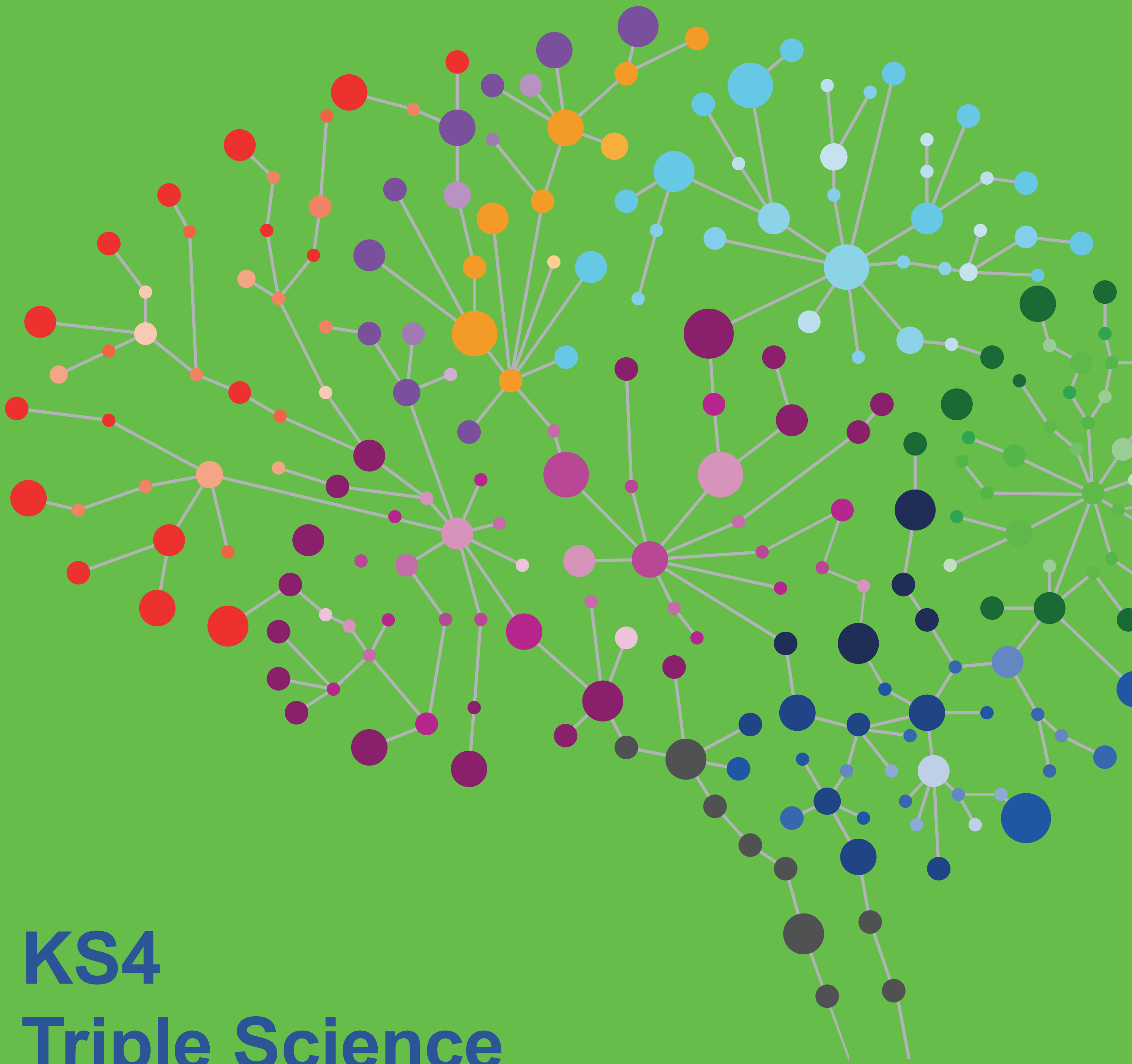


KS4
Triple Science
Knowledge Book

Name: ________________

Teacher: ______________

Form: _________________

Saint Benedict
A Catholic Voluntary Academy

Love, Belief, Integrity, Knowledge

OUR VALUES

BE WHO GOD MEANT YOU TO BE AND YOU WILL SET THE WORLD ON FIRE.

LOVE

As we know we are loved by God, we will learn to love ourselves and care for our own body mind and soul.

We will show love to one another by being patient and kind, not by being rude, boastful or proud.

As one body in Christ, we will ensure that no member of our community is left out or left behind

BELIEF

We will encourage one another and build each other up.

We will let our light shine, making the world a better place for all.

KNOWLEDGE

We will value knowledge: intelligent hearts acquire knowledge, the ears of the wise seek knowledge.

INTEGRITY

We will always strive to make the right choice even when this is the harder path to take.

We will live and work sustainably.

AT SAINT BENEDICT WE DEVELOP THE CHARACTER OF OUR COMMUNITY THROUGH OUR CURRICULUM AND CULTURE.

Respect

What is Respect?

Showing respect is an important part of life, and how you maintain relationships.

Three types of respect:

1. Respect Yourself
2. Respect Others
3. Respect the Planet

Why is respect important?

Receiving respect from others is important because it helps us to feel safe and to express ourselves. Respecting others helps maintain a peaceful world and encourages others to be better people. Showing respect to our planet allows us to maintain it for future generations.

