Khalsa 6th@ ATAM

A Level Physics Transition work

This transition work book are designed to give you an introduction and prepare you for advanced study in your chosen subjects. The tasks are to be completed independently over the summer and handed into your subject teachers in your first lesson. You should aim to spend a **minimum** of four hours on this transition booklet.

GCSE to A-level progression: Student transition activities – Physics

Student booklet with information and key skills activities to support the move from GCSE to A-level Physics.

Published: November 2020

A-Level Physics

Welcome to A-Level Physics at Atam Academy. We follow the AQA Specification 7408

This transition booklet will help prepare you for the start of the course by revisiting the Math and Physics content you learnt at GCSE.

There are two tasks that need to be completed before you start the course in September:

1) Complete the transition activities
2) Learn to take Cornell style notes from page 6-9 (book pages appended to the end of this booklet. Cornell style note template are also included.

Aim of the booklet

This booklet will support your transition from GCSE science to A-level. At first, you may find the jump in demand a little daunting, but if you follow the tips and advice in this guide, you'll soon adapt. As you follow the course you will see how the skills and content you learnt at GCSE will be developed and your knowledge and understanding of all these elements will progress.

We have organised the guide into two sections:

1. Understanding the specification and the assessments
2. Transition activities to bridge the move from GCSE to the start of the A-level course.

Understanding the specification and the assessments

Specification at a glance

The specification is a useful reference document for you. You can download a copy from our website here.

The most relevant areas of the specification for students are the following:

Section 3: Subject content

Section 6: Maths requirements and examples

Section 7: Practical assessment

In Physics the subject content is split between AS and A-level. Sections 3.1–3.5 are common for AS and A-level, sections 3.6–3.8 are A-level only content, and the A- level only options are in sections 3.9–3.13. You will study one of the option choices at A-level, this is usually decided by your teacher depending on resources.

The section titles are listed here.

3.1 Measurements and their errors
3.2 Particles and radiation
3.3 Waves
3.4 Mechanics and materials
3.5 Electricity
3.6 Further mechanics and thermal physics (A-level only)
3.7 Fields and their consequences (A-level only)
3.8 Nuclear physics (A-level only)
3.9 Astrophysics (A-level option)
3.10 Medical physics (A-level option)
3.11 Engineering physics (A-level option)
3.12 Turning points in physics (A-level option)
3.13 Electronics (A-level option)

Each section of the content begins with an overview, which describes the broader context and encourages an understanding of the place each section has within the subject. This overview will not be directly assessed.

The specification is presented in a two-column format. The left-hand column contains the specification content that you must cover, and that can be assessed in the written papers.

The right-hand column exemplifies the opportunities for Maths and practical skills to be developed throughout the course. These skills can be assessed through any of the content on the written papers, not necessarily in the topics we have signposted.

Assessment structure

AS

The assessment for the AS consists of two exams, which you will take at the end of the course.

Paper 1	+	Paper 2
What's assessed Sections 1–5		**What's assessed** Sections 1–5
How it's assessed • Written exam: 1 hour 30 mins • 70 marks • 50% of the AS		**How it's assessed** • Written exam: 1 hour 30 mins • 70 marks • 50% of the AS
Questions • 70 marks of short and long answer questions split by topic		**Questions** • Section A: 20 marks of short and long answer questions on practical skills and data analysis • Section B: 20 marks of short and long answer questions from across all areas of AS content • Section C: 30 multiple choice questions

A-level

The assessment for the A-level consists of three exams, which you will take at the end of the course.

Paper 1	Paper 2	Paper 3
What's assessed • Sections 1–5 and 6.1 (Periodic motion)	**What's assessed** • Sections 6.2 (Thermal Physics), 7 and 8 • Assumed knowledge from sections 1–6.1	**What's assessed** • Section A: Compulsory section: Practical skills and data analysis • Section B: Students enter for **one** of sections 9, 10,11,12 or 13
How it's assessed • Written exam: 2 hours • 85 marks • 34% of the A-level	**How it's assessed** • Written exam: 2 hours • 85 marks • 34% of the A-level	**How it's assessed** • Written exam: 2 hours • 80 marks • 32% of the A-level
Questions • 60 marks of short and long answer questions and 25 multiple choice questions on content.	**Questions** • 60 marks of short and long answer questions and 25 multiple choice questions on content.	**Questions** • 45 marks of short and long answer questions on practical experiments and data analysis. • 35 marks of short and long answer question on optional topic

Assessment objective

As you know from GCSE, we have to write exam questions that address the Assessment objectives (AOs). It is important you understand what these AOs are, so you are well prepared. In Physics there are three AOs.

- AO1: Demonstrate knowledge and understanding of scientific ideas, processes, techniques, and procedures (A-level about 30% of the marks).
- AO2: Apply knowledge and understanding of scientific ideas, processes, techniques, and procedures:
  - in a theoretical context
  - in a practical context
  - when handling qualitative data
  - when handling quantitative data

  (A-level about 45% of the marks).
- AO3: Analyse, interpret, and evaluate scientific information, ideas, and evidence, including in relation to:
  - make judgements and reach conclusions
  - develop and refine practical design and procedures

  (A-level about 25% of the marks).

Other assessment criteria

At least 40% of the marks for AS and A-level Physics will assess mathematical skills, which will be equivalent to Level 2 (Higher Tier GCSE Mathematics) or above.

At least 15% of the overall assessment of AS and A-level Physics will assess knowledge, skills and understanding in relation to practical work.

Command words

Command words are used in questions to tell you what is required when answering the question. You can find definitions of the command words used in Physics assessments on the website. They are very similar to the command words used at GCSE.

Subject-specific vocabulary

You can find a list of definitions of key working scientifically terms used in our AS and A-level specification here.

You will become familiar with, and gain understanding of, these terms as you work through the course.

Transition activities

The following activities cover some of the key skills from GCSE science that will be relevant at AS and A-level. They include the vocabulary used when working scientifically and some maths and practical skills.

You can do these activities independently or in class. The booklet has been produced so you can complete it electronically or print it out and do the activities on paper.

The activities are **not a test**. Try the activities first and see what you remember and then use textbooks or other resources to answer the questions. **Don't** just go to Google for the answers, as actively engaging with your notes and resources from GCSE will make this learning experience much more worthwhile.

The answer booklet guides you through each answer. It is not set out like an exam mark scheme but is to help you get the most out of the activities.

Understanding and using scientific vocabulary

Understanding and applying the correct terms are key for practical science. Much of the vocabulary you have used at GCSE for practical work will not change but some terms are dealt with in more detail at A-level so are more complex.

Activity 1 Scientific vocabulary: Designing an investigation

Link each term on the left to the correct definition on the right.

Term	Definition
Hypothesis	The maximum and minimum values of the independent or dependent variable
Dependent variable	A variable that is kept constant during an experiment
Independent variable	The quantity between readings, eg a set of 11 readings equally spaced over a distance of 1 metre would give an interval of 10 centimetres
Control variable	A proposal intended to explain certain facts or observations
Range	A variable that is measured as the outcome of an experiment
Interval	A variable selected by the investigator and whose values are changed during the investigation

Activity 2 Scientific vocabulary: Making measurements

Link each term on the left to the correct definition on the right.

Term	Definition
True value	The range within which you would expect the true value to lie
Accurate	A measurement that is close to the true value
Resolution	Repeated measurements that are very similar to the calculated mean value
Precise	The value that would be obtained in an ideal measurement where there were no errors of any kind
Uncertainty	The smallest change that can be measured using the measuring instrument that gives a readable change in the reading

Activity 3 Scientific vocabulary: Errors

Link each term on the left to the correct definition on the right.

Term	Definition
Random error	Causes readings to differ from the true value by a consistent amount each time a measurement is made
Systematic error	When there is an indication that a measuring system gives a false reading when the true value of a measured quantity is zero
Zero error	Causes readings to be spread about the true value, due to results varying in an unpredictable way from one measurement to the next

Understanding and using SI units

All measurements have a size (eg 2.7) and a unit (eg metres or kilograms). Sometimes, there are different units available for the same type of measurement. For example, milligram, gram, kilogram and tonne are all units used for mass. Some values like strain and refractive index are not followed by a unit.

To reduce confusion, and to help with conversion between different units, there is a standard system of units called the SI units which are used for most scientific purposes.

These units have all been defined by experiment so that the size of, say, a metre in the UK is the same as a metre in China.

There are seven SI base units, which are given in the table.

