature of

5 **degrees Celsius** .... to 100 **degrees Celsius** ....

The heater has a **power** .... of 50 **watts** .... i.e. it delivers

50 **joules per second** ....

The heater has to be connected to a 24-**volt** .... supply.

An amount of **energy** .... is used to heat the water.

The temperature rise of the water depends on the **specific heat capacity** ....

of water, measured in **joules per kilogram degree Celsius** ....

Step 1: Make sure you know the proper symbols. Never make up symbols.

Step 2: Take care to use lower and upper case letters correctly.

Step 3: Make sure you know when you need a / symbol.

Check your answers below.

A 1 **kilogram** kg mass of water is heated from a temperature of 5 **degrees Celsius** °C to 100 **degrees Celsius** °C.

The heater has a **power** *P* of 50 **watts** W i.e. it delivers 50 **joules per second** J/s.

The heater has to be connected to a 24-**volt** V supply.

An amount of **energy** *E* is used to heat the water.

The temperature rise of the water depends on the **specific heat capacity** *c* of water, measured in **joules per kilogram degree Celsius** J/(kg °C).

LOOK OUT

The brackets in J/(kg °C) show that joules are divided by both kg and °C,

that is $\frac{\text{J}}{\text{kg °C}}$.

Questions

3 The electric power needed for a kettle can be found by using the equation:

power = potential difference × current

Complete the table to show the correct symbols for the variables and names and symbols for the units.

Variable	Symbol for the variable	Name of unit	Symbol for unit
power			
potential difference			
current			

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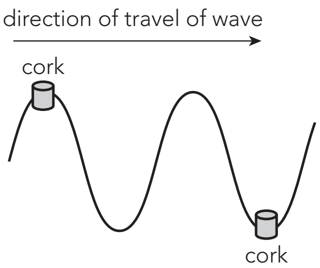

Figure 1.6: Corks on a water wave.

A student places two corks in a bowl of water. The student uses a ruler and a stopwatch to take measurements as a water wave moves across the surface (Figure 1.6). Which line in Table 1.5 gives the correct variable symbols and units for the measurements and average speed calculations?

Circle A, B, C or D.

	Speed		Distance		Time	
	Variable symbol	Unit symbol	Variable symbol	Unit symbol	Variable symbol	Unit symbol
A	*v*	cm/s	*d*	cm	*t*	s
B	*s*	m/s	*D*	m	*t*	s
C	*s*	cm/s	*d*	m	*T*	s
D	*v*	m/s	*s*	m	*T*	s

Table 1.5: Measurements on a water wave for Question 4.

5 A digital radio is 90% efficient. The radio is powered by chemical energy from the Sun transferred as light through solar cells.

a Write the correct variable symbol, unit symbols and unit names in the table.

Variable	Symbol for the variable	Name of unit	Symbol for unit
power			
energy			

b An equation for efficiency is:

$$\text{efficiency} = \frac{\text{useful energy out}}{\text{energy input}} \times 100\%$$

Explain why efficiency has a % sign rather than units.

....

....

....

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Maths focus 3: Determining significant figures

Some figures (digits) in a number are more important than others. This section is about how to decide which parts of a number are most significant in calculations and when estimating.

What maths skills do you need to determine significant figures?

1 Understanding place value	• Compare the size of different numbers • Relate place value to the size of common measurements
2 Determining a correct number of significant figures	• Identify and count significant figures • State numbers to a required number of significant figures

Maths skills practice

How are significant figures useful in physics measurements?

The number of **significant figures** in a value indicates how precisely you know the number. For example, a measurement given as 2.34 m has three significant figures and means the measurement is known to the nearest 0.01 m (1 cm).

KEY WORDS

significant figures: the number of digits in a measurement, not including any zeros at the beginning; for example, the number of significant figures in 0.0682 is three

See Chapter 2 for more on precision and accuracy.

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Maths skill 1: Understanding place value

When we write numbers, the position (place) of each digit is important (see Figure 1.7).

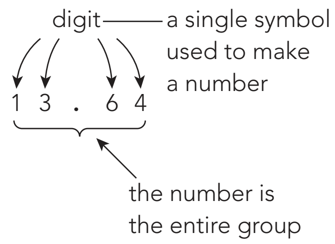

Figure 1.7: Digits in a decimal number.

The positions of the digits give you information about the value represented by the digits. Each place represents ten times the place to the right (Figure 1.8).

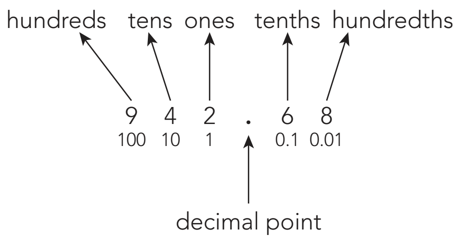

Figure 1.8: How place values are shown in decimal numbers.

Place values in measurements are very important because they indicate value in hundreds, tens and ones of each digit in a measurement. You can see in Figure 1.8 that the 4 in the number really means *4 tens,* or *40,* because of its position.

KEY WORDS

decimal place: the place-value position of a number after a decimal point; the number 6.357 has three decimal places

The number of digits after the decimal point indicates the number of **decimal places** in the number. In Figure 1.8, the number is given to two decimal places (2 d.p.).