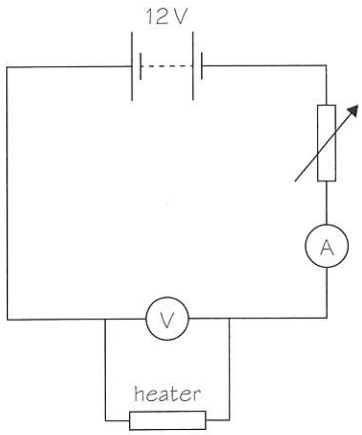
5 Dealing with equations, calculations and SI units

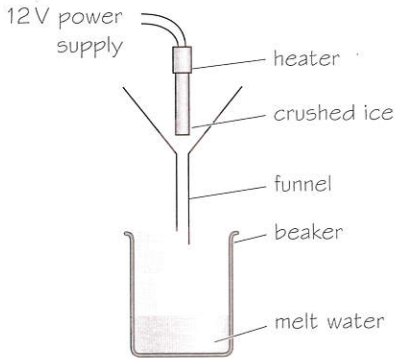
This unit will help you to answer questions involving physics equations and calculations.

In the exam, you will be asked to answer questions such as the one below.

Exam-style question

1 A student wants to find the specific latent heat of ice by doing an experiment. The diagram shows the circuit she uses, and how she sets up the experiment.





The student sets the current to 4.0 A and the potential difference across the heater to 8.0 V using the variable resistor. She runs the experiment for exactly 5 minutes.

(a) Calculate the thermal energy supplied by the heater. Use an equation from the formula sheet.

..... (3 marks)

(b) During the experiment, 34.3 g of melt water dripped into the beaker. Calculate the specific latent heat of fusion of water. Give your answer in J/kg.

..... (3 marks)

You will already have done some work on equations, calculations and SI units. Before starting the **skills boosts**, rate your confidence in equations, calculations and SI units. Colour in the bars.

1 **How do I choose and use the correct equation?**

2 **How do I know which units to use for quantities?**

3 **How do I set out my calculations to gain full marks?**

Physics

Get started

There are many equations used in physics to describe the relationships between physical quantities. These equations may be written in words or symbols. In the exam, you are given some equations on a formula sheet, but you need to remember others.

Symbols are a way of representing physical quantities and units. For example, the equation momentum = mass × velocity is represented by $p = m \times v$.

1 In $p = m \times v$, p and v are lowercase letters. What physical quantities or units would they represent if they were uppercase?

P represents ..... and .....

V represents ....., ... and .....

The International System of Units is used by all scientists. Units in this system are called SI units.

2 All the physical quantities below have an SI unit. Circle (A) the correct SI unit for each quantity.

Distance/length **centimetre / metre / kilometre**	Time **second / minute / hour**	Energy **joule / kilojoule / megajoule**
Power **watt / kilowatt / megawatt**	Mass **gram / kilogram / tonne**	Current **milliampere / ampere**
Force **newton / kilonewton**	Potential difference **millivolt / volt / kilovolt**	Pressure **pascal / kilopascal**

Make sure you know what the correct SI units are for each physical quantity. Some equations in physics only work when SI units are used. For example, $F = m \times a$ does not work if the mass is in grams – it must be in kilograms!

The base units you will use in physics are: metre, kilogram, second, ampere and kelvin. Other units are formed from these base units and are called derived units.

For example, density = $\frac{\text{mass}}{\text{volume}}$, so the unit of density will be the unit of mass divided by the unit of volume, which is kg/m^3.

3 Derive the unit for momentum from the equation.

momentum = mass × velocity

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You often need to rearrange an equation. For example, to calculate mass using the equation:

momentum = mass × velocity, $p = m \times v$

We need to make m the subject of the equation. The subject of the equation $p = m \times v$ is p. This is the letter on its own on one side of the equals sign.

To do this we divide both sides by v:

$$\frac{p}{v} = m \times \frac{v}{v}$$

$$\frac{p}{v} = m \times \frac{\cancel{v}}{\cancel{v}}$$

$\frac{v}{v} = 1$

leaving us with

$$\frac{p}{v} = m \text{ or } m = \frac{p}{v}$$

4 Rearrange $F = m \times a$ to make a the subject of the equation. .....

1 How do I choose and use the correct equation?

There are many equations that you need to use and apply in combined science physics. There are 20 that you need to remember and eight that you are given on a formula sheet.

Exam-style question

1 A lamp has a current of 1.6 A flowing through it.

Calculate the charge that passes through the lamp in 25 s. (3 marks)

First you need to identify the physical quantities. A physical quantity is a physical property that you can measure such as temperature, potential difference and mass.

Remember to learn the unit for each physical quantity. The unit for charge is the coulomb.

1 a Underline (A) the physical quantities given in the question above.

Remember A question might not state the name of the physical quantity, but it will give you the value of the quantity instead.

b Circle (A) the physical quantity you are being asked to calculate.

c Write the symbols for the three physical quantities.

Remember These are the symbols for the physical quantities rather than the symbols for the units.

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We now need to choose an equation that contains these three quantities.

d Here are some equations related to electricity. Circle (A) the equation that contains the three quantities.