Physical quantity	Unit	Abbreviation
Mass	kilogram	kg
Length	metre	m
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
luminous intensity	candela	cd

All other units can be derived from the SI base units. For example, area is measured in metres square (written as m^2) and speed is measured in metres per second (written as $m\ s^{-1}$ this is a change from GCSE, where it would be written as m/s).

Some derived units have their own unit names and abbreviations, often when the combination of SI units becomes complicated. Some common derived units are given in the table below.

Physical quantity	Unit	Abbreviation	SI unit
Force	newton	N	$kg\ m\ s^{-2}$
Energy	joule	J	$kg\ m^2\ s^{-2}$
Frequency	hertz	Hz	s^{-1}

Using prefixes and powers of ten

Very large and very small numbers can be complicated to work with if written out in full with their SI unit. For example, measuring the width of a hair or the distance from Manchester to London in metres (the SI unit for length) would give numbers with a lot of zeros before or after the decimal point, which would be difficult to work with.

So, we use prefixes that multiply or divide the numbers by different powers of ten to give numbers that are easier to work with. You will be familiar with the prefixes milli (meaning 1/1000), centi (1/100), and kilo (1 × 1000) from millimetres, centimetres and kilometres.

There is a wide range of prefixes. Most of the quantities in scientific contexts will be quoted using the prefixes that are multiples of 1000. For example, we would quote a distance of 33 000 m as 33 km.

Kg is the only base unit with a prefix.

The most common prefixes you will encounter are given in the table.

Prefix	Symbol	Power of 10	Multiplication factor	
Tera	T	10^{12}	1 000 000 000 000	
Giga	G	10^9	1 000 000 000	
Mega	M	10^6	1 000 000	
kilo	k	10^3	1000	
deci	d	10^{-1}	0.1	1/10
centi	c	10^{-2}	0.01	1/100
milli	m	10^{-3}	0.001	1/1000
micro	μ	10^{-6}	0.000 001	1/1 000 000
nano	n	10^{-9}	0.000 000 001	1/1 000 000 000
pico	p	10^{-12}	0.000 000 000 001	1/1 000 000 000 000
femto	f	10^{-15}	0.000 000 000 000 001	1/1 000 000 000 000 000

Activity 4 SI units and prefixes

1. Re-write the following quantities using the correct SI units.

   a. 1 minute
   b. 1 milliamp
   c. 1 tonne

2. What would be the most appropriate unit to use for the following measurements?

   a. The wavelength of a wave in a ripple tank
   b. The temperature of a thermistor used in hair straighteners
   c. The half-life of a source of radiation used as a tracer in medical imaging
   d. The diameter of an atom
   e. The mass of a metal block used to determine its specific heat capacity
   f. The current in a simple circuit using a 1.5 V battery and bulb

Activity 5 Converting data

Re-write the following quantities.

1. 1.5 kilometres in metres

2. 450 milligrams in kilograms

3. 96.7 megahertz in hertz

4. 5 nanometers in metres

5. 3.9 gigawatts in watts

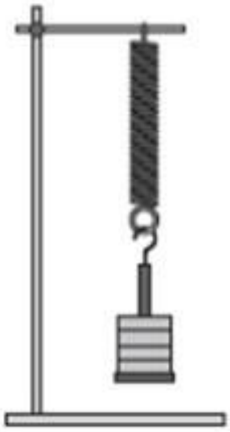
Practical skills

The practical skills you learnt at GCSE will be further developed through the practicals you undertake at A-level. Your teacher will explain in more detail the requirements for practical work in Physics.

There is a practical handbook for AS and A-level Physics, which has lots of very useful information to support you in developing these important skills. You can download a copy here.

Activity 6 Investigating springs

A group of students investigated how the extension of a spring varied with the force applied. They did this by hanging different weights from the end of the spring and measuring the extension of the spring for each weight.



The results are below.

Weight added to the spring / N	Extension of spring / cm			
	Trial 1	Trial 2	Trial 3	Mean
2	3.0	3.1	3.2	
4	6.0	5.9	5.8	
6	9.1	7.9	9.2	
8	12.0	11.9	12.1	
10	15.0	15.1	15.12	

1. What do you predict the result of this investigation will be?
2. What are the independent, dependent and control variables in this investigation?
3. What is the difference between repeatable and reproducible?
4. What would be the most likely resolution of the ruler you would use in this investigation?
5. Suggest how the student could reduce parallax errors when taking her readings.
6. Random errors cause readings to be spread about the true value.

   What else has the student done in order to reduce the effect of random errors and make the results more precise?

7. Another student tries the experiment but uses a ruler which has worn away at the end by 0.5 cm. What type of error would this lead to in his results?

8. Calculate the mean extension for each weight.

9. A graph is plotted with force on the *y* axis and extension on the *x* axis. What quantity does the gradient of the graph represent?

Greek letters

Greek letters are used often in science. They can be used:

- as symbols for numbers (such as π = 3.14…)
- as prefixes for units to make them smaller (eg μm = 0.000 000 001 m)
- as symbols for particular quantities.

The Greek alphabet is shown below.

Capital letter	Lower case letter	Name
Α	α	alpha
Β	β	beta
Γ	γ	gamma
Δ	δ	delta
Ε	ε	epsilon
Ζ	ζ	zeta
Η	η	eta
Θ	θ	theta

Capital letter	Lower case letter	Name
Ι	ι	iota
Κ	κ	kappa
Λ	λ	lambda
Μ	μ	mu
Ν	ν	nu
Ξ	ξ	ksi
Ο	ο	omicron
Π	π	pi

Capital letter	Lower case letter	Name
Ρ	ρ	rho
Σ	ς or σ	sigma
Τ	τ	tau
Υ	υ	upsilon
Φ	φ	phi
Χ	χ	chi
Ψ	ψ	psi
Ω	ω	omega

Activity 7 Using Greek letters

Use your knowledge from GCSE to complete the table. The first line has been completed for you.

Object or quantity represented by the Greek letter	Greek letter
Wavelength	λ
Type of ionising radiation which cannot pass through paper and is used in smoke detectors	
	Ω
Type of ionising radiation which is an electron ejected from the nucleus. Can be used to monitor paper thickness	
Very short wavelength electromagnetic wave	

The Physics formula and data sheet

You will need to use the AQA Physics formula and data sheet in your exams.

You can download a copy here.

Activity 8 Using the Physics formula and data sheet

1. Use the sheet to find the symbols used to represent the following particles. (You will learn about these particles when you study particle physics.)

   a. Photon
   b. Neutrino
   c. Muon
   d. Meson (two letters used depending on type of meson)

2. Look through the Electricity and Materials formula sections on the data sheet.

   There is one Greek letter that is used to represent two different quantities. Give the letter and the quantities is it used to represent.

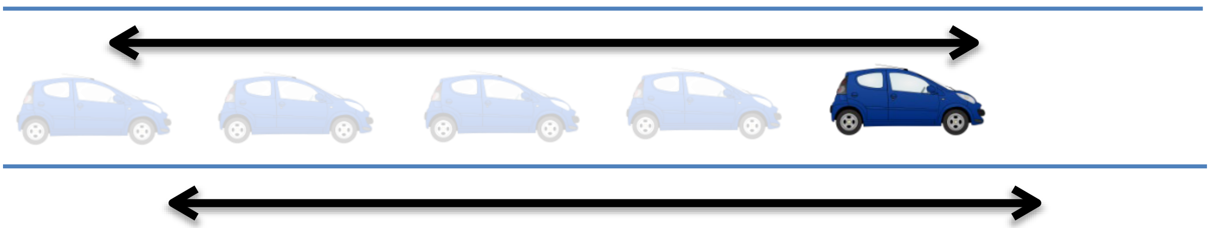
The delta symbol (Δ)

The delta symbol (Δ) is used to mean ‘change in’. For example, at GCSE, you would have learned the formula:

$$\text{speed} = \frac{\text{distance}}{\text{time}} \quad \text{which can be written as} \quad s = \frac{d}{t}$$

What you often measure is the **change** in the distance of the car from a particular point, and the **change** in time from the beginning of your measurement to the end of it.

change in distance along road



change in time

time at
starting point
of
measureme
nt

time at
end point
of
measurem
ent

As the distance and the speed are changing, you use the delta symbol to emphasise this. The A-level version of the above formula becomes:

$$\text{velocity} = \frac{\text{displacement}}{\text{time}} \quad \text{which can be written as} \quad v = \frac{\Delta s}{\Delta t}$$

Note: the delta symbol is a property of the quantity it is with, so you treat ‘Δs’ as one thing when rearranging, and you cannot cancel the delta symbols in the equation above.