Key words	Definitions
Respect	Due regard for the feelings, wishes and rights of others
Honour	The quality of knowing and doing what is morally right
Dignity	Sense of pride and self respect
Relationships	The way two or more people or groups connect and behave towards each other
Worthiness	The quality of being good enough

Rules and Sanctions

Build up a loving community

Key word	
Conduct	The way in which a person behaves.
Unacceptable	Something that is not suitable or appropriate.
Boundaries	The limits of something.
Sanction	A penalty or action taken when a rule or law has been broken.
Consistent	Acting in the same way overtime to be fair.

Behaviour

Rules and sanctions are things which guide our behaviour. We follow rules and regulations to be fair and consistent. Sanctions occur if we do not follow rules or deliberately break them.

Preparation for life

All aspects of life require us to follow rules. There are rules in school; rules in your family and home; rules to follow when crossing the road and using the bus and so on. Structure and rules allow us all to know what is acceptable and how to conduct ourselves. Rules reassure us

The law

We are all bound by the rules of the law. If we break the law, we face a raft of different sanctions. Ultimately, having rules in schools is about a lifelong understanding about what is right and what is wrong.

Kindness

Key word	
Empathy	Understand and share feelings of others
Compassion	Concern for misfortune of others
Compliment	Praise or congratulate others
Considerate	Thoughtfulness and sensitivity to others
Generous	Being liberal with things

Treat others how you would want to be treated yourself.

What is Kindness?

The quality of being friendly, generous and considerate

What does it mean to be kind?

To have empathy/sympathy, be compassionate, looking for good in people.

Why is it important to be kind?

Makes you feel happy, feel good about yourself
Builds strong relationships
Inspires others

How can we show kindness?

Smile
Hold the door open for somebody
Say something nice (compliment)
Invite somebody sat on their own to join you
Manners
Listen to somebody

Emotions

Key Words	
Feelings	An emotional state or reaction.
Relationships	The state of being connected with someone else.
Instinct	A fixed pattern of behaviour.
Intuitive	Using what you feel to be true even without conscious reasoning.
Reaction	Something done, felt or thought in response to a situation or event.
Identification	The act or process of identifying someone or something.

Work and play in harmony

What are emotions?

Emotions are biological states associated with the nervous system.

Thoughts, feelings, behavioural responses, and relationships all generate emotions.

An instinct or, intuitive reaction or feeling can create emotions

Identifying feelings

Making sense of what and how you feel is not always easy. To do this, we need to regularly check in with ourselves, making time to think about the feelings we are having and naming them. To do this, we need to think about our daily lives which may help us to see patterns of behaviour.

Not all feelings or emotions are bad or negative!

It is important to recognise when you feel happy; relaxed and good about yourself. Knowing what has led to these feelings can help us identify things we do not like which may cause us negative feelings.

Verbal Communication

Treat each other with dignity and justice

Key Words	
Clarity	Vocal clarity means you do not speak too fast or too slowly. You consider carefully the words you mean and whether your listener can understand you.
Honesty	Honesty is speaking the truth.
Respect	Respect means that you accept somebody for who they are, even when they are different from you or you do not agree with them.
Appropriate	fitting the practical or social requirements of the situation.
Tone	a quality in the voice that expresses your feelings or thoughts, often towards the person being spoken to or the subject being spoken about
Courtesy	politeness, good manners, or consideration for other people.

What is verbal communication?
Verbal communication is the use of words to share information with other people.

What does it mean to communicate effectively?
Every time you verbally interact with someone you are aiming to develop your understanding of the world; you may be wishing to obtain information, respond to a request or offer support or guidance to another. In every one of these exchanges you are representing your tutor, your family and most importantly yourself.

Why is it important to communicate effectively?
All young people need to develop good speech, language and communication skills to reach their full potential.

Speech, language and communication underpin the basic skills of literacy and numeracy and are essential for you to understand and achieve in all subjects.

How can we communicate effectively?
Make eye contact
Speak honestly
Consider your role within the school
Consider the role of the person you are speaking to
Think carefully why you need to speak to the person you are addressing
Where necessary adapt as your conversation develops

Manners

Key Words	
Manners	A person's words or way of behaving towards others.
Respect	A regard for the feelings, wishes, or rights of others.
Listen	To take in what you hear.
Harmony	A time of behaving in one way to produce a pleasing effect.
Vocabulary	The range of words that we know and use.
Gratitude	The quality of being thankful; readiness to show appreciation for and to return kindness.

Loving...harmony...dignity

Treat your neighbour as yourself
The way in which we behave and speak
towards others, reflects in their actions and words towards us.

Show the best side of yourself
When you speak to others, always show respect; be polite and thankful. Use the words 'please, thank you, sorry and pardon' when communicating with others.

Manners are for every situation
Every interaction has space for the use of manners:
speech, emails, messages. Often when we get
upset or angry we don’t use manners.
However it does calm a situation if you do.

Change

Key Words	Definition
Change	Make or become different
Organised	Make arrangements or preparations for an event or activity
Opportunity	A time set of circumstances that make it possible to do something
Coping	To deal effectively with something difficult
Embrace	Accept (a belief, theory or change) willing and enthusiastically
Strategies	A plan of action designed to achieve a long term or overall aim

Develop potential to the full

Find the positive

Don't allow yourself to become negative about the changes in your life. Change is good, keep repeating it.

