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.
- 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

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*).

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

WATCH OUT

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

Maths skills practice

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

If we all use different units of measurement, we cannot easily compare the size of variables and calculations become confusing. This is why the international SI system was agreed. When all scientists use the same system mistakes are minimised. Table 1.1 shows the basic SI units for some variables.

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

Table 1.1 SI units for length, time and mass

As Table 1.1 shows, each unit has a symbol, which makes the unit easier to recognise and write quickly.

Sometimes you will see different units used, such as hours for time and kilometres, centimetres or millimetres for distance.

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.

WATCH OUT

The symbol / is used as a separator between a variable name and its unit in tables and on graphs.

Here, you read the / sign as 'in', so 'Resistance / Ω' is said 'resistance *in* ohms'. 'Speed / m/s' is 'speed *in* metres per second' but may be written more clearly as $\frac{\text{Speed}}{\text{m/s}}$.

Maths skill 1: Choosing the correct unit for a variable

In a calculation, you need to ensure that the units you use are consistent (match) with one another. For example, if you are calculating an area using the equation

$$\text{area} = \text{length} \times \text{width}$$

the length and width must have the same units. If the length measurement is taken in centimetres (cm) and the width measurement in millimetres (mm), you must convert (change) one of the units to make them consistent with one another.

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

If you need 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

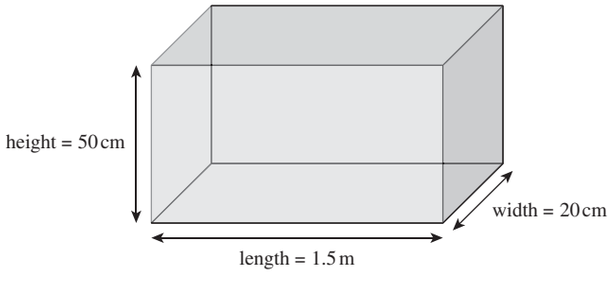
The conversion factors are shown in Table 1.2.

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

Table 1.2 Converting units of length, area and volume

WORKED EXAMPLE 1

Find the volume of this block of material.



TIP

Other SI units that you need to be familiar with are:

- newton (N) a measure of force
- joule (J) a measure of energy
- watt (W) a measure of power
- degrees Celsius (°C) a measure of temperature
- hertz (Hz) a measure of frequency
- volt (V) a measure of potential difference
- amp (A) a measure of current
- ohm (Ω) a measure of resistance
- coulomb (C) a measure of charge (if you are studying the Supplement).

LINK

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

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 = 20 cm

height = 50 cm

volume = ?

Step 3: Check for consistency and decide which unit you are going work in. Here we will work in metres.

length = 1.5 m

width = 0.2 m

height = 0.5 m

volume = ?

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

volume = 1.5 m × 0.2 m × 0.5 m

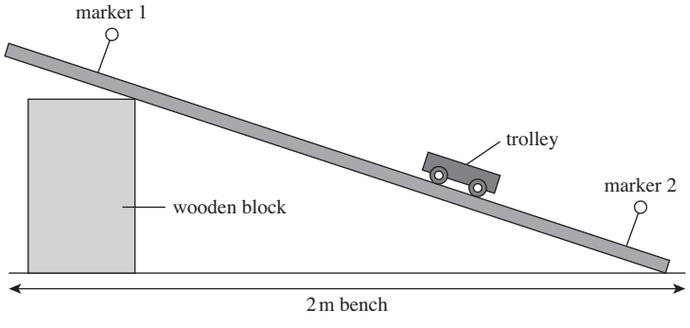
volume = 0.15 m^3

TIP
Remember there are 10 mm in 1 cm.

LINK
See more on unit prefixes in Maths focus 4, 'Representing very large and very small values'.

WATCH OUT
In area calculations: cm × cm = cm^2 but in volume calculations: cm × cm × cm = cm^3

Practice question 1



A student releases a trolley down a long ramp. As the front of the trolley passes marker 1, a stopwatch is started. It is stopped as the trolley reaches marker 2.

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

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

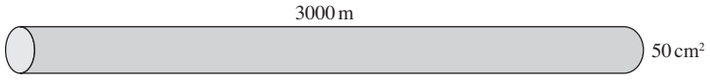
The length of the ramp is measured in .....

The mass of the trolley is measured in .....