Activity 9 Using the delta symbol

1. What is the difference between:

   a. **speed** and **velocity**
   b. **distance** and **displacement**

2. Look at the A-level Physics formula sheet (https://filestore.aqa.org.uk/sample-papers-and-mark-schemes/2018/june/AQA-74081-INS-JUN18.PDF) *.*

   Which equations look similar to ones you used at GCSE, but now include the delta symbol?

3. A coffee machine heats water from 20 °C to 90 °C.

   The power output of the coffee machine is 2.53 kW.

   The specific heat capacity of water is 4200 J/kg °C

   Calculate the mass of water that the coffee machine can heat in 20 s.

4. An unused pencil has a length of 86.0 mm.

   A student uses the pencil to draw 20 lines on a piece of paper.

   Each line has a length of 25 cm.

   The length of the pencil has changed to 84.5 mm.

   Calculate the length of line that would need to be drawn for the original length to be halved.

Rearranging formulas

Activity 10 Rearranging formulas
1. Rearrange $c = f\lambda$ to make f the subject. 2. Rearrange $\rho = \frac{m}{V}$ to make m the subject. 3. Rearrange $w = \frac{\lambda D}{s}$ to make s the subject 4. Rearrange $P = I^2 R$ to make I the subject 5. Rearrange $E = ½ m v^2$ to make v the subject. 6. Rearrange $h f = \varphi + E_k$ to make φ the subject 7. Rearrange $v = u + a t$ to make a the subject. 8. Rearrange $s = u t + ½ a t^2$ to make a the subject. 9. Rearrange $\varepsilon = I(R + r)$ to make r the subject. 10. Rearrange $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ to make T the subject.

Using maths skills

Physics uses the language of mathematics to make sense of the world. It is important that you are able to apply maths skills in Physics. The maths skills you learnt and applied at GCSE are used and developed further at A-level.

Activity 11 Standard form

1. Write the following numbers in standard form.

   a. 379 4
   b. 0.0712

2. Use the data sheet to write the following as ordinary numbers.

   a. The speed of light
   b. The charge on an electron

3. Write one quarter of a million in standard form.

4. Write these constants in ascending order (ignoring units).

   Permeability of free space
   The Avogadro constant
   Proton rest mass
   Acceleration due to gravity
   Mass of the Sun

Activity 12 Significant figures and rounding

1. A rocket can hold 7 tonnes of material.

   Calculate how many rockets would be needed to deliver 30 tonnes of material to a space station.

2. A power station has an output of 3.5 MW.

   The coal used had a potential output of 9.8 MW.

   Calculate the efficiency of the power station.

   Give your answer as a percentage to an appropriate number of significant figures.

3. A radioactive source produces 17 804 beta particles in 1 hour.

   Calculate the mean number of beta particles produced in 1 minute.

   Give your answer to one significant figure.

Activity 13 Fractions, ratios and percentages

1. The ratio of turns of wire on a transformer is 350 : 7000 (input : output)

   What fraction of the turns are on the input side?

2. A bag of electrical components contains resistors, capacitors and diodes.

   $^2/_5$ of the components are resistors.

   The ratio of capacitors to diodes in a bag is 1 : 5. There are 100 components in total.

   How many components are diodes?

3. The number of coins in two piles are in the ratio 5 : 3. The coins in the first pile are all 50p coins. The coins in the second pile are all £1 coins.

   Which pile has the most money?

4. A rectangle measures 3.2 cm by 6.8 cm. It is cut into four equal sized smaller rectangles.

   Work out the area of a small rectangle.

5. Small cubes of edge length 1 cm are put into a box. The box is a cuboid of length 5 cm, width 4 cm and height 2 cm.

   How many cubes are in the box if it is half full?

6. In a circuit there are 600 resistors and 50 capacitors. 1.5% of the resistors are faulty. 2% of the capacitors are faulty.

   How many faulty components are there altogether?

7. How far would you have to drill in order to drill down 2% of the radius of the Earth?

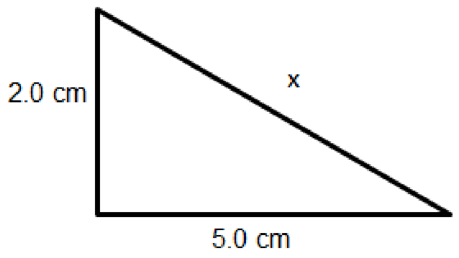
8. Power station A was online 94% of the 7500 days it worked for.

   Power station B was online $^8/_9$ of the 9720 days it worked for.

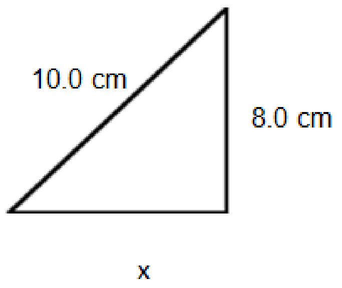
   Which power station was offline for longer?

Activity 14 Pythagoras' theorem

1. Calculate the length of side x.

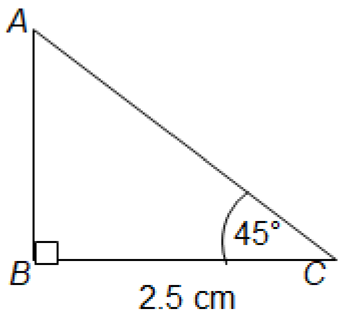


2. Calculate the length of side x.



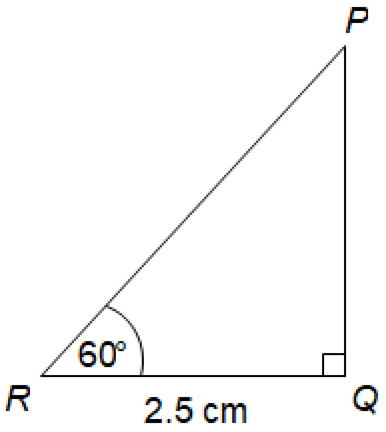
Activity 15 Using sine, cosine and tangent

1. Calculate length AB



(not drawn to scale)

2. Calculate length PR



(not drawn accurately)

Activity 16 Arithmetic means

1. The mean mass of 9 people is 79 kg.

   A 10th person is such that the mean mass increases by 1 kg

   What is the mass of the 10th person?

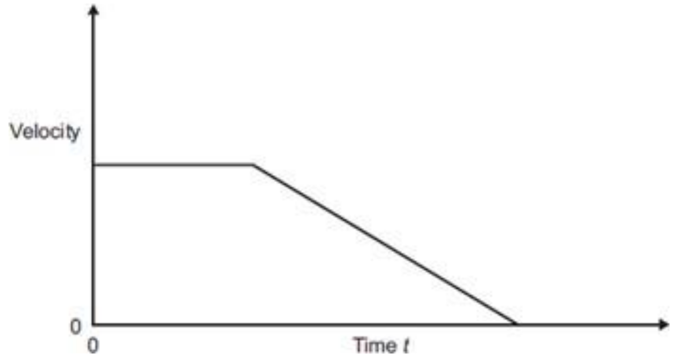
2. A pendulum completes 12 swings in 150 s.

   Calculate the mean swing time.

Activity 17 Gradients and areas

1. A car is moving along a road. The driver sees an obstacle in the road at time $t = 0$ and applies the brakes until the car stops.

   The graph shows how the velocity of the car changes with time.

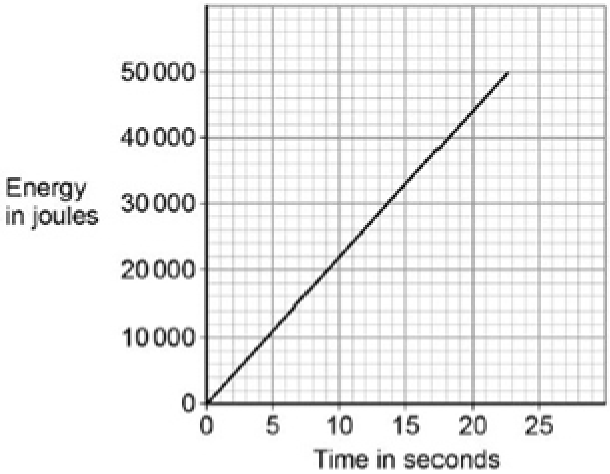


From the list below, which letter represents:

- the negative acceleration of the car
- the distance travelled by the car?

a. The area under the graph
b. The gradient of the sloping line
c. The intercept on the y axis

2. The graph shows how the amount of energy transferred by a kettle varies with time.



The power output of the kettle is given by the gradient of the graph.