Feeling vulnerable

Facing change can be very overwhelming, leaving you feeling very emotional. Make it your mission to be proactive and respond to it positively.

Talk about it

It's good to talk about change in your life. Focus on problems, solutions and the positives that change will bring. Try to avoid focussing on the negatives and letting emotions take over.

Study Skills – Ways to **learn and remember**

Self quizzing (look, cover, write)

Read through the information in the knowledge book that you want to learn

Cover the information up

Write down as much as you can remember

Use the knowledge book to;

a) Correct any mistakes
b) Add any information that you forgot

Study Skills – Ways to **learn and remember**

Spacing

Complete a self quiz of the information you want to learn

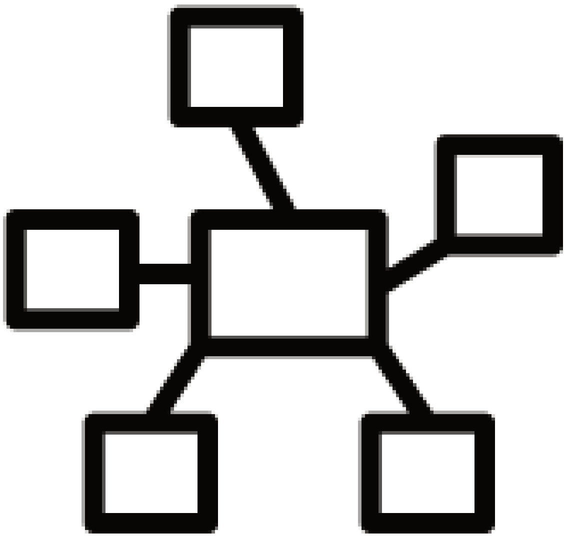
Wait for a day or 2 (depending on the deadline)

Repeat the self quiz.

The more times you can repeat this process, the more you will be able to remember without the book

Study Skills – Ways to **learn and remember**

Elaboration



Think about the topic that you are studying

Ask questions such as who, what , why , where , when how. Try to find the answers

See how these ideas connect - a mind map will be useful for this

---

Study Skills – Ways to **learn and remember**

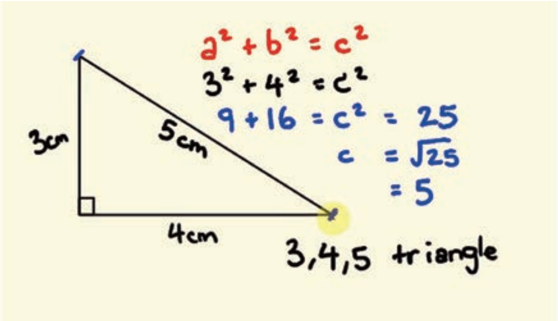
Concrete Examples

A concrete example is an clear example of an abstract idea

Pythagoras theorem example

If you tried to explain Pythagoras's theorem to someone verbally, it would be quite hard to understand.

By using a concrete example that shows exactly how to use Pythagoras theorem, it is much easier to remember, understand and use



Study Skills – Ways to **learn and remember**

Interleaving

Research says we will actually learn more effectively if we mix our study skills up rather than using the same techniques all the time

1. Try to use different study skills rather than just one technique.

2. When revising for exams, prepare a revision timetable and try to revise more than one subject during a session

---

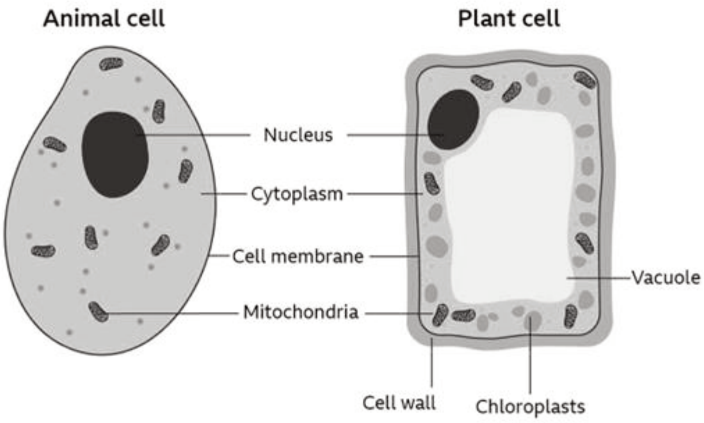
Study Skills – Ways to **learn and remember**

Dual Coding

As well as **writing** information down, **create an icon/ drawing** too for individual facts. This helps your brain to remember the information

Biology Paper 1 (Triple)