TIP
When reading aloud, cm^2 is said as *square centimetres*, and cm^3 as *cubic centimetres*.

TIP
m × m × m = m^3

Practice question 2



A pipe has a cross-sectional area of 50 cm^2 and a length of 3000 m. What is its volume?

Use the formula

volume = cross-sectional area × length

TIP
Convert the cross-sectional area unit to square metres (m^2).

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

Maths focus 2: Using symbols for variables

A *variable* is a measurable characteristic. It has a value, expressed as a number with a unit. To help scientists find and work with relationships between variables, they use symbols instead of the variable names and units. A relationship can then be expressed 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

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

When reading $W = mg$ learn to say it as letters, but also learn to say the word version just by looking at the letters. This will help you learn the meaning.

Maths skills practice

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

Look at this equation that shows how the gravitational field strength impacts on mass to give the weight of an object:

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

Writing formulae 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.

TIP
Your teacher will be able to give you a list of the variable symbols that you need to know. These can be found in Appendix 6 of the Cambridge IGCSE Physics syllabus.

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.

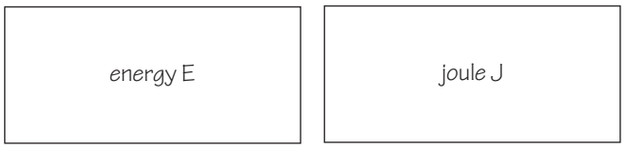


Figure 1.2 Each side of one flashcard, used to help you remember variable symbols and units

Practise your knowledge of symbols. It is a good idea to 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. Practise until you know them all.

WATCH OUT

Avoid being confused by these:

- m represents both metre and milli (the prefix for 10^{-3}); *m* represents mass.
- V represents volt; *V* represents both volume and potential difference.
- *P* represents power; *p* represents pressure.

You can usually tell which one is meant from the context of the physics.

TIP

Say the variable and unit names out loud. Hearing yourself speak them will fix them in your memory better than just silent reading.

TIP

The brackets in J/(kg °C) show that joules are divided by both kg and °C, that is $\frac{1}{\text{kg °C}}$.

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

- Sometimes lower case (small) letters are used and sometimes upper case (CAPITALS).
- 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, e.g. θ for temperature in °C.

WORKED EXAMPLE 2 (SUPPLEMENT)

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).

Practice question 3

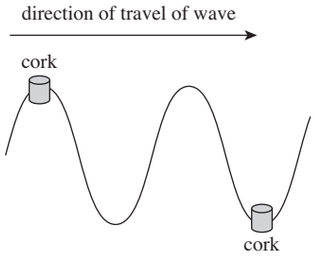
Resistance is a measure of how hard it is for a potential difference to make a current flow in a circuit. It is found by using the formula

$$\text{resistance} = \frac{\text{potential difference}}{\text{current}}$$

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

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

Practice question 4



Two corks are placed in a bowl of water. A ruler and a stopwatch are used to take measurements as a water wave moves across the surface. Which line in the table 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

TIP

Some expressions are **ratios**. A ratio has no unit because it is a comparison of two numbers or of two measurements with the same unit.

Practice question 5 (Supplement)

A transformer is used to change the size of a potential difference. There are 3000 primary turns and 12000 secondary turns. The transformer is 80% efficient. The transformer is used to transmit power at a high voltage so that by reducing the current, the energy losses are low.

a Add the correct variable symbol, unit symbols and unit names to the table.

Variable	Symbol for the variable	Symbol for unit	Name of unit
potential difference			
number of primary turns			
number of secondary turns			
power			
current			
energy			

b An equation for efficiency is

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

Explain why efficiency has a % sign rather than units.

.....

.....

.....

LINK
See Chapter 2, 'Working with data', for more on precision and accuracy.

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 • Change numbers into 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 1.23 m has three significant figures and means the measurement is known to the nearest 0.01 m (1 cm).

TIP
In physics, always write a decimal point in the same way as a full stop. Avoid commas and raised dots.

Maths skill 1: Understanding place value

When we write numbers, the position (place) of each digit is important (see Figure 1.3).

TIP
When saying a decimal number, say each digit after the decimal point separately. 13.64 is said as *thirteen point six four* (never thirteen point sixty four).

If a number includes the digit 0, it is better to read this as zero or nought rather than 'oh'.