Calculate the power output of the kettle.

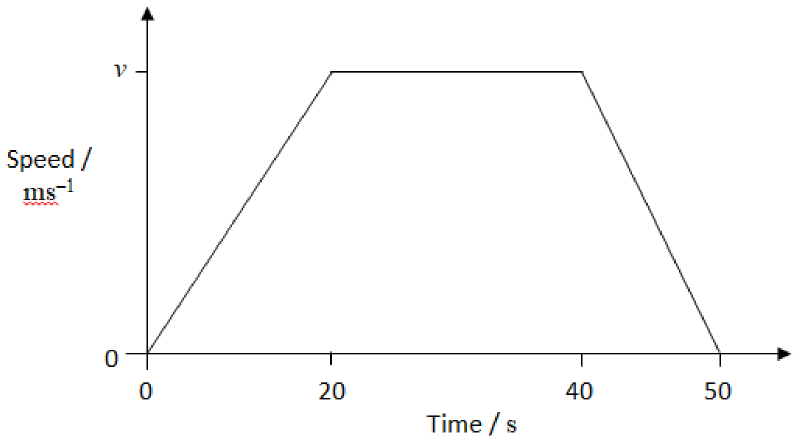
Activity 17 Gradients and areas

3. The graph shows the speed of a car between two sets of traffic lights.

   It achieves a maximum speed of *v* metres.

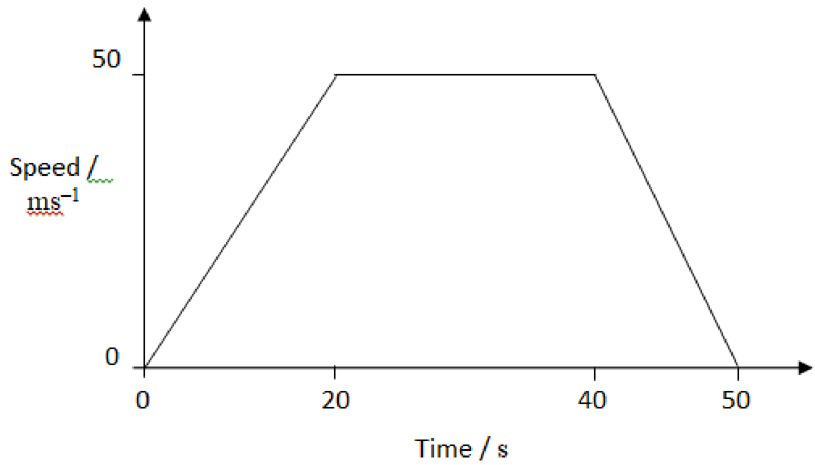
   per second. It travels for 50 seconds.

   The distance between the traffic lights is 625 metres.



   Calculate the value of v.

4. The graph shows the speed of a train between two stations.



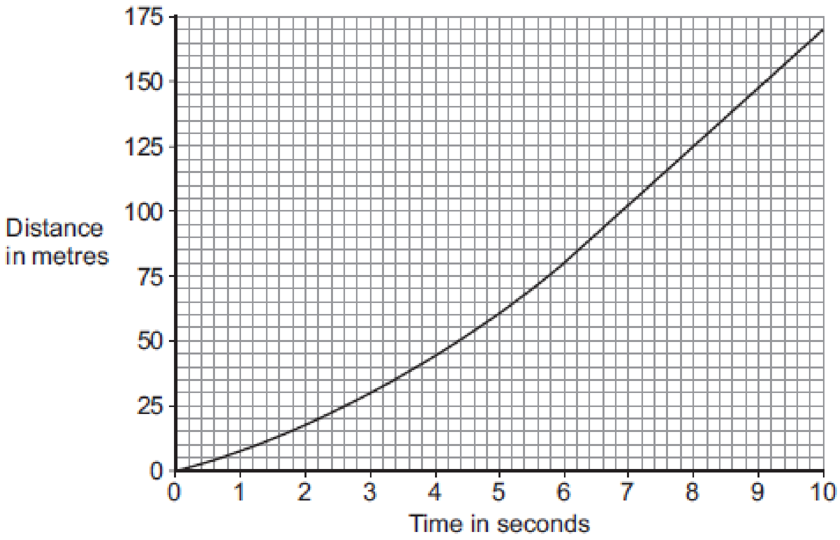
   (not drawn accurately)

   Calculate the distance between the stations.

Activity 18 Using and interpreting data in tables and graphs

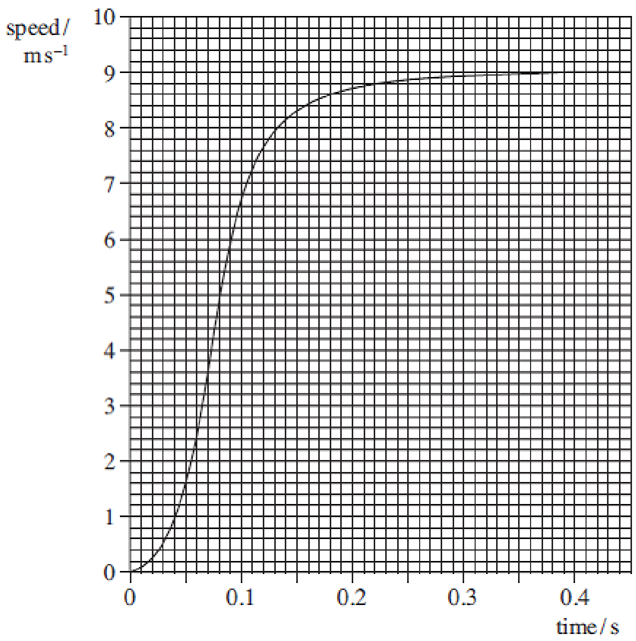
1. The graph shows the motion of a car in the first 10 seconds of its journey.

Figure 1



Use the graph to calculate the maximum speed the car was travelling at.

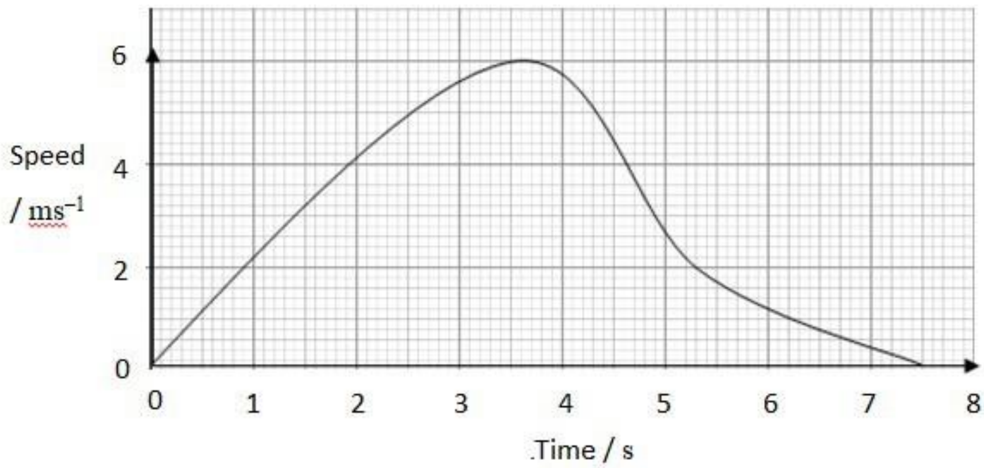
2. The figure below is a speed–time graph for a sprinter at the start of a race.



Determine the distance covered by the sprinter in the first 0.3 s of the race.

Activity 18 Using and interpreting data in tables and graphs

3. The graph shows the speed–time graph of a car.

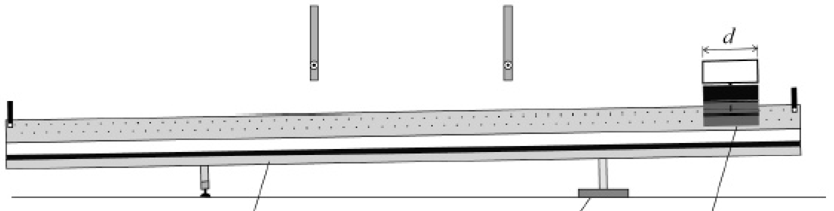


Use the graph to determine:

a. the maximum speed of the car
b. the total distance travelled
c. the average speed for the journey.