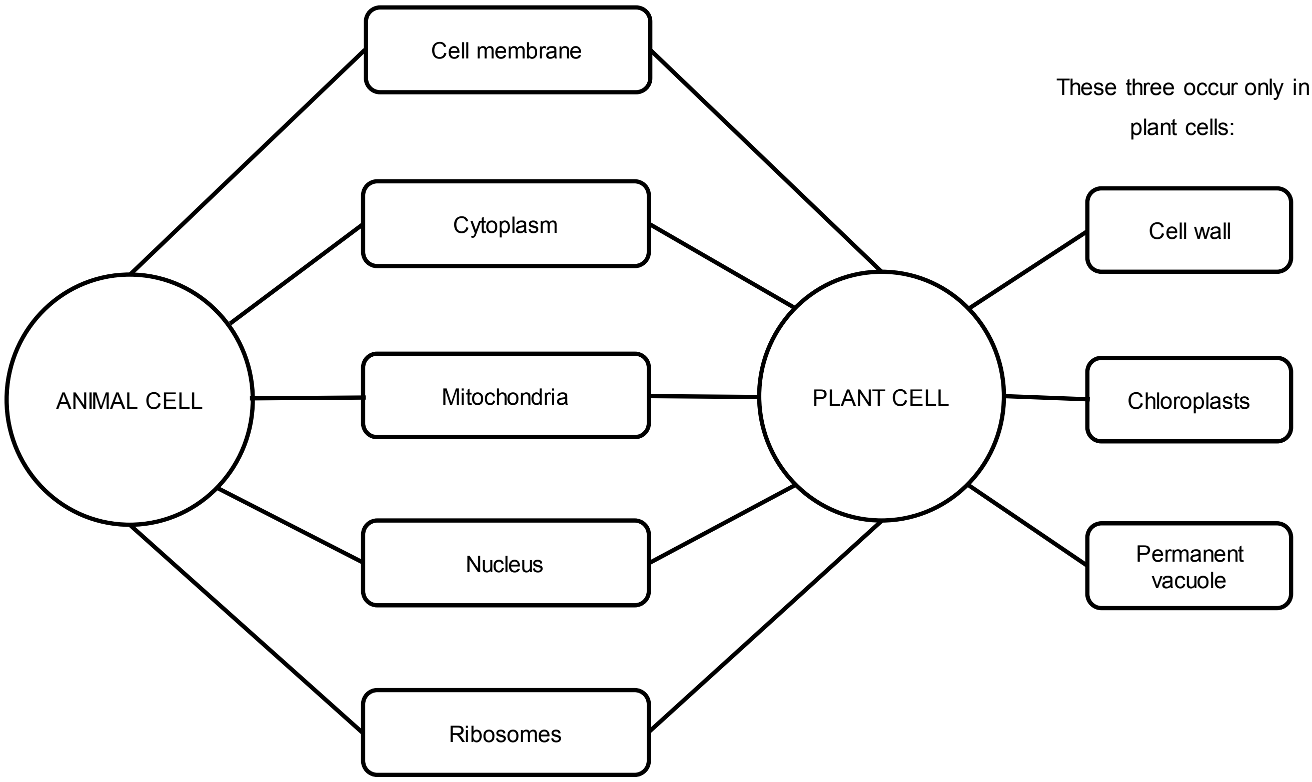
1. Cells



Both animal and plant cells contain a nucleus, cytoplasm, cell membrane, mitochondria and ribosomes. Plant cells also contain a cell wall, chloroplasts, and a permanent vacuole.

Cell organelle	Description
Cell membrane	Controls what enters and leaves the cell.
Cell wall	Made of cellulose, to strengthen the cell.
Chloroplast	The site of photosynthesis.
Cytoplasm	The site of chemical reactions.
Mitochondria	To release energy during respiration.
Nucleus	Contains **chromosomes** made of DNA molecules. Each chromosome carries a large number of genes.
Permanent vacuole	Filled with cell sap (a weak solution of sugars and salts).
Ribosomes	The site of protein synthesis (where proteins are made).

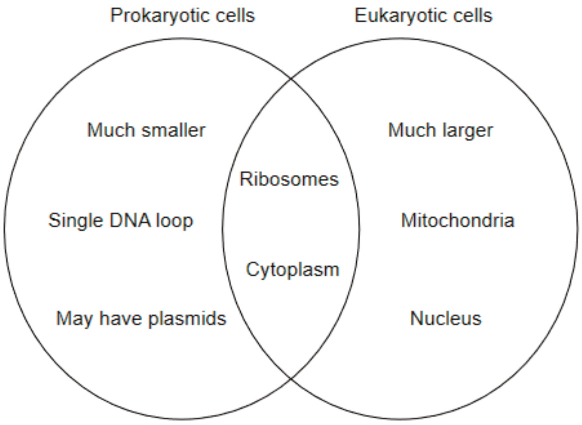
2. Organisation of Cells

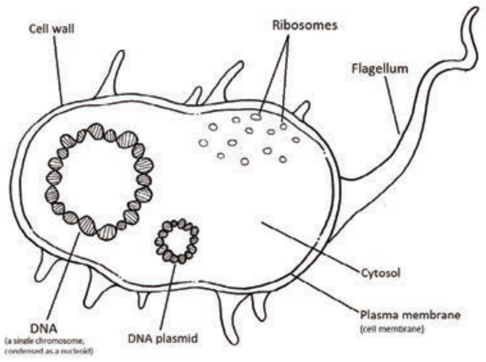


3. Eukaryotic and prokaryotic cells

Eukaryotic cells contain a nucleus.
Plant cells and animal cells are eukaryotic.

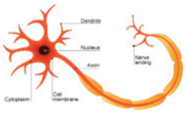
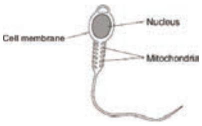
Prokaryotic cells (bacteria) are much smaller than eukaryotic cells.
They do not have a nucleus.
They do not have mitochondria but do have ribosomes.
They have a single DNA loop and may also have small rings of DNA called plasmids.



