AQA GCSE **Combined Science** Trilogy 8464

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Each specification topic has been referenced and distilled into the key points to make in an examination for top marks. Questions on all topics assessing knowledge, application and analysis are all specifically and carefully devised throughout this book.

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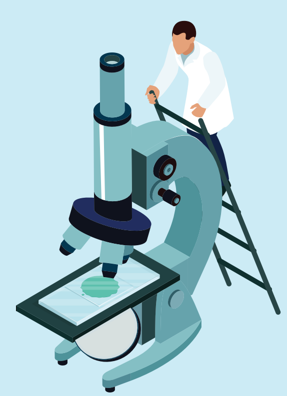

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PREFACE

Absolute clarity! That's the aim.

This is everything you need to ace the examined component in this course and beam with pride. Each topic is laid out in a beautifully illustrated format that is clear, approachable and as concise and simple as possible.

Content and questions for the Higher tier are clearly indicated. The checklist on the contents pages will help you keep track of what you have already worked through and what's left before the big day.

We have included worked exam-style questions with answers for almost every topic. This helps you understand where marks are coming from and to see the theory at work for yourself in an exam situation. There is also a set of exam-style questions at the end of each section for you to practise writing answers for. You can check your answers against those given at the end of the book.

LEVELS OF LEARNING

Based on the degree to which you are able to truly understand a new topic, we recommend that you work in stages. Start by reading a short explanation of something, then try and recall what you've just read. This has limited effect if you stop there but it aids the next stage. Question everything. Write down your own summary and then complete and mark a related exam-style question. Cover up the answers if necessary but learn from them once you've seen them. Lastly, teach someone else. Explain the topic in a way that they can understand. Have a go at the different practice questions – they offer an insight into how and where marks are awarded.

ACKNOWLEDGEMENTS

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THE SCIENCE OF REVISION

Illustrations and words

Research has shown that revising with words and pictures doubles the quality of responses by students.[1] This is known as 'dual-coding' because it provides two ways of fetching the information from our brain. The improvement in responses is particularly apparent in students when asked to apply their knowledge to different problems. Recall, application and judgement are all specifically and carefully assessed in public examination questions.

Retrieval of information

Retrieval practice encourages students to come up with answers to questions.[2] The closer the question is to one you might see in a real examination, the better. Also, the closer the environment in which a student revises is to the 'examination environment', the better. Students who had a test 2–7 days away did 30% better using retrieval practice than students who simply read, or repeatedly reread material. Students who were expected to teach the content to someone else after their revision period did better still.[3] What was found to be most interesting in other studies is that students using retrieval methods and testing for revision were also more resilient to the introduction of stress.[4]

Ebbinghaus' forgetting curve and spaced learning

Ebbinghaus' 140-year-old study examined the rate in which we forget things over time. The findings still hold true. However, the act of forgetting things and relearning them is what cements things into the brain.[5] Spacing out revision is more effective than cramming – we know that, but students should also know that the space between revisiting material should vary depending on how far away the examination is. A cyclical approach is required. An examination 12 months away necessitates revisiting covered material about once a month. A test in 30 days should have topics revisited every 3 days – intervals of roughly a tenth of the time available.[6]

Summary

Students: the more tests and past questions you do, in an environment as close to examination conditions as possible, the better you are likely to perform on the day. If you prefer to listen to music while you revise, tunes without lyrics will be far less detrimental to your memory and retention. Silence is most effective.[5] If you choose to study with friends, choose carefully – effort is contagious.[7]

1. Mayer, R. E., & Anderson, R. B. (1991). Animations need narrations: An experimental test of dual-coding hypothesis. *Journal of Education Psychology*, (83)4, 484–490.
2. Roediger III, H. L., & Karpicke, J.D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, 17(3), 249–255.
3. Nestojko, J., Bui, D., Kornell, N. & Bjork, E. (2014). Expecting to teach enhances learning and organisation of knowledge in free recall of text passages. *Memory and Cognition*, 42(7), 1038–1048.
4. Smith, A. M., Floerke, V. A., & Thomas, A. K. (2016) Retrieval practice protects memory against acute stress. *Science*, 354(6315), 1046–1048.
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6. Cepeda, N. J., Vul, E., Rohrer, D., Wixted, J. T. & Pashler, H. (2008). Spacing effects in learning a temporal ridgeline of optimal retention. *Psychological Science*, 19(11), 1095–1102.
7. Busch, B. & Watson, E. (2019), *The Science of Learning*, 1st ed. Routledge.

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Topic 2 Electricity

Topic 3 Particle model of matter

Topic 4 Atomic structure

Physics Paper 2

Topic 5 Forces

Topic 6 Waves

Topic 7 Magnetism and electromagnetism

MARK ALLOCATIONS

Green mark allocations[1] on answers to in-text questions throughout this guide help to indicate where marks are gained within the answers. A bracketed '1' e.g.[1] = one valid point worthy of a mark. In longer answer questions, a mark is given based on the whole response. In these answers, a tick mark[✓] indicates that a valid point has been made. There are often many more points to make than there are marks available so you have more opportunity to max out your answers than you may think.

BIOLOGY
TOPICS FOR PAPER 1

Information about Paper 1:

Trilogy 8464:

Written exam: 1 hour 15 minutes
Foundation and Higher Tier
70 marks
16.7% of the qualification grade
All questions are mandatory

Specification coverage

The content for this assessment will be drawn from topics on: Cell biology; Organisation; Infection and response; and Bioenergetics.

Questions

A mix of calculations, multiple-choice, closed short answer and open response questions assessing knowledge, understanding and skills.

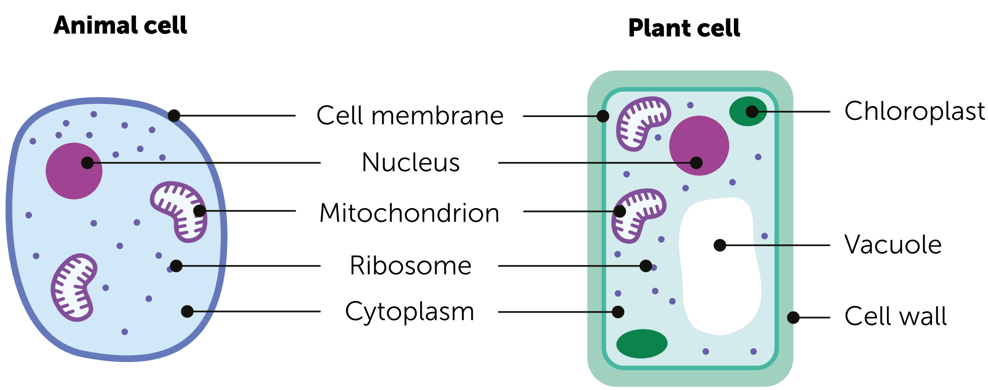
Questions assess skills, knowledge and understanding of Biology.

EUKARYOTES AND PROKARYOTES

Plant and animals are known as eukaryotes. Bacteria are prokaryotes and have a different cell structure.

Eukaryotic cells

Eukaryotic cells have a **cell membrane** containing **cytoplasm**. Within the cytoplasm is a **nucleus**. The genetic material, made of **DNA** organised into chromosomes, is enclosed within the membrane of the nucleus.



1. The genetic material of prokaryotic and eukaryotic cells is organised in different ways. State **two** differences between the genetic material of prokaryotic and eukaryotic cells. [2]
2. Give **two** similarities between the structure of prokaryotic and eukaryotic cells. [2]
3. State the function of the bacterial plasmid. [1]

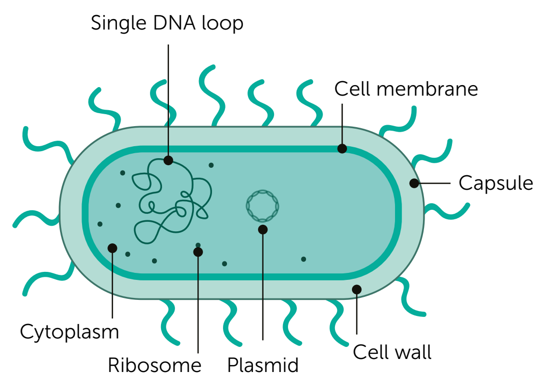
1. Genetic material is found within a nucleus only in eukaryotes.[1] *DNA is organised in a single loop and smaller plasmids in bacteria, but in eukaryotes it is found in chromosomes.*[1]

2. Both have cytoplasm[1]*, a cell membrane*[1] *and ribosomes*[1].

3. Carries additional genes.[1] *Allows genes to be passed from one bacterial cell to another.*[1]

Prokaryotic cells

Prokaryotic cells are much smaller than **eukaryotic** cells. They have a cell wall, which surrounds a cell membrane. The membrane contains cytoplasm but there is no nucleus. Instead, the genetic material is a single **DNA loop** floating freely within the cytoplasm. There may also be one or more small rings of DNA called **plasmids**.



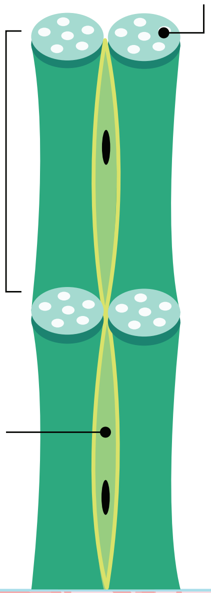
CELL SPECIALISATION

Similar **cells** are organised into **tissues**, tissues are organised into **organs** and organs into **organ systems**. These components work together to carry out a particular function. Cells have different structures so they can carry out their function.

Specialised plant cells

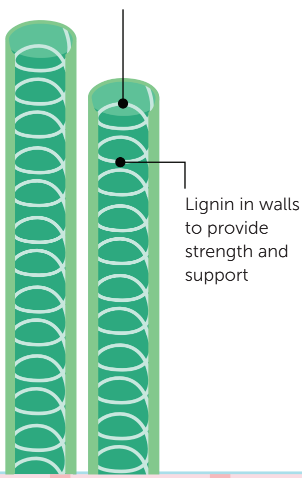
Phloem

Phloem cells transport sugars made in leaves to the rest of the plant.



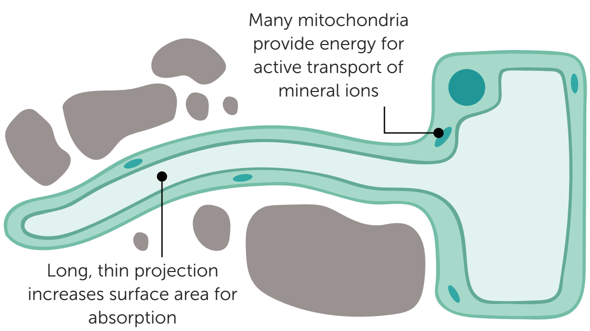
Xylem

Xylem cells transport water and mineral ions through the plant.



Root hair cell

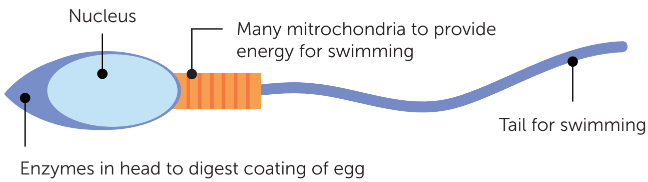
Root hair cells absorb water and mineral ions from soil.