Activity 18 Using and interpreting data in tables and graphs

4. The diagram shows the apparatus used by a student to measure the acceleration due to gravity (g).



In the experiment:

- a block is used to raise one end of the air track
- an air-track glider is released from rest near the raised end of the air track and passes through the first light gate and then through the second light gate
- a piece of card of length d fitted to the air-track glider interrupts a light beam as the air-track glider passes through each light gate
- a data logger records the time taken by the piece of card to pass through each light gate and also the time for the piece of card to travel from one light gate to the other.

a. The table gives measurements recorded by the data logger.

Time to pass through first light gate / s	Time to pass through second light gate / s	Time to travel from first to second light gate / s
0.50	0.40	1.19

The length d of the piece of card is 10.0 cm.

Assume there is negligible change in velocity while the air-track glider passes through a light gate.

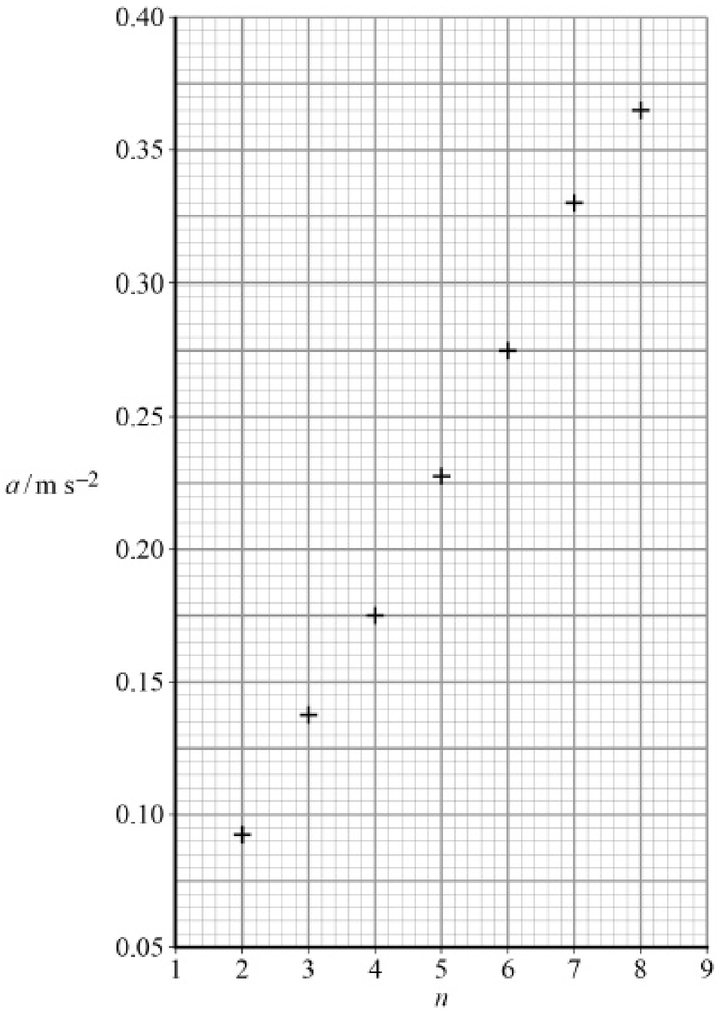
Determine the acceleration a of the air-track glider.

b. Additional values for the acceleration of the air-track glider are obtained by further raising the end of the air track by using a stack consisting of identical blocks.

Adding each block to the stack raises the end of the air track by the same distance.

Activity 18 Using and interpreting data in tables and graphs

Below is a graph of these results showing how *a* varies with *n*, the number of blocks in the stack.



Draw a line of best fit and then determine the gradient of your line (A).

c. It can be shown that, for the apparatus used by the student, *g* is equal to $\frac{2A}{h}$ where *h* is the thickness of each block used in the experiment.

The student obtains a value for *g* of 9.8 m s^{-2}

Calculate *h*.

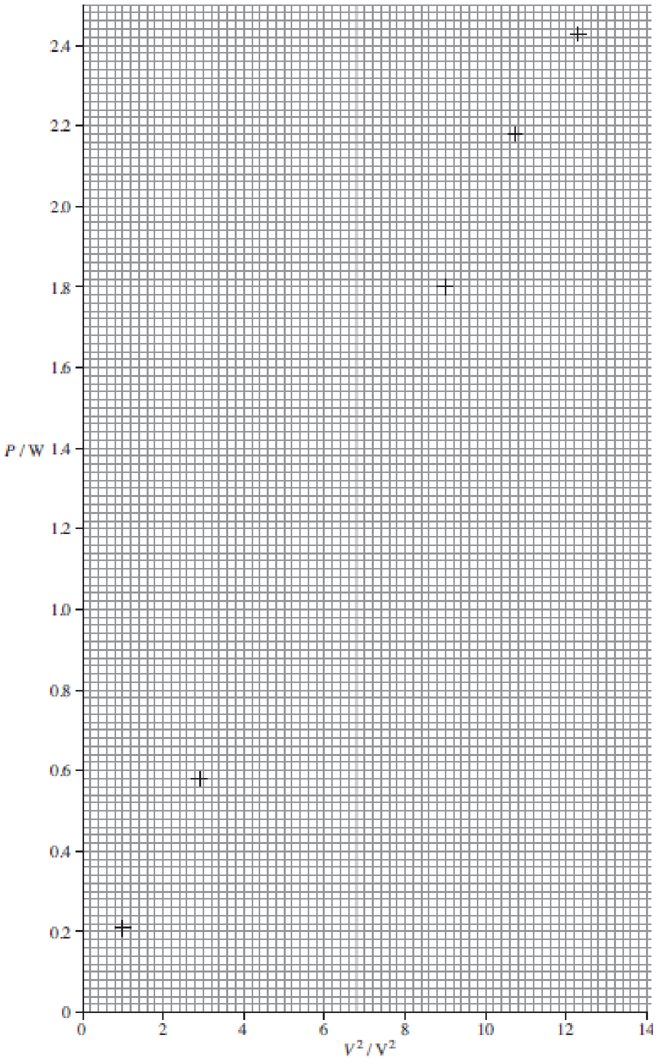
Activity 18 Using and interpreting data in tables and graphs

5. The power *P* dissipated in a resistor of resistance *R* is measured for a range of values of the potential difference *V* across it. The results are shown in the table.

V / V	V^2 / V^2	P / W
1.00	1.0	0.21
1.71	2.9	0.58
2.25		1.01
2.67		1.43
3.00	9.0	1.80
3.27	10.7	2.18
3.50	12.3	2.43

a. Complete the table.

b. Complete the graph below, and draw a line of best fit.



Activity 18 Using and interpreting data in tables and graphs

c. Determine the gradient of the graph.

d. Use the gradient of the graph to obtain a value for *R*.

The relationship is power = potential difference ^{2} / resistance

6. To answer these questions, you will need a copy of the [A-level Physics formula sheet].

In an experiment, a set of LEDs that emitted light of different colours was used.