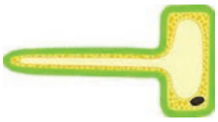
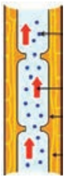


1000nm (nanometres) = 1µm
1000µm (micrometres) = 1mm
1000mm (millimetre) = 1m
10mm = 1cm (centimetre)

4. Animal Specialised Cells

Type of specialised cell	Function	Adaptations
Nerve cell 	Carry electrical impulses around the body	Lots of dendrites to make connections to other cells A very long axon that carries the electrical impulse from one place to another Contain lots of mitochondria to provide the energy needed to make special transmitter molecules, to carry impulses across gaps (synapses) between one nerve cell and the next
Muscle cells 	Contract and relax to allow movement	Contain special fibres that can slide over one another to allow the muscle to contract and relax Contain lots of mitochondria to provide energy for contraction Store glycogen which can be converted into glucose for respiration
Sperm cells 	Fertilise an egg cell	A tail for movement Middle section full of mitochondria to provide energy for tail to move Digestive enzymes in acrosome to digest a pathway into the egg A large nucleus containing half the genetic information needed to make an organism

5. Plant Specialised Cells

Specialised cell	Function	Adaptations
Root hair cell 	Absorb water and mineral ions	Large surface area available for water to move into cell by osmosis Large permanent vacuole that speeds up osmosis Lots of mitochondria that carry out respiration to provide the energy needed for active transport of mineral ions
Xylem cells 	Transport water and mineral ions from the roots to the highest leaves and shoots - always upwards.	When first formed xylem cells are alive but due to build-up of lignin the cells die and form long hollow tubes (vessels). The lignin makes the xylem vessels very strong and helps them withstand the pressure of water moving up the plant.
Phloem cells 	Transport sugars up and down the plant	End walls between cells break down to form sieve plates that allow water carrying dissolved sugars to move up and down the phloem. Neighbouring companion cells are packed with mitochondria to provide their energy needs.

6. Nucleus

Nucleus is found in animal and plant cells. →

Chromosomes in the **nucleus** are made of DNA molecules. →

Chromosomes are long strands of DNA that have been tightly wound together. →

A **gene** is a section of DNA that codes for a protein.
Proteins make up all parts of our cells

The nucleus contains **chromosomes** made of DNA molecules.
Each chromosome carries a large number of genes.

Gametes (sperm and egg cells) only have 1 set of chromosomes, so they have 23 chromosomes.

When human gametes come together in fertilisation, they form a zygote (fertilised egg cell) with 23 pairs of chromosomes (46 chromosomes).
Human body cells contain 23 pairs of chromosomes.

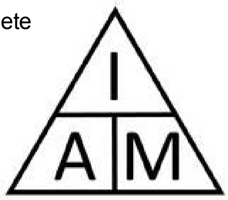
Biological structures in size order

Smallest ↓ Largest

Gene
Chromosome
Nucleus
Cell
Tissue
Organ

7. Stem Cells and Microscopes

Use the EVERY model to complete calculations:
E = equation
V = values
E = enter results
R = result
Y = units



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

Magnification increases the size of the image.
Resolution increases the detail of the image.

Electron microscopes have higher magnification and higher resolution than **light microscopes.**

They have allowed scientists to study cells in much finer detail.

They have increased our understanding of sub-cellular structures such as mitochondria.

Type	Description
Adult stem cells	Adult cells which can form many types of cells, including blood cells.
Embryonic stem cells	Stem cells from embryos which divide and differentiate into specialised cells.
Differentiation	Specialisation of cells
Stem cells	Undifferentiated cells, capable of dividing to make lots of cells, and of differentiating to form specialised cells.
Meristem tissue	Tissue made up of stem cells in plants. It can differentiate into any type of plant cell, throughout the plant's life. Can be used to produce plant clones quickly and economically. Can be used to clone rare species. Can be used to clone plants with useful features, e.g. disease resistance.
Therapeutic cloning	Scientists can use embryo stem cells to make different types of human cells. The cells are not rejected by the patient's body, but some people have ethical or religious concerns.

8. Transport in and out of cells - diffusion

Diffusion: The overall movement of particles from high concentration to low concentration – they spread out.

Examples

Oxygen and carbon dioxide diffuse in and out of cells in **gas exchange.**

Urea moves out of cells into the blood plasma. It is a waste product. It goes to the kidney to be excreted.

Factors that affect the rate of diffusion

- The bigger the difference in concentrations, the faster diffusion is.
- The higher the temperature, the faster diffusion is.
- The bigger the surface area of the membrane, the faster diffusion is.

Diffusion and single celled organisms

Single celled organisms have a large surface area compared with their volume.

Diffusion is enough to get them all the molecules that they need.

Diffusion and larger organisms

Larger organisms have a small surface area compared to their volume.

They need exchange surfaces and transport systems to allow them to absorb enough oxygen and move it around the body.

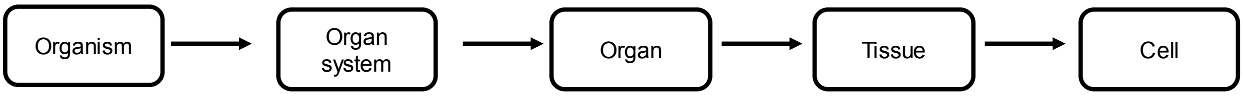
Exchange surfaces in plants have:

1. a large surface area.
2. thin membranes, to provide a short diffusion path.