Specialised animal cells

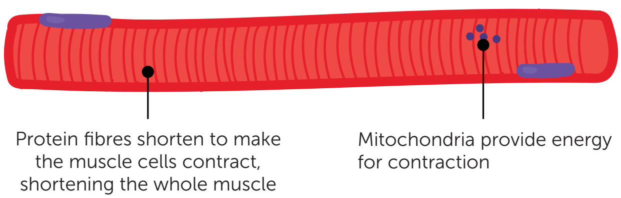
Sperm cell

The function of sperm cells is to carry genetic material to the egg cell.



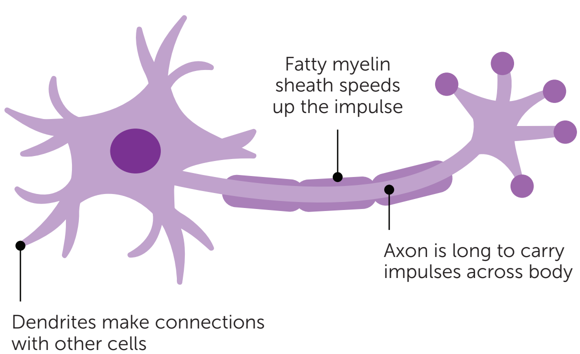
Muscle cell

The function of muscle cells is to produce movement.



Nerve cell (neurone)

The role of nerve cells is to carry electrical impulses around the body. The pattern of these impulses represents a 'message'.



1. Phloem cells are elongated.

   How does this help them to carry out their function? [2]

2. Explain how one structure of a sperm cell helps it to reach the egg cell. [2]

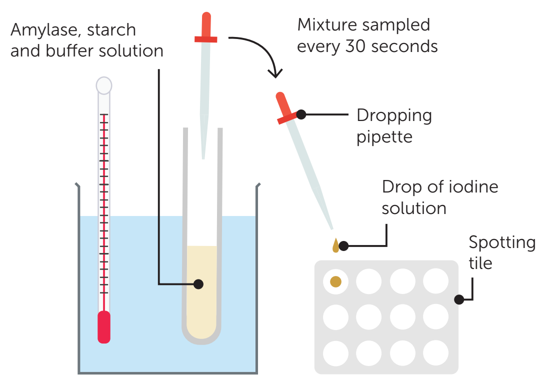
1. *It helps transport sugars*[1] *over a distance*[1].
2. *Tail for swimming.*[1] *Lots of mitochondria to release energy for swimming.*[1] *OR Enzymes in head*[1] *help to digest coating of egg*[1].

REQUIRED PRACTICAL 4

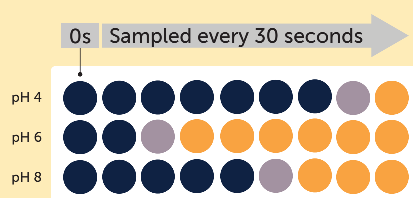
Investigating the effect of pH on the rate of reaction of amylase enzyme

Continuous sampling

The diagram shows how continuous sampling is used to measure the time taken for amylase to digest a starch solution at a range of pH values. Different **buffer solutions** are added which keep the pH at a particular value. The timer is started when the amylase and starch solutions are mixed together. **Iodine** reagent is used to test for starch every 30 seconds. Iodine will turn from orange-brown to blue-black if starch is still present. The time taken for all the starch to be digested (when the iodine first remains orange-brown) is recorded. This approach measures the reaction time to the nearest 30 seconds.



1. Explain why the water bath is used in this investigation. [2]
2. Use the diagram of example results to draw a results table. [3]
3. A student looked at the example results in the diagram. They wrote 'pH 6 is the optimum pH for amylase.' Explain why this may not be a valid conclusion. [2]
3. Use the diagram of example results to draw a results table. [3]
4. The rate of reaction can be calculated using $\frac{1}{\text{Time taken}}$ for the reaction. Calculate the rate of reaction for pH 6. Include appropriate units. [2]



1. To keeps the temperature constant, because changes in temperature affect the rate of enzyme reactions.[1] Raises the temperature to 30°C which speeds up the reaction so results can be obtained more quickly.[1]

2. See table. Times calculated correctly (e.g. pH 4 takes 8 × 30 s to react completely = 240 s) [1]. Table headings correct.[1]

3. Not enough different pH levels were tested to make this conclusion.[1] The optimum pH could be anywhere between pH4 and pH8. [1]

4. Rate = $\frac{1}{90}$ = 0.11[1] per second, or s^{-1}.[1]

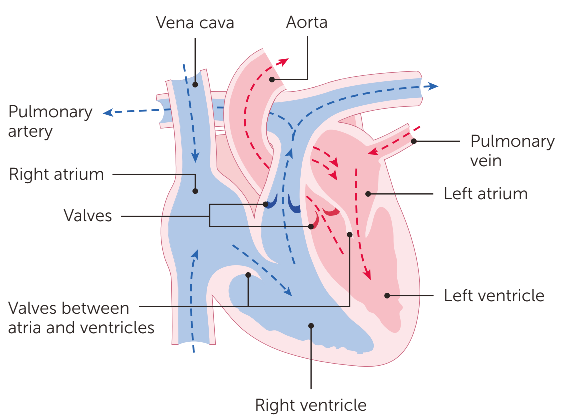
pH	Time for reaction (s)
4	240
6	90
8	180

4.2.2.2

THE HEART AND CIRCULATION

Structure of the heart

The **heart** is an organ that pumps blood around the body. It has walls made of cardiac muscle with four chambers inside. The right ventricle pumps blood to the lungs, where **gas exchange** takes place. The left ventricle pumps blood around the rest of the body. The atria collect blood as it returns and pump it into the ventricles. The atria contract together just before the ventricles contract. Blood shown as blue in the diagram has given up its oxygen to body cells – it is **deoxygenated**. The blood shown as red has been **oxygenated** in the lungs. Valves between the atria and ventricles, and in the veins, prevent blood flowing backwards.

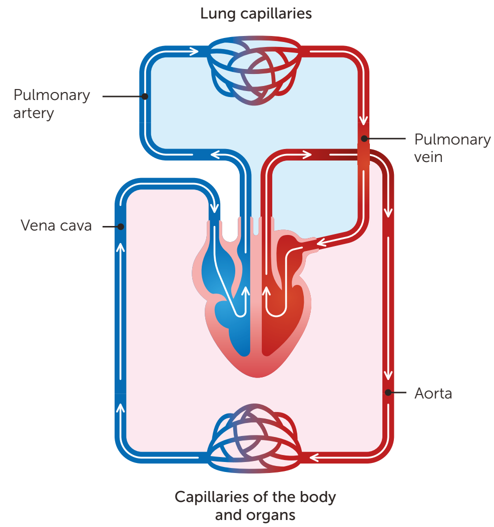


1. The left ventricle has a thicker wall than the right ventricle. Suggest why. [2]
2. Give the benefits of a double circulation. [3]
3. Coronary arteries run down the outside of the heart. State the role of these arteries [1]

1. *The thicker muscle generates greater force[1] needed to push blood around the body compared to through the lungs.*
2. *Passing through twice allows a higher pressure to be maintained[1] increasing blood flow to the tissues.[1] Oxygenated and deoxygenated blood do not mix.[1]*
3. *They supply the cells of the heart / heart muscle with oxygen.[1]*

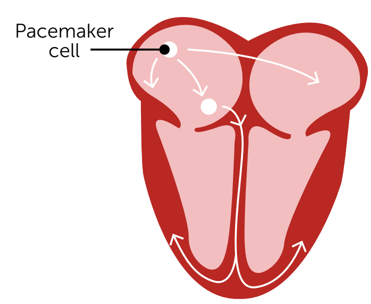
A double circulatory system

Mammals have a double circulation – blood flows through the heart twice during one complete circulation.



Heart rate

Heart rate is the frequency with which the heart contracts. It is measured in **beats per minute**. The natural resting heart rate is controlled by a group of cells found in the right atrium. They act as a **pacemaker**, producing regular impulses that travel through the heart causing it to contract. **Artificial pacemakers** are electrical devices used to correct irregularities in the heart rate.



4.2.2.2

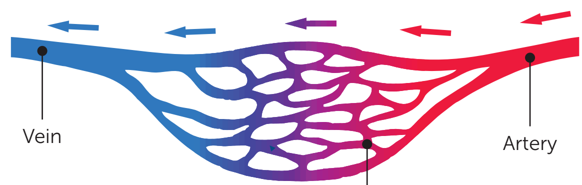
BLOOD VESSELS

The body contains three different types of blood vessel: **arteries**, **veins** and **capillaries**.

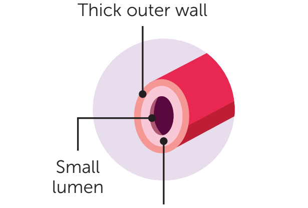
The aorta branches into different arteries that carry blood to the major organs. These branch more and more until they form tiny vessels within tissues called capillaries. Capillaries then join up to form veins.

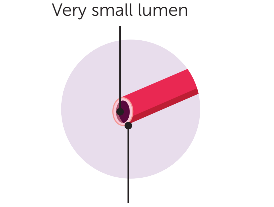
Note that the muscle in arteries does **NOT** pump blood, it simply adjusts the size of the lumen.

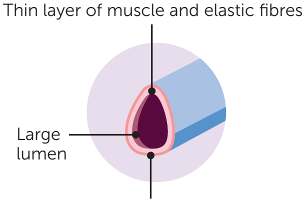
Blood flow



Blood vessel structure and function







	Arteries	Capillaries	Veins
Function	Carry blood at high pressure away from the heart	Exchange of substances with cells	Return blood at low pressure to the heart
Lumen	Narrow to maintain pressure	Very narrow. Keeps red blood cells close to tissue cells	Large, so there is less resistance to blood flow
Wall	Elastic fibres stretch and recoil to maintain pressure. Thick wall resists bursting	Very thin – Short distance to maximise exchange by diffusion	Low pressure so no need for a thick elastic wall
Valve	No – High pressure blood keeps moving	No	Yes – Prevents backflow of low pressure blood

1. A person has a stroke volume of 0.06 dm^3 and a heart rate of 65 beats per minute (bpm). Calculate the cardiac output. [2]
2. Explain how blood keeps flowing in veins despite the low blood pressure in these vessels. [3]

1. 0.06 × 65 = 3.9[1] dm^3 per minute[1].

2. Skeletal muscles press on the veins during activity and squeeze blood along.[1] Valves prevent the blood from going in the wrong direction.[1] The lumen is large so there is little resistance to flow.[1]

Rate of blood flow

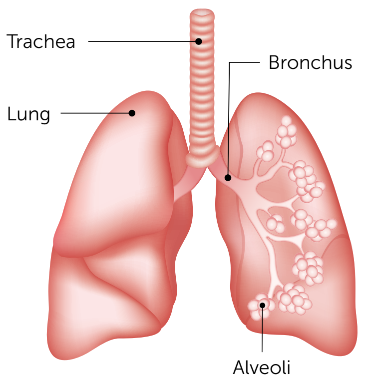
The rate of blood flow from the heart into the aorta is called the cardiac output. It is calculated from the stroke volume (the volume pumped with each heartbeat) and the heart rate.