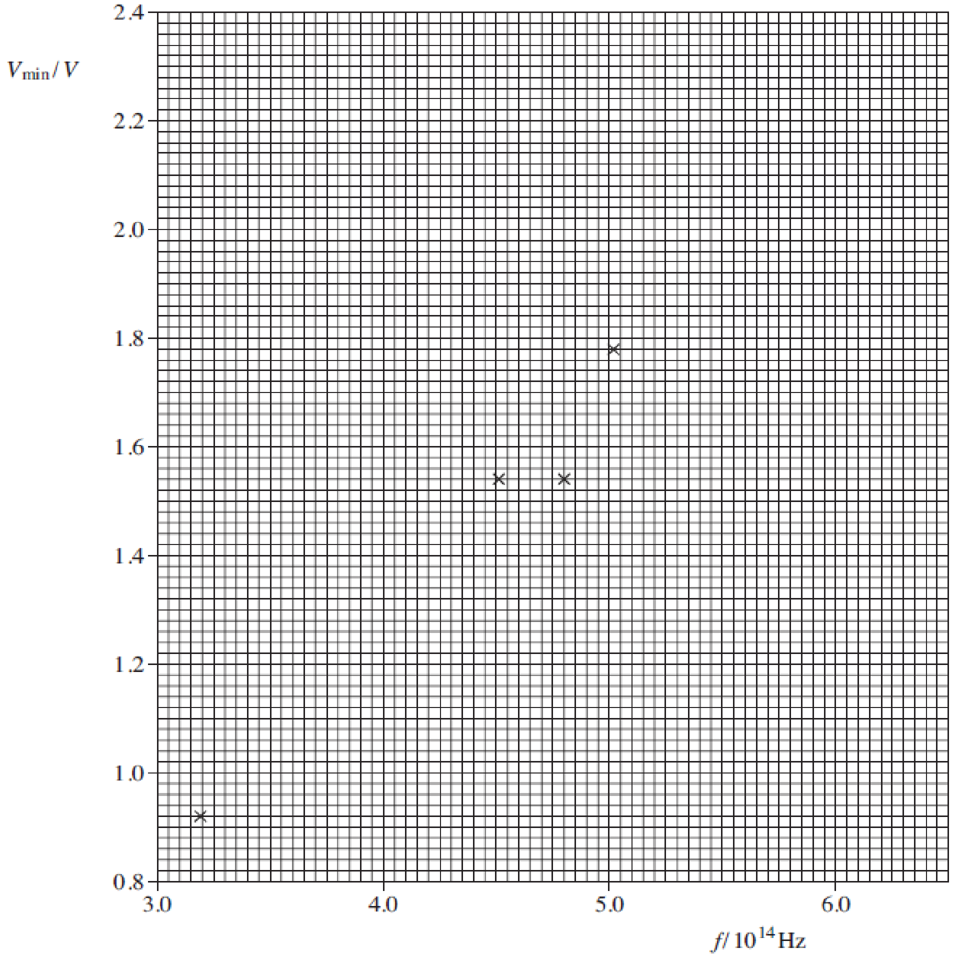
The table below shows the data collected.

Colour	Wavelength λ / nm	Frequency f / 10^{14} Hz	Minimum pd V_{min} / V
Infrared	940	3.19	0.92
Red	665	4.51	1.54
Orange	625	4.80	1.54
Yellow	595	5.04	1.78
Green	565		1.87
Blue	470		2.37

a. Complete the missing values for frequency.

b. Complete the graph by plotting the missing two points and drawing a line of best fit.

Activity 18 Using and interpreting data in tables and graphs



c. Determine the gradient of the graph.

d. Theory predicts that the energy lost by the electron in passing through the LED is the energy of the emitted photon. Hence

$eV_{min} = hf$,

where h is the Planck constant and $e = 1.60 \times 10^{-19}$ C.

Find a value for h by using the general equation of a straight line, $y = mx + c$, and your answer to part (c).

e. The accepted value for $h = 6.63 \times 10^{-34}$ J s. Calculate the percentage difference between the value calculated in part (d) and the accepted value.

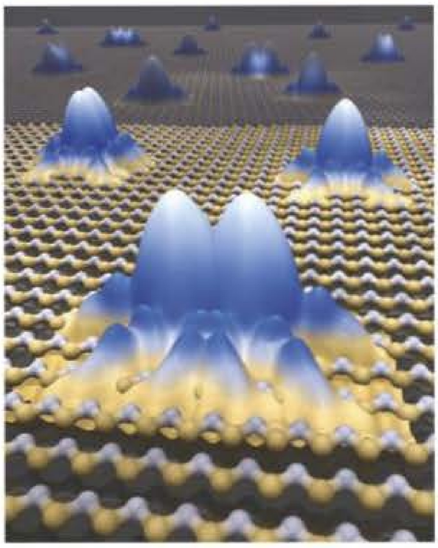
1 Matter and radiation
1.1 Inside the atom

Learning objectives:
- → Describe what is inside an atom.
- → Explain the term isotope.
- → Represent different atoms.

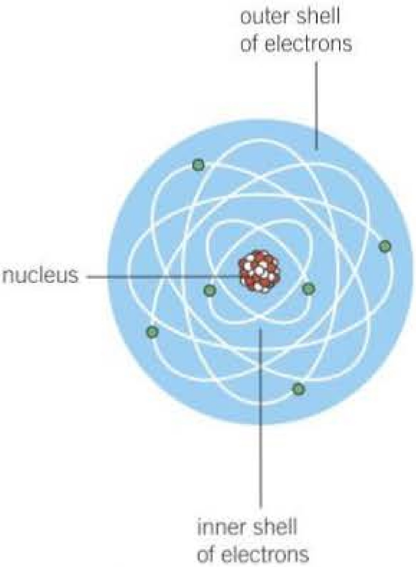
Specification reference: 3.2.1.1

Study tip

Don't mix up 'n' words – nucleus, neutron, nucleon, nuclide!



▲ **Figure 1** *Atoms seen using a scanning tunnelling microscope (STM)*



▲ **Figure 2** *Inside the atom (not to scale)*

The structure of the atom

Atoms are so small (less than a millionth of a millimetre in diameter) that we need to use an electron microscope to see images of them. Although we cannot see inside them, we know, from Rutherford's alpha-scattering investigations, that every atom contains

- a positively charged nucleus composed of protons and neutrons
- electrons that surround the nucleus.

We use the word **nucleon** for a proton or a neutron in the nucleus.

Each electron has a negative charge. Because the nucleus is positively charged, the electrons are held in the atom by the electrostatic force of attraction between them and the nucleus. Rutherford's investigations showed that the nucleus contains most of the mass of the atom and its diameter is of the order of 0.00001 times the diameter of a typical atom.

Table 1 shows the charge and the mass of the proton, the neutron, and the electron in SI units (coulomb for charge and kilogram for mass) and relative to the charge and mass of the proton. Notice that:

1 The electron has a much smaller mass than the proton or the neutron.
2 The proton and the neutron have almost equal mass.
3 The electron has equal and opposite charge to the proton. The neutron is uncharged.

▼ **Table 1** *Inside the atom*

	Charge / C	Charge relative to proton	Mass / kg	Mass relative to proton
proton	$+1.60 \times 10^{-19}$	1	1.67×10^{-27}	1
neutron	0	0	1.67×10^{-27}	1
electron	-1.60×10^{-19}	−1	9.11×10^{-31}	0.0005

This means that an uncharged atom has equal numbers of protons and electrons. An uncharged atom becomes an ion if it gains or loses electrons.

Isotopes

Every atom of a given element has the same number of protons as any other atom of the same element. The **proton number** is also called the **atomic number** (symbol Z) of the element. For example:

- $Z = 6$ for carbon because every carbon atom has six protons in its nucleus.
- $Z = 92$ for uranium because every uranium atom has 92 protons in its nucleus.

The atoms of an element can have different numbers of neutrons. Atoms of the same element with different numbers of neutrons are called **isotopes**.

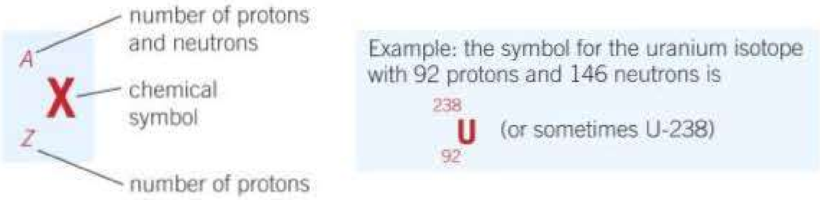
For example, the most abundant isotope of natural uranium contains 146 neutrons and the next most abundant contains 143 neutrons.

Isotopes are atoms with the same number of protons and different numbers of neutrons.

The total number of protons and neutrons in an atom is called the **nucleon number** (symbol A) or sometimes the **mass number** of the atom. This is because it is almost numerically equal to the mass of the atom in relative units (where the mass of a proton or neutron is approximately 1). A nucleon is a neutron or a proton in the nucleus.

We label the isotopes of an element according to their atomic number Z, their mass number A, and the chemical symbol of the element. Figure 3 shows how we do this. Notice that:

- Z is at the bottom left of the element symbol and gives the number of protons in the nucleus.
- A is at the top left of the element symbol and gives the number of protons and neutrons in the nucleus.
- The number of neutrons in the nucleus = $A - Z$.



▲ **Figure 3** *Isotope notation*

Each type of nucleus is called a **nuclide** and is labelled using the isotope notation. For example, a nuclide of the carbon isotope $^{12}_{6}C$ has two fewer neutrons and two fewer protons than a nuclide of the oxygen isotope $^{16}_{8}O$.