Exchange surfaces in animals have:

1. a large surface area
2. thin membranes, to provide a short diffusion path.
3. a good blood supply
4. good ventilation (they breathe)

9. Levels of organisation



Examples:
human
cat
ladybird
oak tree
aphids
sparrowhawk
tiger

Examples:
digestive system
immune system
nervous system
reproductive system
excretory system

Examples:
stomach
heart
lungs
liver
pancreas
small intestine
root (plant)

Examples:
epithelial tissue
endothelial tissue
muscle tissue

Examples:
sperm cell
egg cell
liver cell
epithelial cell
nerve cell
root hair cell
leaf palisade cell

Basics of organisation

Cells are the building blocks of all organisms.

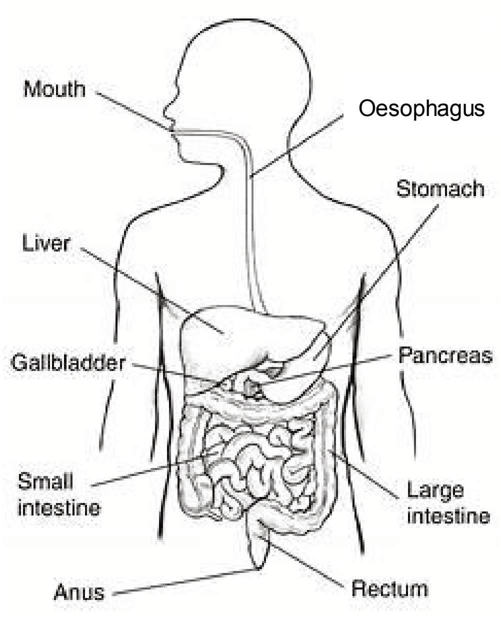
A tissue is a group of cells with a similar structure and function.

An organ is a group of tissues performing similar functions.

An organ system is a group of organs, which work together to perform a particular function.

10. Organisation of cells in the digestive system

The **human digestive system** is an example of an organ system in which several organs work together to digest and absorb food.

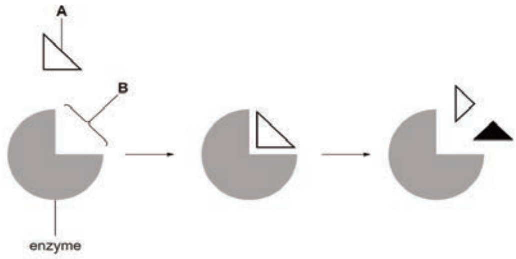


Organ	Function
Mouth	First stage of digestion, teeth break up food with mechanical digestion and salivary amylase breaks down food in chemical digestion.
Oesophagus	Transports food from the mouth to the stomach.
Stomach	Churns food and adds acid.
Small intestine	Adds digestive enzymes (amylase, lipase, and protease) and absorbs nutrients from the food.
Large intestine	Absorbs water, producing waste.
Rectum	Stores waste.
Anus	Waste passes out of the anus.
Liver	Produces bile. Bile neutralises stomach acid and emulsifies fats. Food does not pass through here.
Gall bladder	Stores bile which has been produced in the liver. Food does not pass through here.
Pancreas	Produces digestive enzymes: amylase, lipase, and protease. Food does not pass through here.

11. Enzymes in the digestive system

Digestive enzymes break down food into small soluble molecules that can be absorbed into the blood stream.

Digestive Enzyme	Produced by	Converts…	Into…
Amylase (carbohydrase)	Mouth, small intestine, pancreas	Starch (carbohydrates)	Sugar
Lipase	Small intestine, pancreas	Lipid (fat)	Glycerol + fatty acid
Protease	Stomach, small intestine, pancreas	Protein	Amino acids



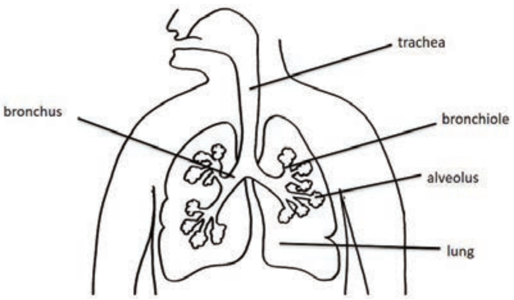
Enzymes are **specific.**
They have a specific shape (**the active site**) which works on a specific substrate – like a lock and key.

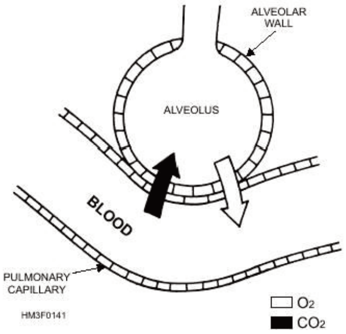
If the active site changes shape, it no longer works. Changes in pH and temperature can **denature** – change the shape of the active site - so that it no longer works.

The products of digestion are used to build new carbohydrates, lipids and proteins.
Glucose can also be respired.

Bile is made in the liver and is stored in the gall bladder.
It is alkaline and neutralises the hydrochloric acid from the stomach.
It emulsifies fat to form small droplets, increasing the surface area. This makes fat digestion quicker.