Cardiac output (dm^3 per minute) = stroke volume (dm^3) × heart rate (beats per minute)

LUNGS AND GAS EXCHANGE

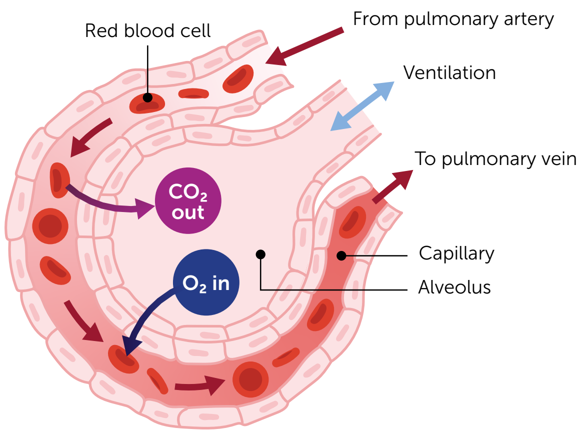
Structure of the lungs

The **trachea** leads from the throat to the lungs. Here it splits into two **bronchi** (*singular*, bronchus). The bronchi divide further and eventually end in small air sacs called **alveoli** (*singular*, alveolus). Muscles in the diaphragm and between the ribs contract and relax again to move air into and out of these airways - a process called **ventilation**.



Gas exchange in the alveoli

The alveoli are surrounded by a network of **capillaries**. Capillaries bring blood to them with a high concentration of **carbon dioxide** and a low concentration of **oxygen**. Oxygen moves by **diffusion** from the air in the alveolus into the blood. Carbon dioxide diffuses in the opposite direction. Blood leaving the alveolus has a high concentration of oxygen and low concentration of carbon dioxide.



How the lungs are adapted for gas exchange

Lung adaptations increase gas exchange by diffusion. A large **surface area** for exchange is provided by the many alveoli with folded surfaces. There is a **short diffusion pathway** because the alveolar wall and capillary wall are both only one cell thick. The **concentration gradient** for diffusion is maintained by having a good blood supply from many capillaries and by ventilation (by breathing). This maintains significant differences in the concentration of CO_2 and O_2 between alveoli and blood, so that diffusion is maximised.

1. Suggest why trachea and bronchi have rings of stiff tissue called cartilage. [1]
2. Explain the importance of: (a) carbon dioxide removal. [1]
   (b) oxygen uptake by the lungs. [1]
3. Describe the path taken by an oxygen molecule as it moves from the air in the alveolus to the blood. [4]

1. To keep the airways open and allow unobstructed air movement.[1]

2. (a) CO_2 from cellular respiration is toxic.[1] *(b) Oxygen is needed for aerobic respiration.*[1]

3. It diffuses [1] *through the single cell layer of the alveolus wall*[1] *through the single-celled wall of the capillary* [1] *through the blood plasma*[1] *then into a red blood cell*[1].

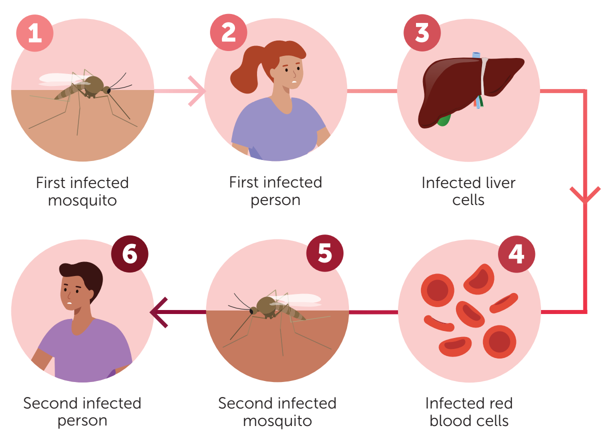
PROTIST DISEASES

Protists are a varied group of eukaryotic organisms. Most are single-celled, but some are multicellular. Some are pathogens but most are not.

Malaria infection

Malaria is caused by a single-celled protist called Plasmodium. The malarial protist has a complicated life cycle. A stage inside a host **mosquito** is an essential part of this life cycle. Malaria is not spread directly from person to person. It is only spread when a mosquito bites an infected person and feeds on blood containing the protist. The mosquito becomes infected and can then infect another person when it bites them. The mosquito is a **vector** for malaria.

The symptoms of malaria are repeated **episodes of fever** with a high temperature and a headache. The disease can be fatal. Globally there are more than four hundred thousand deaths a year from malaria, mostly in young children.



Control of malaria

The spread of malaria is mainly controlled by preventing the spread of the disease by the vector.

- Mosquitoes lay their eggs in stagnant water where their larvae develop and hatch. Malaria can be controlled if mosquitoes are **prevented from breeding** by draining water from ditches and small ponds, or by using insecticides to kill the larvae.
- **Mosquito nets**. Mosquitoes are most active during the night so this is effective in preventing people being bitten while asleep. Some nets also contain an insecticide.

1. The mosquito is a disease vector. State the meaning of the term 'disease vector'. [1]
2. Describe **two** ways that the spread of malaria is controlled. [2]
3. Populations of carnivorous fish have been introduced to ponds in some malaria regions. Suggest how this may reduce local cases of malaria. [3]

1. A disease vector is an organism that carries and spreads a disease.[1]

2. Mosquito nets prevent bites that transmit the disease.[1] *Draining areas of still water and using insecticides prevent mosquitoes from breeding.*[1]

3. The fish will eat mosquito larvae that live in the ponds.[1] *There will be fewer adult mosquitoes to spread malaria.*[1] *The malaria protist must infect mosquitoes to complete its life cycle.*[1]

EXAMINATION PRACTICE

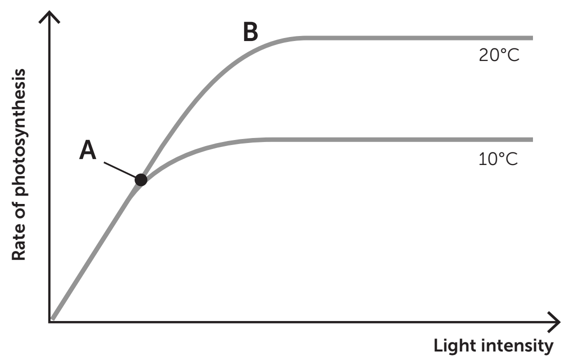
01 Plants use the energy from sunlight to make food.

01.1 Complete the word equation for photosynthesis. [1]

Carbon dioxide + ____________________ → ____________________ + oxygen

01.2 State where in a cell photosynthesis takes place. [1]

The graph shows the effect of light on the rate photosynthesis at two different temperatures.



01.3 Look at the line for the temperature of 10 °C. Explain the change in the rate of photosynthesis at light intensities below point A and above point A. [4]

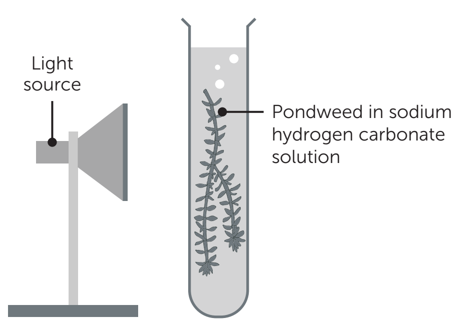
01.4 Explain the reason for the difference between the lines for 10 °C and 20 °C. [2]

01.5 Temperature can be increased in a greenhouse by using a heater and this may increase photosynthesis and crop growth. Explain what factors a farmer would consider when deciding whether to use heaters in a greenhouse.
Use the graph and your own knowledge. [4]

01.6 Increasing light intensity may increase the rate of photosynthesis. Suggest **one** other aspect of lighting that a farmer might change to increase crop growth rates. [1]

02 Students investigated the effect of changing light intensity on the rate of photosynthesis. They used the apparatus shown in the diagram.

Light intensity was changed by using bulbs of different power. The number of bubbles released in one minute were counted.



02.1 The bulb in the light source gets hot which may affect the rate of photosynthesis. Suggest how this problem could be reduced while using the same light source. [2]

BIOLOGY TOPICS FOR PAPER 2

Information about Paper 2:

Trilogy 8464:

Written exam: 1 hour 15 minutes
Foundation and Higher Tier
70 marks
16.7% of the qualification grade
All questions are mandatory

Specification coverage

The content for this assessment will be drawn from Topics 5–7: Homeostasis and response; Inheritance, variation and evolution; and Ecology

Questions

A mix of calculations, multiple-choice, closed short answer and open response questions assessing knowledge, understanding and skills.

Questions assess skills, knowledge and understanding of Biology.

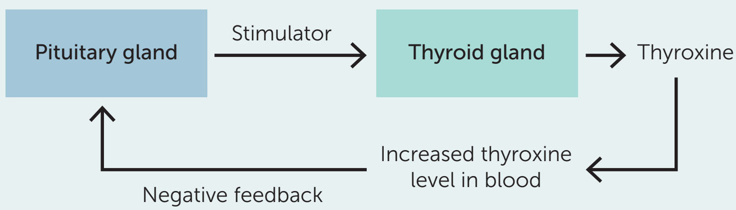
NEGATIVE FEEDBACK SYSTEMS

Once a hormone has caused enough of a response, its secretion from a gland is reduced by **negative feedback**.

Thyroxine

Thyroxine is a hormone secreted by the **thyroid gland**. Thyroxine regulates the rate of metabolism in all body cells. When the thyroid gland secretes more thyroxine, the rate of metabolism (called the **basal metabolic rate**) increases.

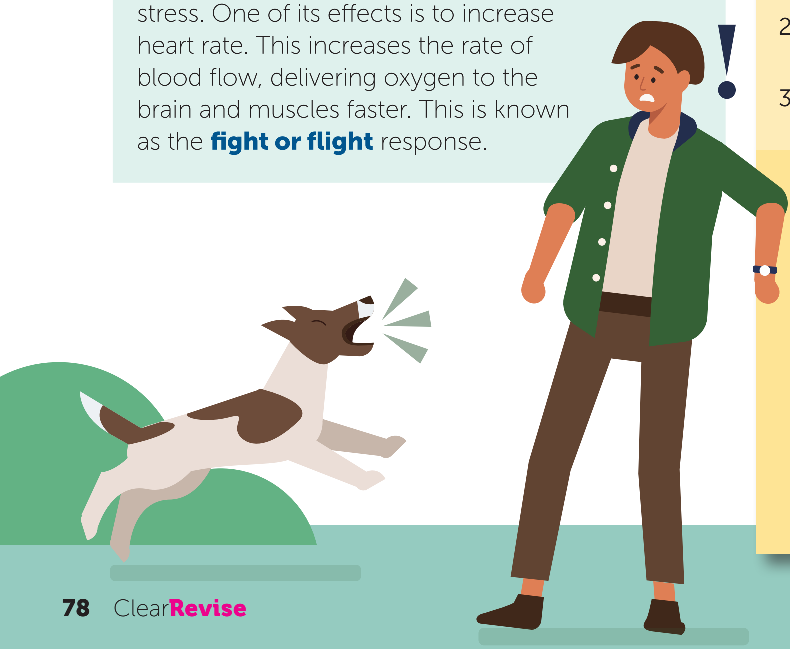
Metabolism includes the synthesis of new molecules, including proteins and lipids used for growth. This means that thyroxine plays a part in regulating growth and development. The level of thyroxine in the blood is controlled by a negative feedback cycle.



The **pituitary gland** releases a hormone that stimulates the secretion of thyroxine by the thyroid gland. However, as the level of thyroxine increases, it has a negative feedback effect on the pituitary gland so the stimulation of the thyroid gland is reduced again.

Adrenaline

Adrenaline is a hormone secreted by the **adrenal glands**. It is released as a response to fear or stress. One of its effects is to increase heart rate. This increases the rate of blood flow, delivering oxygen to the brain and muscles faster. This is known as the **fight or flight** response.