Specific charge

The **specific charge** of a charged particle is defined as its charge divided by its mass. We can calculate the specific charge of a charged particle if we know the charge and the mass of the particle. For example:

A nucleus of $^{1}_{1}H$ has a charge of 1.60×10^{-19} C and a mass of 1.67×10^{-27} kg. Its specific charge is therefore $9.58 \times 10^{7}\ \mathrm{C\,kg^{-1}}$.

The electron has a charge of -1.60×10^{-19} C and a mass of 9.11×10^{-31} kg. Its specific charge is therefore $1.76 \times 10^{11}\ \mathrm{C\,kg^{-1}}$. Note that the electron has the largest specific charge of any particle.

An ion of the magnesium isotope $^{24}_{12}Mg$ has a charge of $+3.2 \times 10^{-19}$ C and a mass of 3.98×10^{-26} kg (ignoring the mass of the electrons). Its specific charge is therefore $8.04 \times 10^{6}\ \mathrm{C\,kg^{-1}}$.

Summary questions

You will need to use data from the data sheet on pages 262–265 to answer some of the questions below.

1 **a** State the number of protons and the number of neutrons in a nucleus of

  i $^{12}_{6}C$ **ii** $^{16}_{8}O$

  iii $^{235}_{92}U$ **iv** $^{24}_{11}Na$

  v $^{63}_{29}Cu$.

  b Which of the above nuclei has

  i the smallest specific charge?

  ii the largest specific charge?

2 Name the part of an atom which

  a has zero charge

  b has the largest specific charge

  c when removed, leaves a different isotope of the element.

3 A $^{63}_{29}Cu$ atom loses two electrons. For the ion formed,

  a calculate its charge in C

  b state the number of nucleons it contains

  c calculate its specific charge in $\mathrm{C\,kg^{-1}}$.

4 **a** Calculate the mass of an ion with a specific charge of $1.20 \times 10^{7}\ \mathrm{C\,kg^{-1}}$ and a negative charge of 3.2×10^{-19} C.

  b The ion has eight protons in its nucleus. Calculate its number of neutrons and electrons.

1.2 Stable and unstable nuclei

Learning objectives:

- → State what keeps the protons and neutrons in a nucleus together.
- → Explain why some nuclei are stable and others unstable.
- → Describe what happens when an unstable nucleus emits an alpha particle or a beta minus particle.

Specification reference: 3.2.1.2

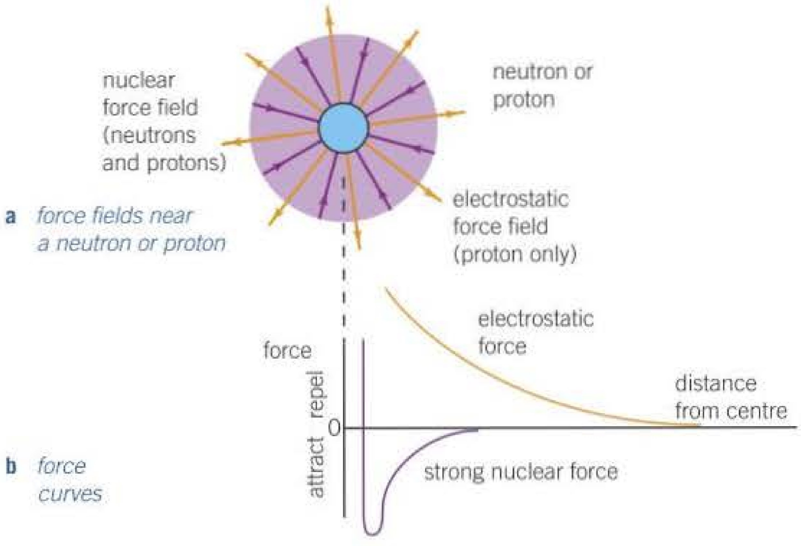
The strong nuclear force

A stable isotope has nuclei that do not disintegrate, so there must be a force holding them together. We call this force the **strong nuclear force** because it overcomes the electrostatic force of repulsion between the protons in the nucleus and keeps the protons and neutrons together.

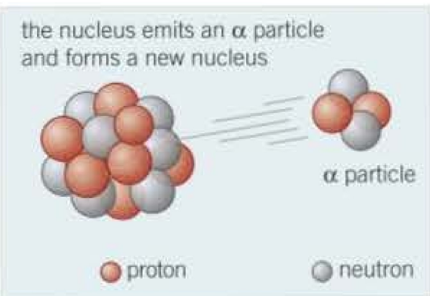
Some further important points about the strong nuclear force are:

- Its range is no more than about 3–4 femtometres (fm), where 1 fm = 10^{-15} m = 0.000 000 000 000 001 m. This range is about the same as the diameter of a small nucleus. In comparison, the electrostatic force between two charged particles has an infinite range (although it decreases as the range increases).
- It has the same effect between two protons as it does between two neutrons or a proton and a neutron.
- It is an attractive force from 3–4 fm down to about 0.5 fm. At separations smaller than this, it is a repulsive force that acts to prevent neutrons and protons being pushed into each other.

Figure 1 shows how the strong nuclear force varies with separation between two protons or neutrons. Notice that the equilibrium separation is where the force curve crosses the *x*-axis.



▲ **Figure 1** *The strong nuclear force*

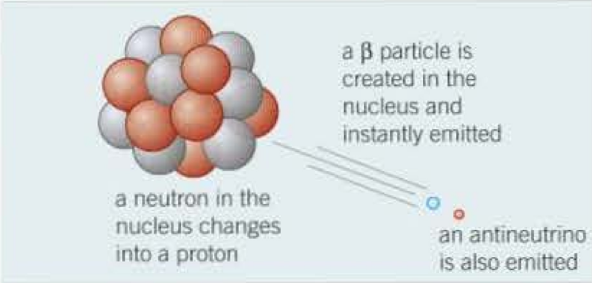


▲ **Figure 2** *Alpha particle emission (not to scale)*

Radioactive decay

Naturally occurring radioactive isotopes release three types of radiation.

1 **Alpha radiation** consists of alpha particles which each comprise two protons and two neutrons. The symbol for an alpha particle is $^{4}_{2}\alpha$ because its proton number is 2 and its mass number is 4. Figure 2 shows what happens to an unstable nucleus of an element X when it emits an alpha particle. Its nucleon number *A* decreases by 4 and its atomic number *Z* decreases by 2. As a result of the change, the product nucleus belongs to a different element Y.



▲ **Figure 3** *Beta particle emission (not to scale)*

We can represent this change by means of the equation below:

$$^{A}_{Z}X \rightarrow \, ^{A-4}_{Z-2}Y + \, ^{4}_{2}\alpha$$

2 **Beta radiation** consists of fast-moving electrons. The symbol for an electron as a beta particle is $^{0}_{-1}\beta$ (or β^-) because its charge is equal and opposite to that of the proton and its mass is much smaller than the proton's mass.

Figure 3 shows what happens to an unstable nucleus of an element X when it emits a β^- particle. This happens as a result of a neutron in the nucleus changing into a proton. The beta particle is created when the change happens and is emitted instantly. In addition, an antiparticle with no charge, called an antineutrino (symbol $\bar{\nu}$), is emitted. You will learn more about antiparticles in Topic 1.4, and neutrinos in Topic 1.5. Because a neutron changes into a proton in the nucleus, the atomic number increases by 1 but the nucleon number stays the same. As a result of the change, the product nucleus belongs to a different element Y. This type of change happens to nuclei that have too many neutrons.

We can represent this change by means of the equation below:

$$^{A}_{Z}X \rightarrow \, ^{A}_{Z+1}Y + \, ^{0}_{-1}\beta + \bar{\nu}$$

3 **Gamma radiation** (symbol γ) is electromagnetic radiation emitted by an unstable nucleus. It can pass through thick metal plates. It has no mass and no charge. It is emitted by a nucleus with too much energy, following an alpha or beta emission.

Journey into the atom (part 1): A very elusive particle!