12. The breathing system





The lungs provide a good exchange surface for oxygen:

1. **Large surface area** provided by alveoli.
2. **Thin walls** of alveoli (one cell thick) and blood supply (capillary), providing a short diffusion distance.
3. **Good blood supply** to transport the oxygen away from the lungs.
4. **Well ventilated** to supply more oxygen.

Air enters the body through the **mouth** and **nose**.

⇩

Air enters the **trachea**.

⇩

The trachea divides into two **bronchi**. One **bronchus** enters each lung.

⇩

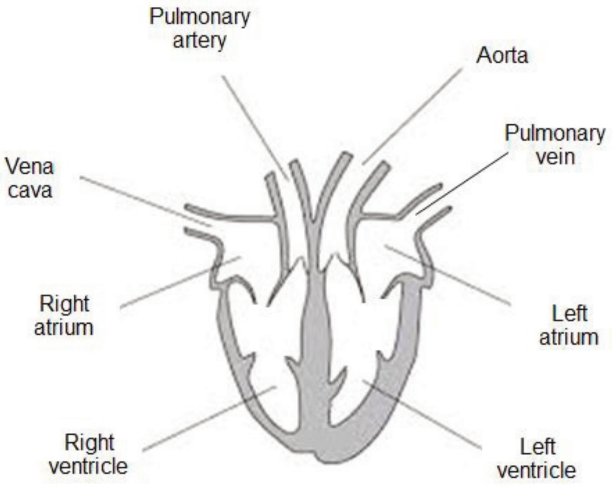
Each bronchus branches out into smaller tubes called **bronchioles**. Air travels through these bronchioles.

⇩

At the end of the bronchioles, the air enters one of the many millions of **alveoli** where gaseous exchange takes place

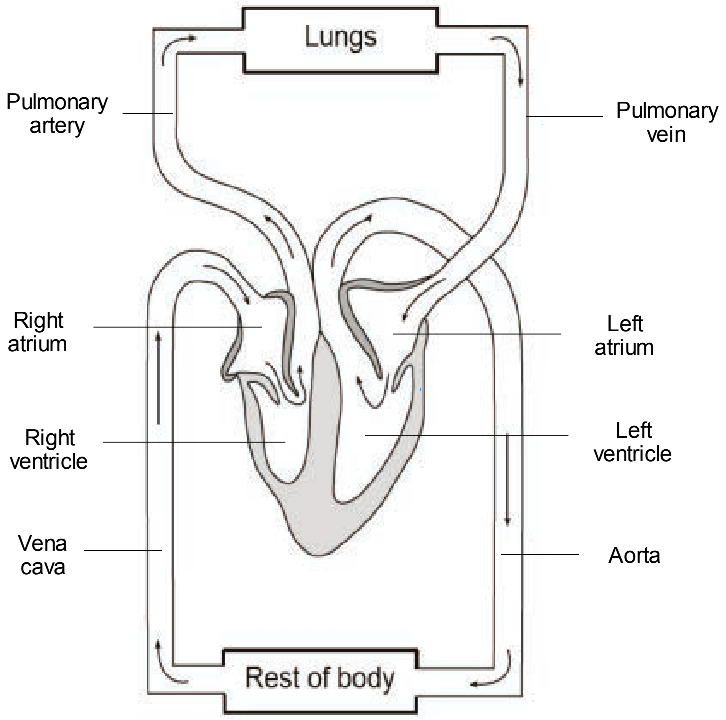
13. Organisation of cells in the circulatory system 1

The heart is an **organ**.
The function of the heart is to pump blood around the body. Humans have a **double circulatory system**, which means that blood must pass through the heart **twice** to complete a full circuit of the body.



Organ	Function
Heart	Organ that pumps blood around the body in a double circulatory system.
Vena cava	Vein which brings blood from the body to the right atrium of the heart.
Right ventricle	Chamber which pumps blood to the lungs where gas exchange takes place.
Pulmonary artery	Artery takes blood from the right ventricle to the lungs.
Left ventricle	Chamber which pumps blood around the rest of the body
Pulmonary vein	Vein which brings blood from the lungs to the left atrium of the heart.
Aorta	The aorta takes blood from the left ventricle to the body.
Pacemaker	In the wall of the right atrium, controls heart rate.