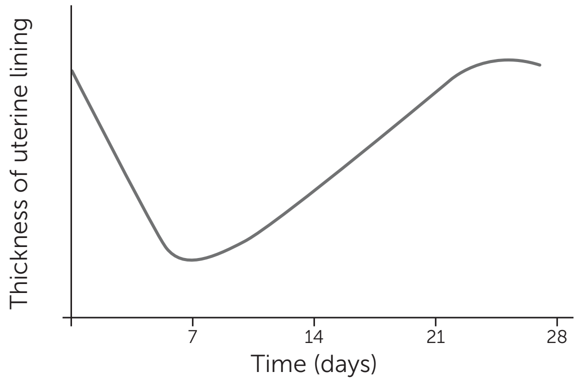


1. Give the response caused by the hormones below:
   (a) Adrenaline [1]
   (b) Thyroxine [1]
2. Explain why the pituitary gland is sometimes called the 'master gland'. [2]
3. Explain why the effects of a fright take a while to wear off. [3]

1. (a) Adrenaline increase in heart rate.[1]
(b) Thyroxine to increase in metabolic rate.[1]
2. The pituitary gland secretes hormones that act on other glands[1] stimulating the release of other hormones[1].
3. The effects of a fright are caused by release of the hormone adrenaline[1] into the blood[1]. The adrenaline is carried in the blood for some time.[1]

EXAMINATION PRACTICE

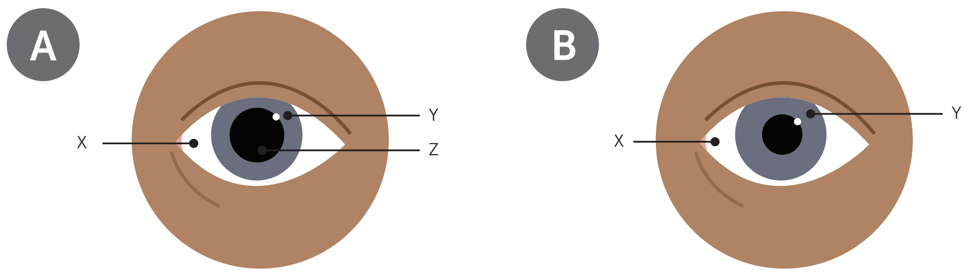
01 The graph shows some events during the menstrual cycle.



01.1 Describe what is happening between days 1 and 7. [1]

01.2 Explain the purpose of the change between days 7 and 26. [2]

02 The image below shows the human eye in two different conditions, A and B.



02.1 Name structures X, Y and Z. [3]

02.2 Suggest a change in conditions that might have caused the response seen in B. [1]

02.3 Explain how effectors lead to this response. [2]

03 Explain why it does not matter which way up seeds are planted in the soil. [4]

04 The table shows some information about different methods of contraception.

	Number of unintended pregnancies per 100 women in a year
Diaphragm plus spermicide	8
Contraceptive pill	1
Spermicide	28

CHEMISTRY
TOPICS FOR PAPER 1

Information about Paper 1:

Trilogy 8464:

Written exam: 1 hour 15 minutes
Foundation and Higher Tier
70 marks
16.7% of the qualification grade
All questions are mandatory

Specification coverage

The content for this assessment will be drawn from topics on: Atomic structure and the periodic table; Bonding, structure, and the properties of matter; Quantitative chemistry; Chemical changes; and Energy changes.

Questions

Multiple-choice, structured, closed short answer and open response questions. They may include calculations.

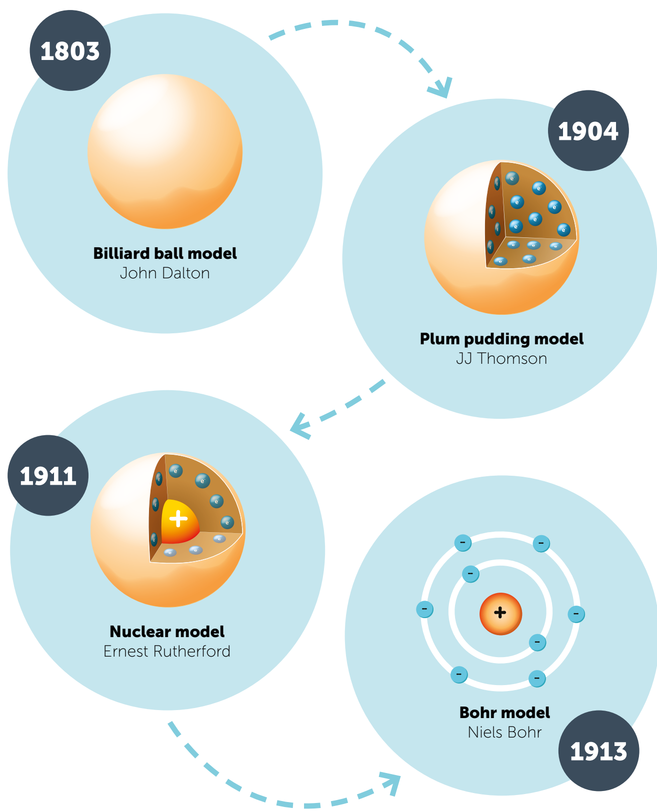
Questions assess skills, knowledge and understanding of Chemistry.

DEVELOPING THE ATOMIC MODEL

The atomic model has changed over time because of new experimental evidence.

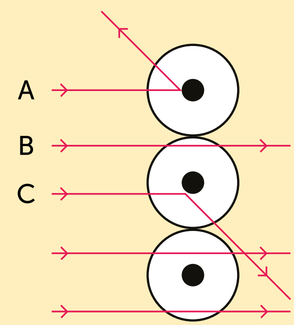
Atomic theories

In the early 19th century, atoms were imagined as tiny, solid spheres. The discovery of the **electron** by J.J. Thomson in 1897 led to his **plum pudding model**. This model was disproved by a series of results from the **alpha particle scattering experiment**.



In this experiment, beams of alpha particles (tiny positively charged particles) were aimed at thin gold foil. The results led to the **nuclear model**. Shortly afterwards, Niels Bohr carried out theoretical calculations showing that electrons orbit the nucleus at set distances. Observations from experiments supported his **electron shell model** and also showed the existence of positively charged **protons**. About 20 years later, James Chadwick demonstrated the existence of **neutrons**.

1. Compare the plum pudding and nuclear models of the atom [3]
2. The diagram shows paths taken by alpha particles through gold foil.



(a) Give a reason why most particles followed the path labelled B. [1]

(b) Explain why some particles followed path C. [2]

(c) Explain why a very small number of particles followed path A. [2]

1. Both models have negatively charged electrons[1]*. These are embedded in a sphere of positive charge in the plum pudding model*[1] *but surround a positively charged nucleus in the nuclear model*[1]*.*

2. (a) Atoms are mostly empty space[1] *so particles passed straight through.*

(b) The nucleus was positively charged[1] *so it repelled the positively charged alpha particles*[1]*.*

(c) The nucleus was very small[1] *but it had a relatively high mass*[1] *and high charge*[1]*.*

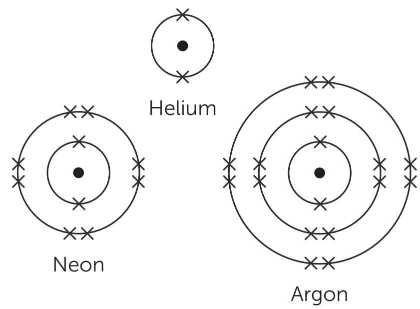
GROUP 0

The Group 0 elements are called the **noble gases**.

Chemical properties

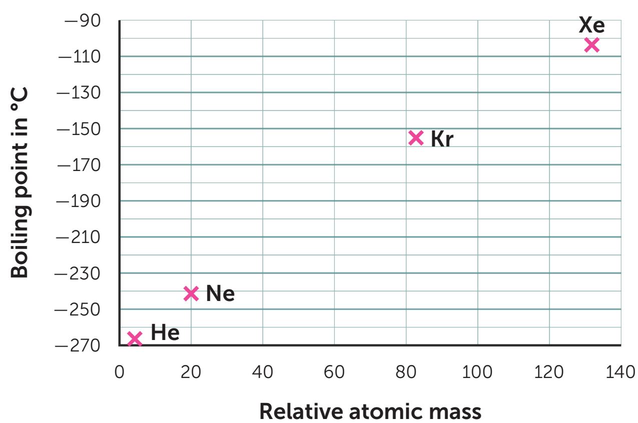
The Group 0 elements are unreactive non-metals.
The highest occupied energy levels of their atoms are completely filled. These stable arrangements mean that the noble gases:

- have little tendency to lose or gain electrons in chemical reactions, so they do not easily form **ionic compounds**.
- have little tendency to share electrons, so they do not easily form **molecules**.



Physical properties

The noble gases have very low boiling points, so they are all in the gas state at room temperature. There is a gradual change or **trend** in their boiling points going down the group.



1. Compare the electronic configuration of helium with the electronic configurations of the other elements in Group 0. [1]
2. (a) Describe the relationship in Group 0 between boiling point and relative atomic mass. [1]
   (b) The relative atomic mass of argon is 40. Predict the boiling point of argon. [1]

1. Helium has 2 outer electrons but the other elements have 8 outer electrons[1].

2. (a) Boiling point increases as the relative atomic mass increases[1].

(b) Between −230 °C and −210 °C [1].

Group 0 atoms do lose electrons to form ions when high voltages are applied to them. They give off coloured light when the electrons return to the ions. This is how neon lights work.

IONIC COMPOUNDS

The ions in **ionic compounds** are held together by **ionic bonding**.

Giant ionic lattice

Ionic compounds have a **giant ionic lattice** structure:

- Lattice – A regular structure.
- Ionic – The structure consists of ions with ionic bonding.
- Giant – The regular structure is repeated very many times.

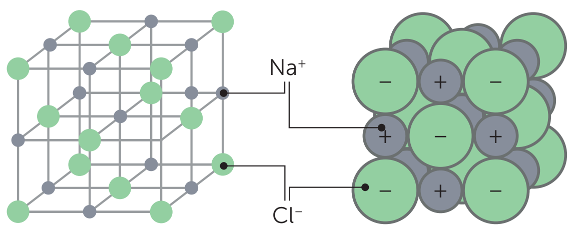
Ionic bonding acts in all directions in the lattice. It is the strong electrostatic force of attraction between oppositely charged ions.

You should know the structure of sodium chloride, but not the structures of other ionic compounds

Representing ionic structures

Ionic structures extend in three dimensions. You can represent these structures using plastic molecular modelling kits. Each ball represents an ion and each stick represents the bonding.

You can also show ionic structures in two dimensions.



Ball and stick

Space-filling

A third representation of bonding in ionic compounds is through dot and cross diagrams. (See **page 154**.)

The different diagrams have limitations.

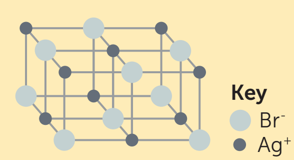
	Dot and cross	Ball and stick	Space-filling
Shows bonding	In detail	As lines	×
Shows relative sizes of atoms	×	Inaccurately	✓
Shows shape of lattice	×	✓	✓

The diagram shows the structure of silver bromide.

(a) Explain why the diagram shows that silver bromide is an ionic compound. [2]

(b) Define the term **empirical formula**. [2]

(c) Determine the empirical formula of silver bromide. [2]



(a) It shows oppositely charged ions[1] from more than one element[1].