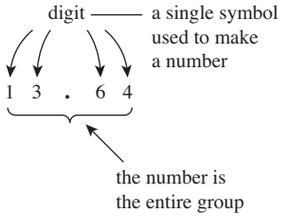


Figure 1.3 Digits in a decimal number

The positions of the digits give you information about the value represented by the digits. Each place represents 10 times the place to the right (Figure 1.4).

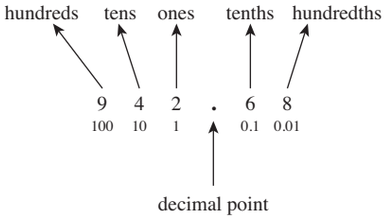


Figure 1.4 How place values are shown in decimal numbers

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 1.4 the 4 in the number really means *4 tens* or *40* because of its position.

The number of digits after the decimal point indicates the number of **decimal places** in the number. In Figure 1.4 the number is given to two decimal places (2 dp).

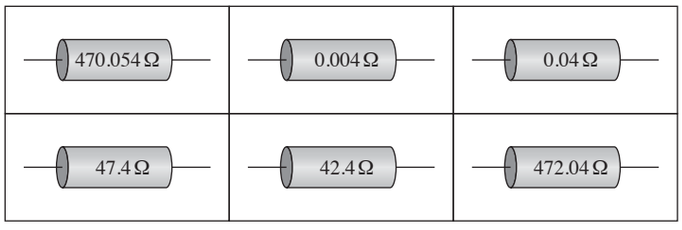
TIP
Think about the number in Figure 1.4 as *9 hundreds, 4 tens, 2 ones, 6 tenths and 8 hundredths*. Thinking about a number in this way will help you to understand the value of each digit.

TIP

If you want to put readings in increasing or decreasing order, decide which number is largest by looking for the digit with the highest place value. This number will go in the row for the highest reading. If, in a place value column, there are two digits of the same value, then move to the next digit to the right and compare these.

WORKED EXAMPLE 3

A student has to decide which resistor to use in his circuit. He has a box containing the following resistors with their resistance values marked.



The student needs a resistor that is close to 4 hundredths of an ohm. Which one should he choose?

Step 1: Check that all of the resistances are expressed in the same unit, Ω or kΩ. In this case, they are all in Ω. Comparisons are easier to make if the same units are used.

Step 2: Prepare a grid to hold the numbers.

Practice question 7

100s	10s	1s	Decimal point	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$
			.			

Step 3: Always keeping the decimal points directly below one another, fill in the grid with all the values.

100s	10s	1s	Decimal point	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$
4	7	0	.	0	5	4
		0	.	0	0	4
		0	.	0	4	
	4	7	.	4		
	4	2	.	4		
4	7	2	.	0	4	

Step 4: Now that you can compare values, choose the one that is equal or closest to the value 4 hundredths of an ohm.

This is 0.04 Ω.

WATCH OUT

Be clear of the difference between *thousands* (1000) and *thousandths* ($\frac{1}{1000}$).

Practice question 6

How many thousandths of a joule (J) are shown in each of the following numbers?

a 2316.475 J .....

b 0.008 24 J .....

c 3614.009 2 J .....

d 0.0207 J .....

TIP
It may help to draw a place value grid like that in Worked example 3.

Practice question 7

A student is writing down the power of appliances used in her home. These are her results.

660.85 W 6.106 W 68.105 W
686.501 W 66.85 W 6.0154 W

a Which line shows increasing power from smallest to largest? Circle A, B, C or D.

A 686.501 W 660.85 W 66.851 W 68.105 W 6.0154 W 6.106 W

B 6.0154 W 6.106 W 66.851 W 68.105 W 660.85 W 686.501 W

C 68.105 W 6.106 W 660.85 W 66.851 W 686.501 W 6.0154 W

D 6.106 W 6.0154 W 68.105 W 66.851 W 660.85 W 686.501 W

100s	10s	1s	Decimal point	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$
			.			
			.			
			.			
			.			
			.			
			.			

b State which one or more of the power figures could belong to a microwave cooker.

.....

c State which one or more of the power figures could belong to a mobile phone charger.

.....

LINK
See Chapter 2, 'Working with data', for more on precision and accuracy.

Practice question 8

The melting point of mercury is stated to be −38.829 0 °C. What fraction of a degree Celsius is this value precise to?

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