When the energy spectrum of beta particles was first measured, it was found that beta particles were released with kinetic energies up to a maximum that depended on the isotope. The scientists at the time were puzzled why the energy of the beta particles varied up to a maximum, when each unstable nucleus lost a certain amount of energy in the process. Either energy was not conserved in the change or some of it was carried away by mystery particles, which they called **neutrinos** and **antineutrinos**. This hypothesis was unproven for over 20 years until antineutrinos were detected. Antineutrinos were detected as a result of their interaction with cadmium nuclei in a large tank of water. This was installed next to a nuclear reactor as a controllable source of these very elusive particles. Now we know that billions of these elusive particles from the Sun sweep through our bodies every second without interacting!

Summary questions

1 Which force, the strong nuclear force or the electrostatic force,

a does not affect a neutron

b has a limited range

c holds the nucleons in a nucleus

d tends to make a nucleus unstable?

2 Complete the following radioactive decay equations:

a $^{229}_{90}Th \rightarrow Ra + \alpha$

b $^{65}_{28}Ni \rightarrow Cu + \beta + \bar{\nu}$.

3 A bismuth $^{213}_{83}Bi$ nucleus emits a beta particle then an alpha particle then another beta particle before it becomes a nucleus X.

a Show that X is a bismuth isotope.

b i Determine the nucleon number of X.

ii How many protons and how many neutrons are in the nucleus just after it emits the alpha particle?

4 The neutrino hypothesis was put forward to explain beta decay.

a Explain the term *hypothesis*.

b i State one property of the neutrino.

ii Name two objects that produce neutrinos.

1.3 Photons

Learning objectives:

- → Recall what is meant by a photon.
- → Calculate the energy of a photon.
- → Estimate how many photons a light source emits every second.

Specification reference: 3.2.1.3

Electromagnetic waves

Light is just a small part of the spectrum of **electromagnetic waves**. Our eyes cannot detect the other parts. The world would appear very different to us if they could. For example, all objects emit infrared radiation. Infrared cameras enable objects to be observed in darkness.

In a vacuum, all electromagnetic waves travel at the speed of light, c, which is $3.00 \times 10^8\ \mathrm{m\,s^{-1}}$. As you know from GCSE, the wavelength λ of **electromagnetic radiation** of frequency f in a vacuum is given by the equation

$$\lambda = \frac{c}{f}$$

Note that we often express light wavelengths in nanometres (nm), where $1\ \mathrm{nm} = 0.000\,000\,001\mathrm{m} = 10^{-9}\ \mathrm{m}$.

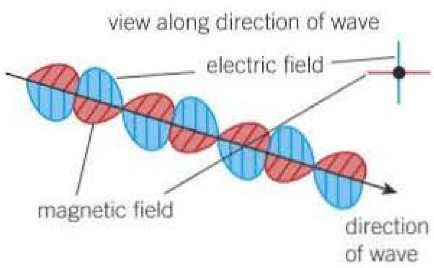
The main parts of the electromagnetic spectrum are listed in Table 1.

▼ **Table 1** *The main parts of the electromagnetic spectrum*

Type	radio	microwave	infrared	visible	ultraviolet	X-rays	gamma rays
Wavelength range	>0.1 m	0.1 m to 1 mm	1 mm to 700 nm	700 nm to 400 nm	400 nm to 1 nm	10 nm to 0.001 nm	<1 nm

As shown in Figure 1, an electromagnetic wave consists of an electric wave and a magnetic wave which travel together and vibrate

- at right angles to each other and to the direction in which they are travelling
- in phase with each other. As you can see the two waves reach a peak together so they are in step. When waves do this we say they are in phase.



▲ **Figure 1** *Electromagnetic waves*

Photons

Electromagnetic waves are emitted by a charged particle when it loses energy. This can happen when

- a fast-moving electron is stopped (for example, in an X-ray tube) or slows down or changes direction
- an electron in a shell of an atom moves to a different shell of lower energy.

Electromagnetic waves are emitted as short bursts of waves, each burst leaving the source in a different direction. Each burst is a packet of electromagnetic waves and is referred to as a **photon**. The photon theory was established by Einstein in 1905, when he used his ideas to explain the **photoelectric effect**. This is the emission of electrons from a metal surface when light is directed at the surface.

Synoptic link

You will meet the photoelectric effect and the photon theory in more detail in Topic 3.1, The photoelectric effect.

Einstein imagined photons to be like *flying needles*, and he assumed that the energy E of a photon depends on its frequency f in accordance with the equation

$$\textbf{photon energy } E = hf$$

where h is a constant referred to as the Planck constant. The value of h is 6.63×10^{-34} J s.

Worked example

Calculate the frequency and the energy of a photon of wavelength 590 nm.
$h = 6.63 \times 10^{-34}$ J s, $c = 3.00 \times 10^{8}$ m s^{-1}

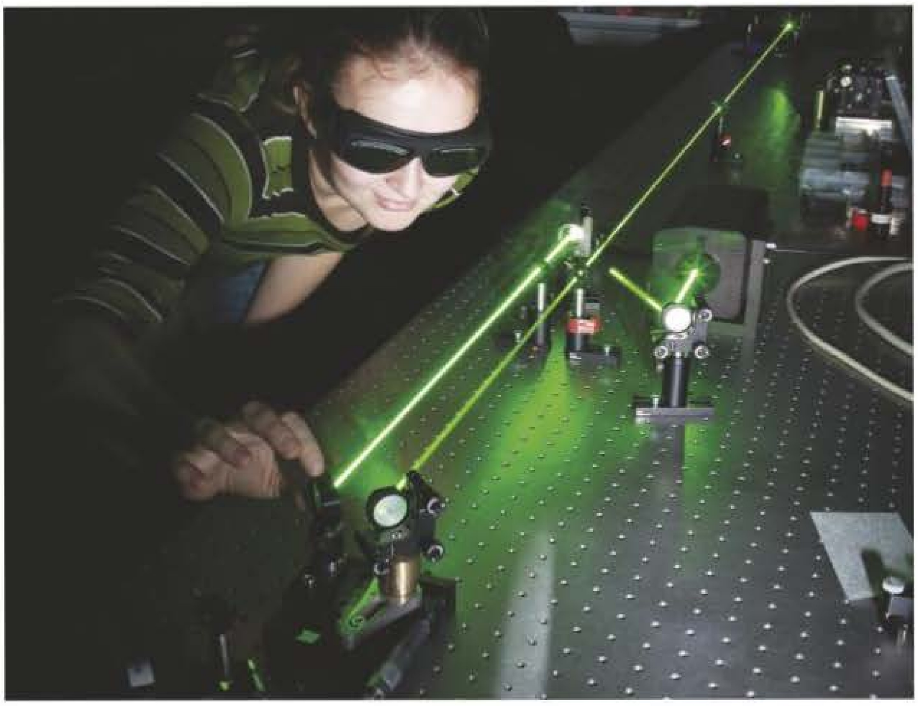
Solution

To calculate the frequency, use $f = \frac{c}{\lambda} = \frac{3.00 \times 10^{8}}{590 \times 10^{-9}} = 5.08 \times 10^{14}$ Hz.

To calculate the energy of a photon of this wavelength, we use $E = hf$.

$E = hf = 6.63 \times 10^{-34} \times 5.08 \times 10^{14} = 3.37 \times 10^{-19}$ J.

Laser power



▲ **Figure 2** *A laser at work*

A laser beam consists of photons of the same frequency. The power of a laser beam is the energy per second transferred by the photons. For a beam consisting of photons of frequency f,

$$\textbf{the power of the beam} = nhf$$

where n is the number of photons in the beam passing a fixed point each second. This is because each photon has energy hf. Therefore, if n photons pass a fixed point each second, the energy per second (or power) is nhf.

Summary questions

$c = 3.00 \times 10^{8}$ m s^{-1}

$h = 6.63 \times 10^{-34}$ J s

1 a List the main parts of the electromagnetic spectrum in order of increasing wavelength.
  b Calculate the frequency of
    i light of wavelength 590 nm
    ii radio waves of wavelength 200 m.
2 With the aid of a suitable diagram, explain what is meant by an electromagnetic wave.
3 Light from a certain light source has a wavelength of 430 nm. Calculate
  a the frequency of light of this wavelength
  b the energy of a photon of this wavelength.
4 a Calculate the frequency and energy of a photon of wavelength 635 nm.
  b A laser emits light of wavelength 635 nm in a beam of power 1.5 mW. Calculate the number of photons emitted by the laser each second.

BEYOND REVISION
GCSE RESOURCES

BEYOND REVISION GCSE RESOURCES

BEYOND REVISION
GCSE RESOURCES

BEYOND REVISION
GCSE RESOURCES

BEYOND REVISION
GCSE RESOURCES