(b) The simplest whole number ratio[1] of ions or atoms in a substance[1].

(c) The diagram shows 9 Ag^+ ions and 9 Br^- ions[1], the simplest whole number ratio is 1 : 1 so the empirical formula is AgBr[1].

EXAMINATION PRACTICE

01 Calculate the relative formula mass (M_r) of the following compounds.

01.1 Magnesium nitride, Mg_3N_2 [1]

01.2 Iron(II) nitrate, $Fe(NO_3)_2$ [1]

Relative atomic masses (A_r): N = 14, O = 16, Mg = 24, Fe = 56

02 Carbonic acid, H_2CO_3, is found naturally in rainwater.

Calculate the percentage by mass of oxygen in carbonic acid.

Relative atomic mass (A_r) of oxygen = 16, relative formula mass (M_r) of H_2CO_3 = 62 [2]

03 Copper(II) carbonate decomposes when it is heated:

$$CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$$

A boiling tube containing a sample of copper(II) carbonate was heated. Give a reason that explains why the mass of the boiling tube and its contents changed from 5.5 g to 4.9 g. [1]

04 A solution of sodium chloride had a concentration of 8 g/dm^3.

Calculate the mass of sodium chloride in 50 cm^3 of this solution. [2]

Higher Tier only

05 Calculate the mass of 0.25 mol of carbon dioxide.

Relative formula mass (M_r) = 44 [1]

06 Chlorine is manufactured by passing an electric current through concentrated sodium chloride solution:

$$2NaCl + 2H_2O \rightarrow 2NaOH + H_2 + Cl_2$$

Calculate the theoretical mass of chlorine that can be made from 7.25 g of sodium chloride.

Relative atomic masses (A_r): Na = 23, Cl = 35.5 [4]

07 Magnesium powder reacts with iron(III) oxide powder:

$$3Mg + Fe_2O_3 \rightarrow 3MgO + 2Fe$$

960 g of magnesium was added to 2.0 kg of iron(III) oxide.

Explain why iron(III) oxide was the limiting reactant.

Relative atomic masses (A_r): O = 16, Mg = 24, Fe = 56 [4]

08 Red lead oxide, Pb_3O_4, is used in some rustproof paints. It can be prepared by heating lead(II) oxide, PbO, with oxygen. In one of these reactions, 6.69 g of PbO reacts with an excess of oxygen to produce 6.85 g of Pb_3O_4.

08.1 Calculate the mass of oxygen used in this reaction. [1]

08.2 Determine the balanced symbol equation for this reaction.

Relative formula masses (M_r): O_2 = 32, PbO = 223, Pb_3O_4 = 685 [3]

REQUIRED PRACTICAL 10

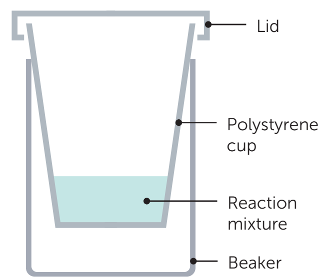
Exothermic and endothermic reactions

This required practical activity helps you develop your ability to carry out and monitor chemical reactions, including using substances carefully and safely.

Simple calorimeters

Reactions in solution cause changes in temperature. A **calorimeter** is used in experiments where these temperature changes are measured. Energy transfer between the surroundings and the reaction mixture is the greatest source of error in these experiments.

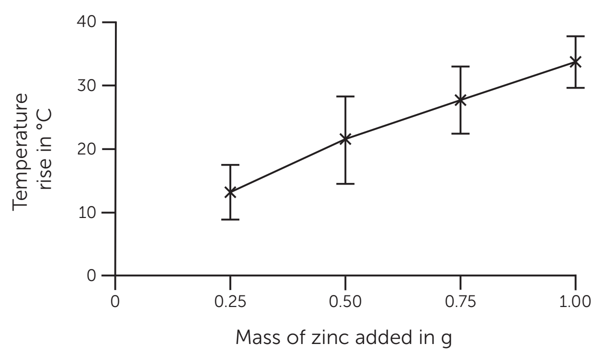
A simple calorimeter consists of a polystyrene cup held securely inside a beaker. The polystyrene and the air gap reduce energy transfers by **conduction**.



An example experiment

A typical experiment involves:

- recording the starting temperature of a solution of an acid, alkali or salt
- mixing the reactants
- recording the temperature of the reaction mixture over several minutes
- determining the maximum change in temperature.



The graph shows the results of an investigation in which different masses of zinc powder were added to copper(II) sulfate solution. The reactions at each mass were repeated several times:

- each × shows a mean rise in temperature
- each I-shaped bar is an **error bar** that shows the **uncertainty** in the results.

1. Give a reason why there is a lid on the polystyrene cup in the diagram. [1]
2. Explain why a line graph was used, rather than a bar chart. [2]

1. The lid reduces energy transfers by convection.[1]

2. The temperature rise and mass of zinc added can both be measured.[1] *They are continuous variables*[1]*, so a line graph is suitable. Bar charts are suitable if a variable is categoric.*[1]

CHEMISTRY
TOPICS FOR PAPER 2

Information about Paper 2:

Trilogy 8464:

Written exam: 1 hour 15 minutes
Foundation and Higher Tier
70 marks
16.7% of the qualification grade
All questions are mandatory

Specification coverage

The content for this assessment will be drawn from topics on: The rate and extent of chemical change; Organic chemistry; Chemical analysis; Chemistry of the atmosphere; and Using resources.

Questions

A mix of multiple-choice, structured, closed short answer and open response questions. They may include calculations.

Questions assess knowledge, understanding and skills.

EXPLAINING CHROMATOGRAPHY

Chromatography separates a mixture of coloured solutes in a solution.

Phases

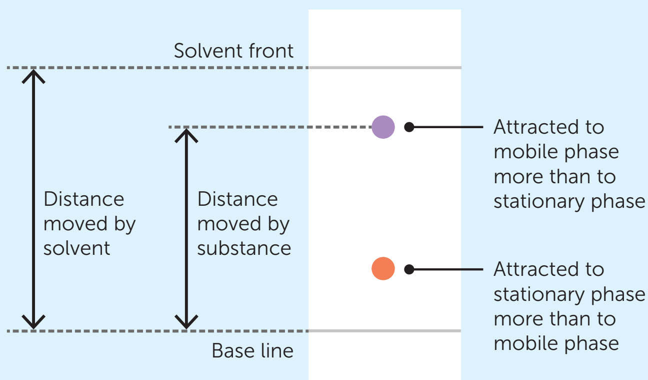
Chromatography relies on two 'phases':

- A **stationary phase** that does not move
- A **mobile phase** that moves past the stationary phase

Required practical activity 6 involves paper chromatography. The stationary phase is in the paper, and the mobile phase is a solvent such as water or propanone.

R_f values

A substance in a solution forms chemical bonds with both phases. The relative strengths of these bonds determine how far the substance travels up the paper with the solvent.



The R_f value of a substance is a measure of the relative distance it travels up the paper:

$$R_f = \frac{\text{Distance moved by substance}}{\text{Distance moved by solvent}}$$

Remember to measure from the centre of a spot to the base line.

Gas-liquid chromatography is an advanced type of chromatography in which the mobile phase is a gas, and the stationary phase is a liquid on a solid support.

1. Explain whether the diagram shows a chromatogram of a pure substance or a mixture. [2]
2. In the diagram, the centre of the blue spot is 72 mm from the base line. The solvent travelled 94 mm. Calculate the R_f value of the blue spot. Give your answer to an appropriate number of significant figures. [3]

1. (It is a mixture because) there are two spots[1] and a pure substance would produce one spot[1].

2. $R_f = \frac{72\text{ mm}}{94\text{ mm}}$ [1] = 0.76595[1] = 0.77[1] to 2 significant figures.

PHYSICS
TOPICS FOR PAPER 1

Information about Paper 1:

Trilogy 8464:

Written exam: 1 hour 15 minutes
Foundation and Higher Tier
70 marks
16.7% of the qualification grade
All questions are mandatory

Specification coverage

The content for this assessment will be drawn from topics on: Energy; Electricity; Particle model of matter; and Atomic structure.

Questions

A mix of calculations, multiple-choice, closed short answer and open response questions assessing knowledge, understanding and skills.

Questions assess skills, knowledge and understanding of Physics.

GRAVITATIONAL POTENTIAL ENERGY (E_p)

When an object is raised it gains **gravitational potential energy** (**g.p.e.**).

Calculating gravitational potential energy

The gravitational potential energy gained by an object raised above the ground can be calculated using the equation:

g.p.e. = mass × gravitational field strength × height

$$E_p = mgh$$

You need to be able to recall and apply this equation.

E_p = gravitational potential energy in joules, J

m = mass in kilograms, kg

g = gravitational field strength in newtons per kilogram, N/kg

h = height in metres, m.

In any calculation the value of the gravitational field strength (*g*) will be given. Remember that *h* is the change in **vertical** height.

The equation can be rearranged to calculate mass, gravitational field strength and height.

Use g = 9.8 N/kg for all questions.

1. Calculate the increase in gravitational potential energy when a mass of 1.2 kg is lifted to a height of 5 m. [2]
2. A skier has a mass of 80 kg. Calculate how much energy is transferred from the gravitational potential energy store as the skier travels 150 m down a mountain. [2]
3. A ball is dropped from a height of 2.0 m. Calculate the speed at which the ball hits the ground. [3]

1. g.p.e. = mgh

= 1.2 × 9.8 × 5 [1]

= 58.8 J [1]

2. g.p.e. = mgh

= 80 × 9.8 × 150 [1]

= 117 600 J [1]

3. decrease in g.p.e. = increase in kinetic energy

$m \times g \times h = 0.5 \times m \times v^2$ [1]

$0.5 \times v^2 = 9.8 \times 2.0$ [1]

$v = \sqrt{\frac{19.6}{0.5}} = 6.3$ m/s [1]

REQUIRED PRACTICAL 16

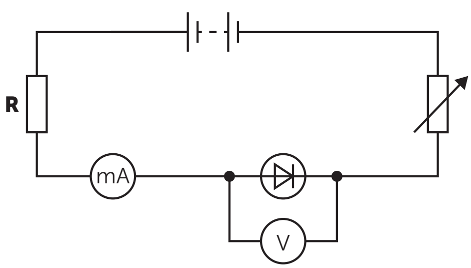
Investigating *I-V* characteristics of components

This practical activity helps you develop your ability to use appropriate circuits and circuit diagrams to measure current and potential difference for different components.

Measuring current and potential difference

Investigate what happens to the current in (i) a **resistor**, (ii) a **filament lamp** and (iii) a **diode** when the potential difference across it is changed.

This is the circuit used for finding the characteristics of the diode.



When testing the resistor and filament lamp, replace the diode and remove resistor *R*.

Use a normal ammeter instead of a milliammeter (mA) to measure current when testing these two components. This depends on the values of the current, and the resolution of the ammeters.

Set up the circuit for each component. Adjust the variable resistor and record several pairs of ammeter and voltmeter readings in a suitable table. Swap the connections on the power supply – connect the ammeter to the negative terminal and connect the component being tested to the positive terminal. This will give readings with **negative values**.

Plot a graph of current against potential difference for each component.

The I-V graphs plotted for each component (current against potential difference) should look similar to those on page 267. The shape of the graph is the *I-V* characteristic of the component.