$E = Q \times V$ $P = \frac{E}{t}$ $E = I \times V \times t$ $Q = I \times t$ $P = I \times V$

$F = B \times I \times l$ $V = I \times R$ $P = I^2 \times R$ $V_P \times I_P = V_S \times I_S$

e Use the equation you have chosen to calculate the answer. Don't forget to give the unit!

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Exam-style question

2 A resistor dissipates 2.4 W of power when a potential difference of 12 V is placed across it. Calculate the current that flows through the resistor.

The equation that links P, V and I is $P = I \times V$ but it needs to be rearranged.

2 a Rearrange $P = I \times V$ to make I the subject.

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b Calculate the answer and give the correct unit.

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Some equations can be more challenging than others. For example, the equation linking electrical power with current and resistance has a (current)^2 term.

As in maths, you use the order of operations (BIDMAS) to work out the right order to do your calculations: B – brackets, I – indices, D – division, M – multiplication, A – addition, S – subtraction.

2 How do I know which units to use for quantities?

Some physical quantities do not have a named unit of their own. For example, the unit for density is derived from the units of mass and volume from which density is calculated.

1 An aluminium cube of side length 0.1 m has a mass of 2.7 kg.

a Calculate the volume of the aluminium cube.

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b Calculate the density of aluminium. Give the unit.

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

As the SI unit of mass is kg and the unit of volume is m^3, the SI unit of density is kg/m^3.

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Units are sometimes given prefixes such as mega, kilo, centi, milli, micro and nano. You need to know how to convert one unit to another. There are 1000 m in 1 km. So, to convert km to m, we need to multiply by 1000. To convert m to km, we need to divide by 1000.

2 Match the prefix to the correct multipliers. One has been done for you.

Prefix name and symbol	Multiplier	Multiplier (standard form)
mega (M)	$\frac{1}{1\,000\,000}$	10^{-9}
kilo (k)	$\frac{1}{1\,000\,000\,000}$	10^{3}
centi (c)	$\frac{1}{100}$	10^{-6}
milli (m)	1 000 000	10^{-2}
micro (μ)	$\frac{1}{1000}$	10^{6}
nano (n)	1000	10^{-3}

Everyday use of prefixes can help you to remember whether they are big or small quantities. For example, 'mega' is used to mean 'very big' and 'micro' is used to mean very small.

3 Convert these quantities.

145 m = ... km	145 m = ... cm	2440 mm = ... m
97.7 MHz = ... Hz	48 mV = ... V	101 300 Pa = ... kPa
2300 W = ... kW		

Questions requiring calculations of speed may sometimes give units of distance in centimetres, metres or kilometres, and units of time in seconds, minutes, hours or even days or years. For example, the average speed of a glacier might be given in cm/day or m/year.

4 Calculate the missing quantities in the table.

Object	Distance	Time	Average speed
car	240 m	40 s	
lizard		15 s	20 cm/s
rocket	480 km		7.5 km/s

For most questions using average speed, you do not need to use SI units. For questions that use velocity, such as the equations of motion, momentum and kinetic energy, you would need to convert units for distance, time and velocity to SI units.

3 How do I set out my calculations to gain full marks?

It is good practice to structure calculations in a logical way and show your working. Five logical steps are: identify information, choose equation, rearrange, put numbers in, calculate and add unit.

It is important to do this in an exam because you are more likely to get the answer right. In your exam, you usually gain full marks for a correct answer but zero marks for an incorrect answer without working. You will gain some marks for correct working even if the answer is wrong.

A mains electric hoist uses an electric motor to lift a car engine in a workshop.

Calculate the current drawn by the motor when it is working at its full power rating of 0.5 kW. Assume mains electricity is 230 V.

Look at the logical way this calculation has been laid out.

A: $P = 0.5\,kW = 500\,W;\ V = 230\,V;\ I = ?$

B: $P = I \times V$

C: $I = \frac{P}{V}$

D: $I = \frac{500}{230}$

E: $I = 2.2\,A$

Notice how the equals signs in the calculation are all aligned.

In mathematics you are taught to put the numbers in first, then rearrange the equation. However, in science you need to be able to rearrange the equations yourself.

1 Match each line in the laid out calculation above to its description below. Write the letters in the boxes. One has been done for you.

Choose the right equation and write it down. [B]

Calculate the answer and give the unit. [ ]

Identify the physical quantities, making sure the units are SI units if needed. [ ]

Put the numbers in. [ ]

Rearrange the equation if needed. [ ]

2 A small electrical immersion heater supplies 6.25 kJ of energy to an insulated copper block of mass 1.00 kg. The block is initially at 20 °C and the maximum temperature it reaches is 36 °C. Calculate the specific heat capacity of copper using: change in thermal energy = mass × specific heat capacity × change in temperature

3 Name and complete the five steps in the calculation in the table below.

Step	Calculation
	$\Delta Q = 6.25\,kJ = 6250\,J$; change in temperature ($\Delta\theta$) = ...; specific heat capacity (c) = ...
	$\Delta Q = m \times c \times \Delta\theta$
	$c =$ .....
	$c = \frac{6250}{1} \times 16$
	$c =$ ..... unit .....