1. The gradient of the graph for the resistor is a straight line that goes through the point (0, 0). Explain what this tells you about the resistor. [2]
2. Give reasons why the circuit to test the diode has an extra resistor in it and uses a milliammeter. [2]

1. *The resistor is an ohmic conductor*[1] *because the graph is directly proportional which means that the resistance is constant*[1].
2. *The extra resistor is used to protect the diode from high currents*[1] *and a milliammeter is used because the current values are low*[1].

PHYSICS
TOPICS FOR PAPER 2

Information about Paper 2:

Trilogy 8464:

Written exam: 1 hour 15 minutes
Foundation and Higher Tier
70 marks
16.7% of the qualification grade
All questions are mandatory

Specification coverage

The content for this assessment will be drawn from topics on: Forces; Waves; and Magnetism and electromagnetism.

Questions

A mix of calculations, multiple-choice, closed short answer and open response questions assessing knowledge, understanding and skills.

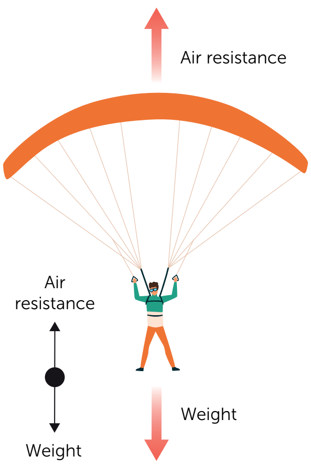
Questions assess skills, knowledge and understanding of Physics.

FREE BODY DIAGRAMS

A **free body force diagram** is a simplified diagram showing the forces acting on an object shown as a simple box or a dot. The force arrows act away from the centre of the box or dot.

Balanced forces

The air resistance is equal and opposite to the weight of the parachutist so there is no net force on the parachutist and the forces are balanced.

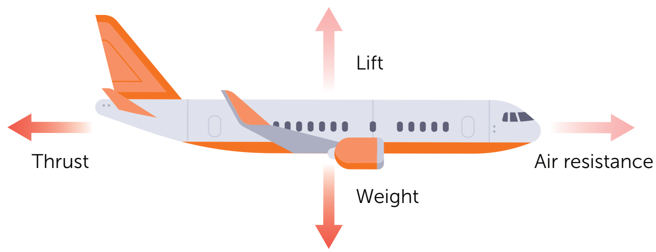


Unbalanced forces

The weight of the aeroplane is equal and opposite to the lift of the plane. So there is no net vertical force.

The thrust from the engines of the aeroplane is greater than the air resistance. So the horizontal forces are unbalanced and there is a resultant force to the left.

The same force can sometimes be described using different words. For example, **drag** and **air resistance**; **forward force** and **thrust**. The situation of the object, and the direction of the force arrow, will make what the force represents clearer.



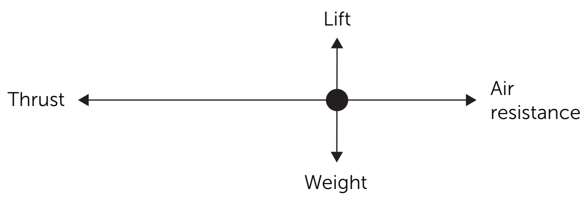
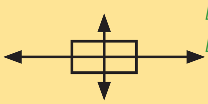
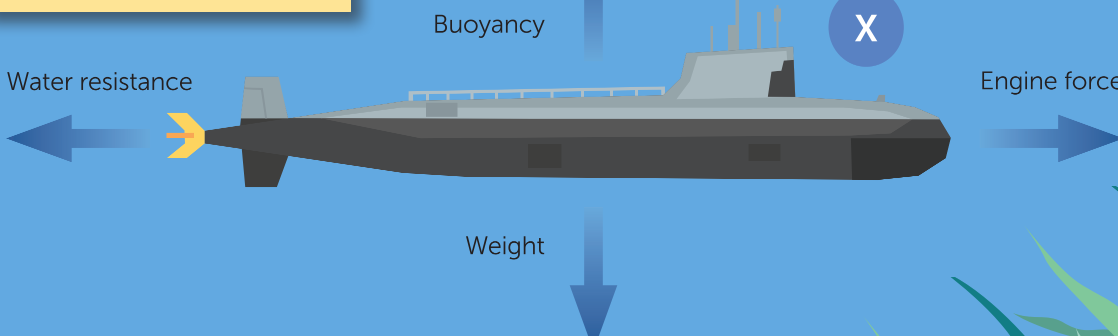


Figure X, below, shows a submarine moving forward at a constant depth.
Draw a free body diagram of this submarine. [2]



[1] Horizontal
[1] Vertical



STOPPING DISTANCE

The stopping distance of a driven vehicle is the total distance that the vehicle travels between the point the driver decides to stop, and the vehicle actually stopping.

Thinking distance and braking distance

The stopping distance of a vehicle is made up of two parts:

stopping distance = thinking distance + braking distance

The **thinking distance** is the distance the vehicle travels during the time the driver is reacting. It is linked to the driver's reaction time. The **braking distance** is the distance the vehicle travels after a force is applied on the brakes.

Given the same braking force, the stopping distance will increase as the speed increases. This is because the vehicle will travel further in the same amount of time.

Describe the relationship between the stopping distance and the speed of a vehicle. [1]

The greater the speed, the greater the stopping distance.[1]

POLES OF A MAGNET

Magnets are made from a magnetic material and are either permanent or induced:

- A **permanent** magnet produces its own magnetic field.
- An **induced** magnet is a temporary magnet created when a magnetic material becomes a magnet while in a magnetic field.

Permanent magnets

Bar and horseshoe magnets are examples of permanent magnets.

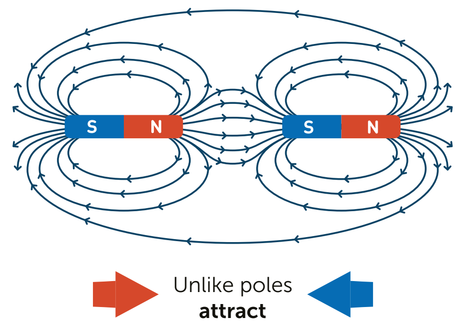
The ends of a magnet are called the **poles** and are described as **north (N)** or **south (S)**. The poles are the places where the magnetic forces are strongest.

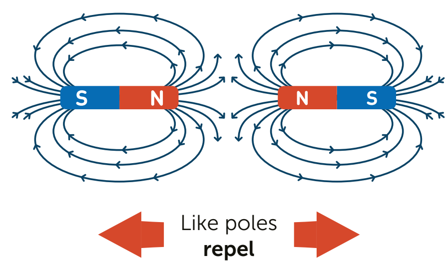
A permanent magnet will always exert a force on another magnet. The type of force exerted depends on the interacting poles. These are non-contact forces as the magnets do not need to touch to experience the force.

When two magnets are brought close together, they exert a force of attraction or repulsion on each other.

- two **like** poles will **repel** each other (N/N; S/S).
- two **unlike** poles will **attract** each other (N/S).

Permanent magnets also attract magnetic materials.





Induced magnets

When a magnetic material (that is not a permanent magnet) is placed in a magnetic field, a magnetic field is **induced**, and the material becomes a **temporary** magnet. When the material is removed from the magnetic field the induced magnet quickly loses nearly all of its magnetism.

An induced magnet will always cause a force of attraction.

1. Magnetic materials are affected by magnets and attracted to both poles of a magnet. Which material is **not** magnetic? Tick **one** box. [1]

   ☐ Cobalt ☐ Copper ☐ Iron ☐ Nickel ☐ Steel

2. How can it be shown that a magnetic material is a permanent magnet? [1]
3. Describe the forces on Magnet 2. [2]

1. *Copper*[1]
2. *It will attract and also repel another magnet.*[1]
3. *The forces are non-contact forces*[1] *Magnet 2 experiences a force of attraction from Magnet 1*[1] *and a force of repulsion from Magnet 3.*[1]

EXAMINATION PRACTICE ANSWERS

Topic 1

01.1 Award one mark for each correct column. [2]

Sub-cellular structure	Eukaryotic cell	Prokaryotic cell
Nucleus	✓	×
Cell membrane	✓	✓

01.2 In a single large DNA loop [1] and in smaller circular plasmids [1]. [2]

02 Chloroplasts [1], large vacuole filled with sap [1], cell wall [1]. [3]

03.1 Without the nucleus there is more space for haemoglobin [1], so the red blood cell can carry more oxygen [1]. [2]

03.2 Correct conversion and standard form i.e. 8.0×10^{-6} m. [2] Correct answer without standard form 0.000008 m is [1] only. [2]

03.3 6 cm = 60,000 µm. [1] 60,000 ÷ 8 = magnification of ×7,500. [1] [2]

03.4 Mitochondria carry out aerobic respiration [1], which provides the energy needed for movement/muscle contraction [1]. [2]

03.5 They contain protein fibres that can shorten, causing the muscle to contract. [1]

04.1 Ribosomes are too small to see using a light microscope [1]. The electron microscope has better resolution [1] and allows greater magnification [1] than the light microscope. [3]

04.2 So that colourless or transparent structures can be more easily distinguished. [1]

04.3 The coarse focus knob is used to quickly bring the cells into view. [1] The fine focus makes smaller adjustments to bring cells into sharp focus especially at higher magnifications. [1] [2]

05.1 The agar contains nutrients that the micro-organisms feed on. [1] It provides a surface for colonies to grow on [1]. [2]

05.2 *This question should be marked with reference to the levels-based mark scheme on* ***page 374***. Indicative content: [6]
Contamination from the **air** in the laboratory [✓]. Prevented by keeping the culture covered/taping the lid on the petri dish. [✓] Using a Bunsen burner to generate upward air currents. [✓]
Contamination from the **equipment** used [✓]. Prevented by flaming the inoculation loop [✓] to kill microorganisms on it [✓] by heat sterilising / autoclaving equipment [✓].
Contamination from the **person** making the culture [✓]. Prevented by not touching the surface of the culture medium [✓], taking care not to breathe on the culture [✓], incubating at temperatures below body temperature/25 °C [✓] to avoid culturing microorganisms that can grow in the body [✓].

06.1 Differentiation. [1]

06.2 Three marks from: Cell division and differentiation for growth continues in mature plants but not in mature animals [1]. In mature animals, cell division is mainly restricted to repair of damaged tissues [1] and replacement of worn out cells [1]. [3]

07 *This question should be marked with reference to the levels-based mark scheme on* ***page 374***. [6]
Indicative content: Disinfectant A is more effective at killing bacteria at all concentrations [✓]. But the difference in effectiveness is small at medium and high concentrations [✓]. Disinfectant A is 5 times more expensive than B [✓]. Disinfectant B may be more cost effective / can be used at a higher concentration for a lower cost [✓]. The human toxicity of B is lower than A, so it would be safer to use [✓]. The effectiveness of both disinfectants increases as concentration increases [✓]. There is a big difference in effectiveness between the low and medium concentrations [✓]. The difference between effectiveness of medium and high concentrations is small [✓]. Manipulation of data to support reasoning e.g. Medium concentration of B is more than four times as effective than the low concentration [✓]. A conclusion is made that is consistent with the reasoning (e.g. a medium concentration of disinfectant B should be used based on effectiveness, dilution factor, cost and toxicity) [✓].

08.1 Mitosis. [1]

08.2 Risk of cell rejection as donated cells are not genetically identical to the patient. [1] Donated stem cells do not use embryos so fewer ethical or religious issues. [1] [2]

09.1 Mass would decrease. [1]

09.2 Water would move out of the solution in the bag by osmosis [1] through the partially permeable membrane [1] from the more dilute solution to the more concentrated sugar solution [1]. [3]

LEVELS BASED MARK SCHEME FOR EXTENDED RESPONSE QUESTIONS

What are extended response questions?

Extended response questions are worth 4, 5 or 6 marks. These questions are likely to have command words such as 'compare', describe', 'explain' or 'evaluate'. You need to write in continuous **prose** when you answer one of these questions. This means you must write in full sentences, not bullet points, and organise your answer into paragraphs.

You may need to bring together skills, knowledge and understanding from two or more areas of the specification. To gain full marks, your answer needs to be logically organised, and ideas linked to give a sustained line of reasoning.

Some extended response questions may involve calculations. These need two or more steps that must be done in the right order. These questions will include the command words 'calculate' or 'determine'.

Marking

Written answers are marked using 'levels of response' mark schemes. Examiners look for relevant points (indicative content) and also use a best fit approach. This is based on your answer's overall quality and its fit to descriptors for each level. Extended response calculations give marks for each step shown.

Example level descriptors

Level descriptors vary, depending on the question being asked. Level 3 is the highest level and Level 1 is the lowest level. No marks are awarded for an answer with no relevant content. The table gives examples of the typical features that examiners look for.

Level	Marks	Descriptors for a method	Descriptors for an evaluation
3	5–6	The method would lead to a valid outcome. All the key steps are given, and they are ordered in a logical way.	The answer is detailed and clear. It includes a range of relevant points that are linked logically. The answer uses relevant data that may be given in the question. A conclusion is made that matches the reasoning in the answer.
2	3–4	The method might not lead to a valid outcome. Most of the key steps are given, but the order is not completely logical.	The answer is mostly detailed but not always clear. It includes some relevant points with an attempt at linking them logically. Data may not be used fully. A conclusion is given that may not fully match the reasoning given.
1	1–2	The method would not lead to a valid outcome. Some key steps are given, but they are not linked in a clear way.	The answer gives separate, relevant points. Uses little or no data that may be given in the question. The points made may be unclear. If a conclusion is given, it may not match the reasoning given in the answer.

COMMAND WORDS

A **command word** in a question tells you what you are expected to do.

The structure of a question

You should see one command word per sentence, with the command word coming at the start. A command word might not be used, however, if a question is easier to follow without one. In these cases, you are likely to see:

- What ...?
- Why ...?
- How ...?

Command word	What you need to do
Balance	Add correct balancing numbers to an equation, chemical equation or nuclear equation.
Calculate	Use the numbers given to work out an answer.
Choose	Select from a range of options.
Compare	Write about **all** the similarities and/or differences between things.
Complete	Complete sentences by adding your answers in the spaces provided.
Define	Give the meaning of something.
Describe	Recall a fact, event or process accurately.
Design	Describe how something will be done, such as a practical method.
Determine	Use the data or information given to you to obtain an answer.
Draw	Produce a diagram, or complete an existing diagram.
Estimate	Work out an approximate value.
Evaluate	Use your knowledge and understanding, and the information supplied, to consider evidence for and against something. You must include a reasoned judgement in your answer.
Explain	Give the reasons why something happens, or make something clear.
Give, name, write	Only write a short answer, commonly just a single word, phrase or sentence.
Identify	Name or point out something.
Justify	Support your answer using evidence from the information given to you.
Label	Add the correct words or names to a diagram.
Measure	Use a ruler or protractor to obtain information from a photo or diagram.
Plan	Write a method.
Plot	Mark data points on a graph.
Predict	Write a likely outcome of something.
Show	Give structured evidence to come to a conclusion.
Sketch	Make an approximate drawing, such as a graph without axis units.
Suggest	Apply your knowledge and understanding to a new situation.
Use	You **must** base your answer on information given to you, otherwise you will not get any marks for the question. You might also need to use your own knowledge and understanding.

USEFUL BIOLOGY EQUATIONS

You need to know how to carry out some calculations that are specific to biology topics.

Magnification

You should learn the equation for magnification and be able to use it. At higher tier you may need to rearrange the equation to calculate the size of an image or object. Don't forget to convert image and object measurements to the same units, for example multiply measurements in mm by 1000 to convert to µm.

$$\text{magnification} = \frac{\text{size of image}}{\text{size of real object}}$$

Cross-sectional areas of colonies or clear areas around colonies

The size (area) of a colony of bacteria and the area of a clear zone where bacteria have been killed (e.g. by an antibiotic) approximate to the area of a circle. The area of a circle = πr^2. Remember that r is the radius of the circle, which is half the diameter.

The number of bacteria in a population

An exam question might state the number of bacteria at the start of an experiment and give you the mean division time. This is the average time taken for the number of bacteria to double. You should be able to calculate the number of bacteria in the population after a certain time. Often, answers can be worked out using simple maths. For more difficult problems this formula can be used:

$$\text{Final population of bacteria} = \text{Number at start} \times 2^{\text{number of divisions}}$$

First work out the number of divisions per hour. Multiply this by time in hours to get the number of divisions.

Surface area to volume ratio

A cell or structure with a large surface area to volume ratio is better adapted to exchange materials with the surroundings. Divide the surface area by the volume to find how many units of surface area there are to a single unit of volume.

USEFUL CHEMISTRY EQUATIONS

Mathematical skills account for 20% of the marks in the exams. Foundation Tier students may be given equations like the ones below. All students may be given an unfamiliar equation if a question needs one.

Shown in the specification

$$\text{mean rate of reaction} = \frac{\text{quantity of reactant used}}{\text{time taken}}$$

$$\text{mean rate of reaction} = \frac{\text{quantity of product formed}}{\text{time taken}}$$

$$R_f = \frac{\text{distance moved by substance}}{\text{distance moved by solvent}}$$

$$\%\ \text{yield} = \frac{\text{mass of product actually made}}{\text{maximum theoretical mass of product}} \times 100$$

$$\%\ \text{atom economy} = \frac{\text{relative formula mass of desired product from equation}}{\text{sum of relative formula masses of all reactants from equation}} \times 100$$

Not shown in the specification

relative formula mass (M_r) = sum of relative atomic masses (A_r) of atoms shown in the formula

relative atomic mass (A_r) using abundances of two isotopes, A and B =

$$\frac{\text{(mass number} \times \text{percentage) of A} + \text{(mass number} \times \text{percentage) of B}}{100}$$

mass of solute (g) = concentration of solution (g/dm^3) × volume of solution (dm^3)

mass (g) = amount (mol) × M_r

$$\text{concentration of solution (mol/dm}^3\text{)} = \frac{\text{amount of solute (mol)}}{\text{volume of solution (dm}^3\text{)}}$$

volume of gas at room temperature and pressure (dm^3) = amount of gas (mol) × 24

overall energy change of a reaction =

(energy in to break bonds in reactants) – (energy out when bonds form in products)

$$\text{gradient of a graph} = \frac{\text{change in vertical axis}}{\text{change in horizontal axis}}$$

USEFUL PHYSICS EQUATIONS

Mathematical skills account for 20% of the marks in Trilogy exams.

Calculation questions in physics usually involve an equation. Most equations need to be learnt and then recalled and applied in the exam. Others need to be selected from a sheet given in the exam.

Some equations are **higher tier only**. H

All the equations you are expected to learn, select and apply are given here.

Select and apply

Word equation	Symbol equation
(final velocity)^2 – (initial velocity)^2 = 2 × acceleration × distance	$v^2 - u^2 = 2as$
elastic potential energy = 0.5 × spring constant × (extension)^2	$E_e = \frac{1}{2} k e^2$
change in thermal energy = mass × specific heat capacity × temperature change	$\Delta E = m c \Delta \theta$
period = $\frac{1}{\text{frequency}}$	$T = \frac{1}{f}$
force on a conductor (at right angles to a magnetic field) carrying a current = magnetic flux density	$F = B I l$ H
thermal energy for a change of state = mass × specific latent heat	$E = m L$
potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil	$V_p I_p = V_s I_s$ H

Recall and apply

Word equation	Symbol equation
weight = mass × gravitational field strength (*g*)	$W = m\,g$
work done = force × distance (along the line of action of the force)	$W = F\,s$
force applied to a spring = spring constant × extension	$F = k\,e$
distance travelled = speed × time	$s = v\,t$
acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$	$a = \frac{\Delta v}{t}$
resultant force = mass × acceleration	$F = m\,a$
momentum = mass × velocity	$p = m\,v$ H
kinetic energy = 0.5 × mass × (speed)^2	$E_k = \frac{1}{2} m\,v^2$
gravitational potential energy = mass × gravitational field strength (*g*) × height	$E_p = m\,g\,h$
power = $\frac{\text{energy transferred}}{\text{time}}$	$P = \frac{E}{t}$
power = $\frac{\text{work done}}{\text{time}}$	$P = \frac{W}{t}$
efficiency = $\frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$	
efficiency = $\frac{\text{useful power output}}{\text{total power input}}$	
wave speed = frequency × wavelength	$v = f\,\lambda$
charge flow = current × time	$Q = I\,t$
potential difference = current × resistance	$V = I\,R$
power = potential difference × current	$P = V\,I$
power = (current)^2 × resistance	$P = I^2\,R$
energy transferred = power × time	$E = P\,t$
energy transferred = charge flow × potential difference	$E = Q\,V$
density = $\frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{V}$

MATHS SKILLS FOR SCIENCE

Standard form

Standard form is a way of writing very large or very small numbers and is written as:

$$A \times 10^B$$

- A is a number greater than or equal to 1 and less than 10
- B is any integer (negative or positive whole number)

Examples

Number	Standard form
0.0050 61	5.61×10^{-3}
170 000 000	1.7×10^{8}
0.012 03	1.203×10^{-2}
8 040 000	8.04×10^{6}

Rounding to *n* decimal places

When rounding to n decimal places (dp):

- look at the nth decimal place
- if the next digit is 5 or more, round up by increasing the preceding digit by one
- if it is 4 or less, keep the preceding digit the same

For example, 0.365 rounded to 2 dp is 0.364 is 0.36.

0.8675 rounded to 1 dp is 0.9

Rounding to *n* significant figures

- Look at the first non-zero digit, go $n - 1$ digits to the right, and follow the rules for rounding to n decimal places
- Fill any places after it with a zero and stop when you reach the decimal point.

Examples

	1 sf	2 sf	3 sf
9375	9000	9400	9380
56.27	60	56	56.3
0.003684	0.004	0.0037	0.00368

Units and conversions

Quantities in one unit can be converted into a different unit and the size of the measurement will still be the same.

Units need to be correct when using equations, it is usually the SI unit.

A common conversion is to change time from hours and minutes to the SI unit of seconds:

seconds = hours × 60 × 60

seconds = minutes × 60

Other conversions depend on the prefix of the unit

Common prefixes

	10^B	Prefix	Symbol
1 000 000 000	10^{9}	Giga-	G
1 000 000	10^{6}	Mega-	M
1 000	10^{3}	Kilo-	k
0.01	10^{-2}	Centi-	c
0.001	10^{-3}	Milli-	m
0.000 001	10^{-6}	Micro-	µ
0.000 000 001	10^{-9}	Nano-	n

Example conversions for the SI unit of metres (m)

Multiply to convert bigger units to smaller units →

km	m	cm	mm
× 1000	× 100	× 10	

Divide to convert smaller units to bigger units →

mm	cm	m	km
÷ 10	÷ 100	÷ 1000	

Using data

The **mean** is an average of a set of values.