Sample response

Remember that many calculation questions are worth several marks. If you have a logical approach to answering these questions (like the five-step approach), you are more likely to gain full marks.

Look at these exam-style questions and student responses.

Exam-style question

1 Harry investigates the specific heat capacity of brass.

He uses a brass cylinder with holes drilled for an immersion heater and a thermometer.

The brass cylinder has a mass of 0.50 kg.

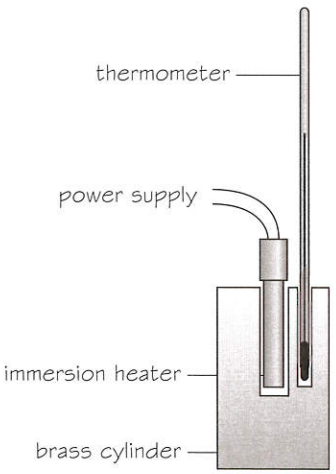
The immersion heater has a power output of 50 W.

Harry heats the brass cylinder for 3 minutes.

(a) Calculate the energy transferred by the immersion heater in 3 minutes. **(3 marks)**

(b) The maximum temperature rise of the brass cylinder is 45 °C.

Calculate the specific heat capacity of brass. **(3 marks)**



(a)

$$P = \frac{E}{t}$$

$$E = P \times t$$

$$E = 50 \times 3$$

$$E = 150$$

(b)

$$\Delta Q = m \times c \times \Delta\theta$$

$$c = \frac{\Delta Q}{m \times \Delta\theta}$$

$$c = \frac{150}{0.5 \times 45}$$

$$c = 6.7\,J/kg\,°C$$

The student has chosen the correct equation but used it incorrectly.

1 a Underline (A) values in the question with SI units.

b Circle (A) any values in the question with non-SI units.

2 a The student has given the wrong answer to part (a). What two mistakes has the student made?

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b Calculate the correct value of E.

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c The student has calculated the wrong answer for part b because they used the incorrect value for E.

Calculate the correct value for the specific heat capacity of brass laying out your calculation in a logical way.

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Your turn!

It is now time to use what you have learned to answer the exam-style question from page 145. Remember to read the question thoroughly, looking for information that may help you. Make good use of your knowledge from other areas of physics.

Exam-style question

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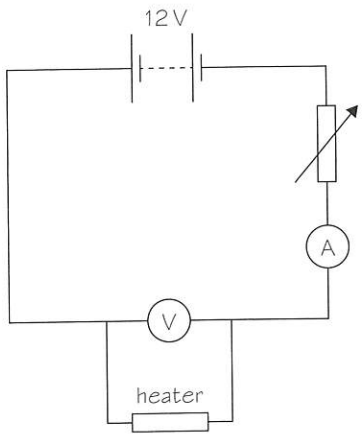

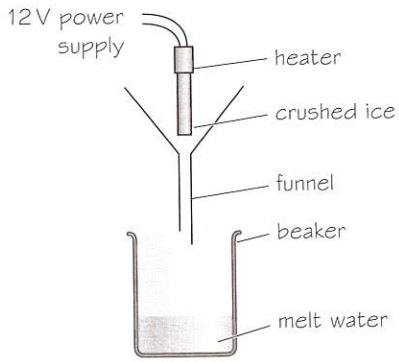

The student sets the current to 4.0 A and the potential difference across the heater to 8.0 V using the variable resistor. She runs the experiment for exactly 5 minutes.

(a) Calculate the thermal energy supplied by the heater. Use an equation from the formula sheet. (3 marks)

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(b) During the experiment, 34.3 g of melt water dripped into the beaker. Calculate the specific latent heat of fusion of water. Give your answer in J/kg. (3 marks)

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Remember to follow the five logical steps: identify information, choose equation, rearrange, put numbers in, calculate and add unit.

Need more practice?

Exam questions may ask about different parts of a topic, or parts of more than one topic. Questions about equations, calculations and SI units could occur as:

- part of a question in many topics
- part of a question about an experiment or investigation.

Have a go at this exam-style question.

The equation that links resistance and current with electrical power is: $P = I^2 R$

Exam-style question

1 A 50 km section of National Grid power line has a resistance of 2.7 Ω and carries a current of 5000 A.

(a) Calculate the power loss in the power line.
Give your answer in megawatts, MW. (3 marks)

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(b) A second power line has the same resistance as the first power line and carries half the current. Describe how this affects the power loss in the second power line. (4 marks)

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To get high marks, back up your answer to part (b) with a second calculation.

Boost your grade

To improve your grade, make sure you learn the twenty equations you need to remember. Make sure too that you learn the symbols for the physical quantities in the equations and their SI units.

Practise using the physics equations, making sure you use the five logical steps to lay out your calculations. Remember to use good maths skills such as order of operations (BIDMAS) in calculations and cross-multiplication when rearranging equations.

How confident do you feel about each of these **skills**? Colour in the bars.

1. How do I choose and use the correct equation?
2. How do I know which units to use for quantities?
3. How do I set out my calculations to gain full marks?