To calculate the mean, add up all the values and divide this total by the number of values there are.

$$\text{mean} = \frac{\text{total sum of the values}}{\text{how many values there}}$$

Graphs

The most commonly used graph in physics is a **line graph** although you could see **bar** charts and **pie** charts too.

A line graph shows the relationship between two **continuous** variables.

- the **independent** variable is plotted on the horizontal ***x*-axis**.
- the **dependent** variable is plotted on the vertical ***y*-axis**.

Plotting a line graph

- Look at the **range** of values you need to plot on each axis.
- Choose appropriate **scales** for the small and large squares.
- Intervals such as 1, 2, 5, and multiples such as 10 or 100 are good to use. Do not use other intervals such as 3, 6 or 9.
- Make sure each axis uses at least half of the height or width of any given grid.
- Label both axes with the correct variable and unit.
- To plot (x, y) find the value on the x-axis, then go up to the value on the y-axis.
- Use a sharp pencil to plot each point as a small x, accurate to $\pm$ 1 small square.

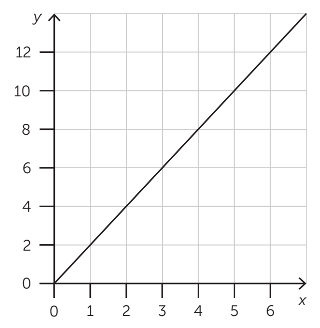
Drawing a line of best fit

A line of best fit is an indication of the relationship between two variables from experimental data. Lines of best fit can be **straight** or **curved**.

- Ignore any clearly **anomalous** points.
- Use a sharp pencil.
- Draw the line of best fit through most of the points with equal numbers of points above and below the line.
- Use a transparent ruler for **straight** lines so you can see all the points.
- Draw a **curved** line free hand as a smooth curve, not dot to dot with a ruler.
- Avoid drawing double lines.

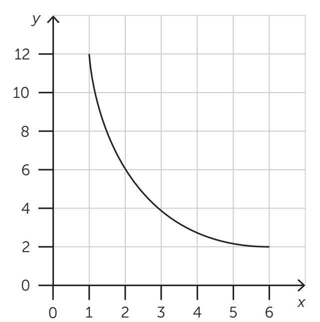
Information from graphs

Directly proportional



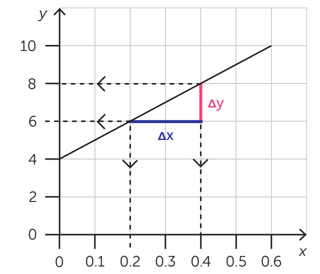
- Straight line graph
- Through the origin
- When x doubles, y doubles
- So x and y are directly proportional to each other

Inversely proportional



- Curved graph
- When x doubles, y halves
- So x and y are inversely proportional to each other.

Determining a gradient from a straight line graph



- Choose 2 points on the line which have easy to read values.
- Draw a right-angled triangle from these 2 points
- Determine the values of Δy and Δx
- Gradient = Δy / Δx
- $y = mx + c$ where m is the gradient and c is the point the line intercepts the y axis

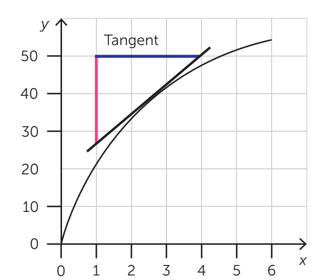
Example

$\Delta y = 8 - 6 = 2$ $\Delta x = 0.4 - 0.2 = 0.2$

gradient = 2 / 0.2 = 10 $y = 10x + 4$

Determining a gradient from a curved graph

Higher Tier only



- A **tangent** is a straight line that touches a curve at one point
- Draw a tangent at the point (e.g. $x = 2$) on the line where you want to find the gradient
- Draw a right-angled triangle from these 2 points
- Determine the values of Δy and Δx
- Gradient = Δy / Δx = (50 – 28) / (3.6 – 1)
- = 22 / 2.6
- = 8.5 (1 dp)

Rearranging equations

The **subject** of an equation is the quantity that is on its own. The **equations** that you need to recall, or choose from a sheet, often need to be **rearranged** to make a different quantity the **subject**.

- Whatever is done to one side of the equation needs to be done to the other
- **Inverse operations** are used, usually **×** and **÷ which are the opposite of each other**.

Examples

$V = I \times R$

V is the subject. Rearrange the equation to make *I* the subject. You need to get *I* on its own.

I is multiplied by *R*, so to remove *R* from the right-hand side, both sides of the equation need to be divided by *R*

$\frac{V}{R} = \frac{I \times R}{R}$, so $I = \frac{V}{R}$

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

P is the subject. Rearrange the equation to make *t* the subject. You need to get *t* on its own.

E is divided by *t*, so first make *E* the subject by multiplying both sides of the equation by *t*

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

Now get *t* on its own by dividing both sides by *P*

$\frac{P \times t}{t} = \frac{E}{P}$, so $t = \frac{E}{P}$

Sometimes knowing the units can help you remember an equation, or you can work out a unit from an equation.

It is much better to understand and learn how to rearrange an equation properly. However, using a **formula triangle** can help as long as you use the correct triangle. Cover the quantity you want to find and then see if you need to multiply or divide the other quantities.

General equation type	$A = B \times C$ A $B \times C$	$A = B / C$ B $A \times C$
Example	potential difference = current × resistance $V = I \times R$	power = $\frac{\text{energy transferred}}{\text{time}}$ $P = E / t$
Formula triangle	V / $I \times R$: $V = I \times R$ V / $I \times R$: $I = \frac{V}{R}$ V / $I \times R$: $R = \frac{V}{I}$	E / $P \times t$: $P = \frac{E}{t}$ E / $P \times t$: $E = P \times t$ E / $P \times t$: $t = \frac{E}{P}$

THE PERIODIC TABLE

1	2											3	4	5	6	7	0
						1 **H** Hydrogen 1											4 **He** Helium 2
7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Fluorine 9	20 **Ne** Neon 10
23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminium 13	28 **Si** Silicon 14	31 **P** Phosphorus 15	32 **S** Sulfur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	59 **Ni** Nickel 28	63.5 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	73 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
85 **Rb** Rubidium 37	88 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	[98] **Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
133 **Cs** Caesium 55	137 **Ba** Barium 56	139 **La** Lanthanum 57	178 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	[209] **Po** Polonium 84	[210] **At** Astatine 85	[222] **Rn** Radon 86
[223] **Fr** Francium 87	[226] **Ra** Radium 88	[227] **Ac** Actinium 89	[261] **Rf** Rutherfordium 104	[262] **Db** Dubnium 105	[266] **Sg** Seaborgium 106	[264] **Bh** Bohrium 107	[277] **Hs** Hassium 108	[268] **Mt** Meitnerium 109	[271] **Ds** Darmstadtium 110	[272] **Rg** Roentgenium 111	[285] **Cn** Copernicium 112	[286] **Nh** Nihonium 113	[289] **Fl** Flerovium 114	[289] **Mc** Moscovium 115	[293] **Lv** Livermorium 116	[294] **Ts** Tennessine 117	[294] **Og** Oganesson 118

Key

Relative atomic mass
Atomic symbol
Name
Atomic (proton) number

Notes

The Lanthanides (atomic numbers 59–71) and the Actinides (atomic numbers 90–103) are omitted.
Relative atomic masses for Cu and Cl have not been rounded to the nearest whole number.

KEY TERMS IN PRACTICAL WORK

Experimental design

Key term	Meaning
Evidence	Measurements or observations collected using a valid method
Fair test	When the dependent variable is only affected by the independent variable
Hypothesis	A suggested explanation for observations or facts
Prediction	A reasoned statement that suggests what will happen in the future
Valid	A valid method involves fair testing and is suitable for an investigation
Valid conclusion	A discussion of a valid experiment and what it shows

Variables

A variable is a characteristic that can be measured or observed.

Type of variable	Meaning
Categoric	It has names or labels rather than values
Continuous	It has values rather than names or labels
Control	It affects the dependent variable, so it must be kept the same or monitored
Dependent	It is measured or observed each time the independent variable is changed
Independent	It is deliberately changed by the experimenter

Measurements and measuring

Key term	Meaning
Accurate	Close to the true value
Calibrated	A device is calibrated when its scale is checked against a known value
Data	Measurements or observations that have been gathered
Interval	The measured gap between readings
Precise	Very little spread about the mean value
Range	The values between the measured maximum and minimum values
Repeatable	When the same results are obtained using the same method and apparatus
Reproducible	Someone else gets the same results, or when different apparatus and methods are used
Resolution	The smallest change a measuring device can show
True value	The value you would get in an ideal measurement
Uncertainty	An interval in which the true value will be found

Errors

Type of error	Meaning
Anomaly	Anomalous results lie outside the range explained by random errors
Measurement	The difference between the true value and a measured value
Random	Unpredictably different readings – their effects are reduced by repeats
Systematic	Readings that differ from true values by the same amount each time
Zero	A type of systematic error where a device does not read 0 when it should

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EXAMINATION TIPS

When you practise examination questions, work out your approximate grade using the following table. This table has been produced using a rounded average of past examination series for this GCSE. Be aware that actual boundaries will vary by a few percentage points either side of those shown.

Combined Science: Trilogy

Grade	5–5	5–4	4–4	4–3	3–3	3–2	2–2	2–1	1–1	U
F Tier (%)	59	54	50	44	37	31	25	19	13	0

Grade	9–9	9–8	8–8	8–7	7–7	7–6	6–6	6–5	5–5	5–4	4–4	4–3	3–3
H Tier (%)	66	62	58	53	49	44	40	35	31	26	22	19	14

1. Read questions carefully. This includes any information such as tables, diagrams and graphs.
2. Remember to cross out any work that you do not want to be marked.
3. Answer the question that is there, rather than the one you think should be there. In particular, make sure that your answer matches the command word in the question. For example, you need to recall something accurately in a describe question but not say why it happens. However, you do need to say why something happens in an explain question and should include a connecting word such as ‘so’, ‘but’, therefore’, or ‘because’.
4. Physics involves a lot of equations. Some are on the equations sheet but most need to be recalled and then used. Forgetting or failing to learn these will cost you a lot of marks. Learn the formulae well and be able to use them confidently. Also, make sure you learn a method for rearranging equations and know the correct SI units.
5. Show all the relevant working out in calculations. If you go wrong somewhere, you may still be awarded some marks if the working out is there. It is also much easier to check your answers if you can see your working out. Remember to give units when asked to do so and follow instructions about standard form or significant figures.
6. Plot the points on graphs to within half a small square. Lines of best fit can be curved or straight,but must ignore anomalous points. If the command word is sketch rather than plot, you only need to draw an approximate graph, not an accurate one.
7. You could be asked to draw and label a diagram from an image. Draw only what you see, making it as big as space allows. Draw lines that are clear using a sharp pencil, don't use shading. Draw label lines with a ruler; the end of the line should just touch the item to be labelled.
8. Make sure you do not mix words and symbols in chemical equations. You will be given full marks if you are asked to write a word equation, but you give the correct balanced equation instead. This does not work the other way round! Check that all the numbers of atoms, ions and charges balance in symbol equations. Remember to include state symbols when asked.
9. Follow instructions carefully when writing or balancing nuclear or chemical equations. Check that all the numbers of particles and charges balance.
10. Remember that you may be asked to label a diagram or to complete a diagram. You may or may not be given the words to use.
11. Make sure you can recall experiments you have done or observed. About 15% of the exam is based on the required practicals.

Good luck!