14. Organisation of cells in the circulatory system 2

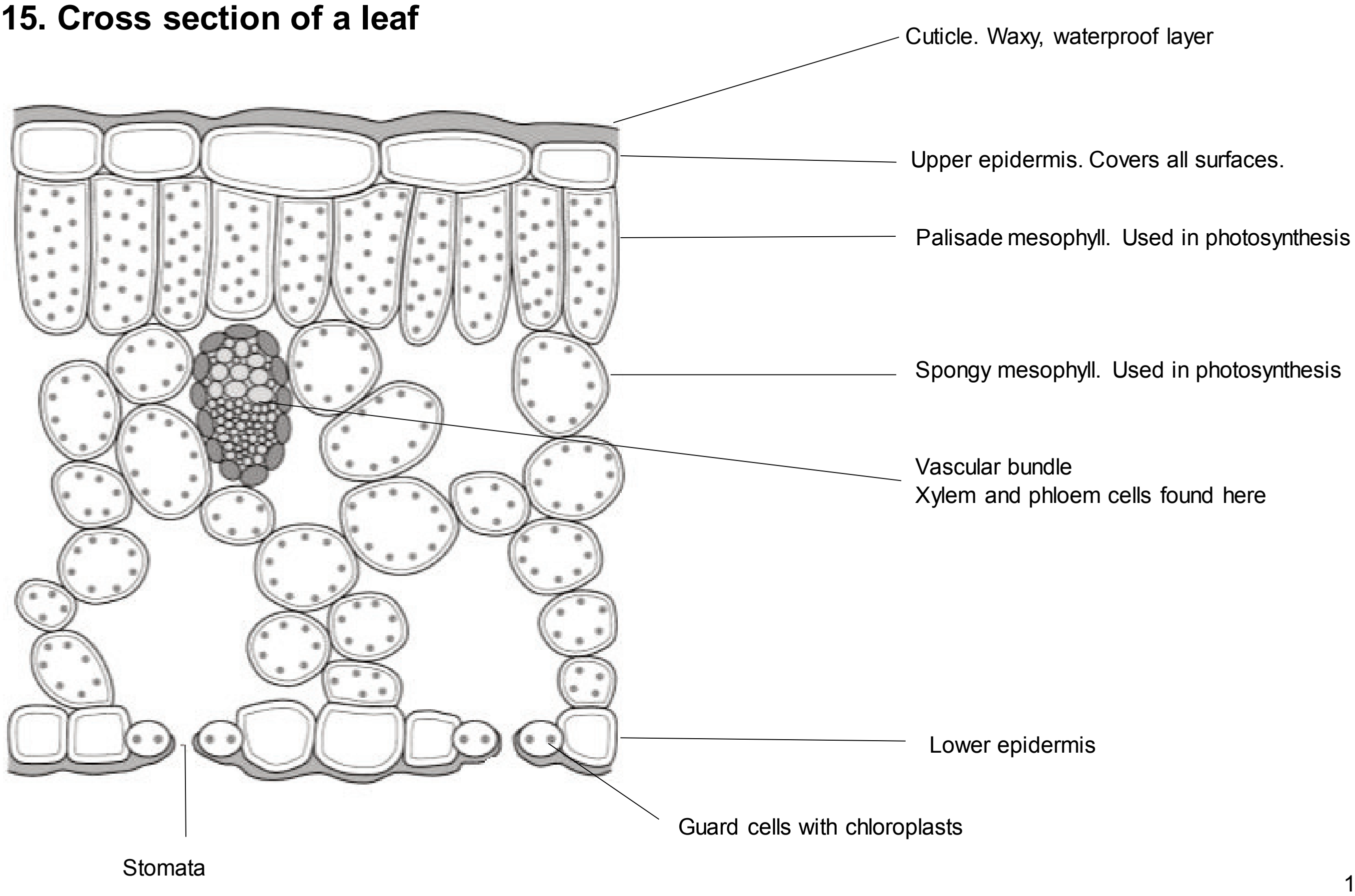


The blood is a tissue.

Blood component	Role
Plasma	Solution in which cells are suspended; carries dissolved food and hormones around the body
Red blood cells	Carry oxygen
White blood cells	Involved in immune response to fight pathogens
Platelets	Involved in blood clotting

Blood vessel	Role	Description
Artery	Carry blood away from heart	Walls contain lots of strong elastic tissue to withstand pressure
Capillary	Allow substances to diffuse into and out of the blood	Walls are one cell thick and include small holes to allow substances to move in and out easily
Vein	Carry blood to the heart	Have valves to keep blood flowing in one direction only

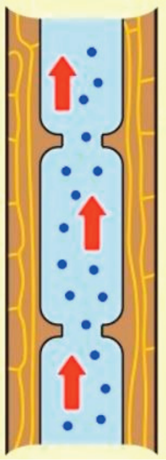
15. Cross section of a leaf



16. Organisation of cells in plants

Water is absorbed (by osmosis) by **root hair cells** that have a large surface area.
The root hair cells also absorb mineral ions (by active transport).

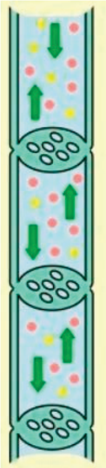
Xylem Cells



Transports **water and mineral ions** from the roots to the stems and leaves.
Made of hollow tubes, strengthened by lignin.

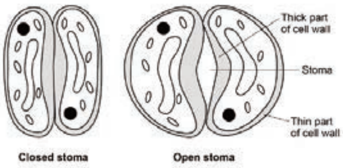
Transpiration is the transport of water and minerals up the xylem of a plant, and the evaporation of water through the stomata.
Transpiration is increased by
- Increased temperature
- Increased air movement
- Increased light intensity
- Decreased humidity

Phloem Cells



Translocation is the transport of sugars in the phloem, to all parts of the plant.
The leaves make sugars through photosynthesis.
The **phloem** transports dissolved sugars from the leaves to the rest of the plant for respiration or for storage of starch.
Phloem is made of tubes of elongated cells.
Cell sap (dissolved sugars) moves from one phloem cell to the next through pores in the end walls.

Stomata and Guard Cells



The **stomata** (small holes in the underside of the leaf) are needed for gas exchange in the leaf.
Water is also lost to the surroundings through the stomata.
To reduce water loss, **guard cells** can change the size of the stomata.

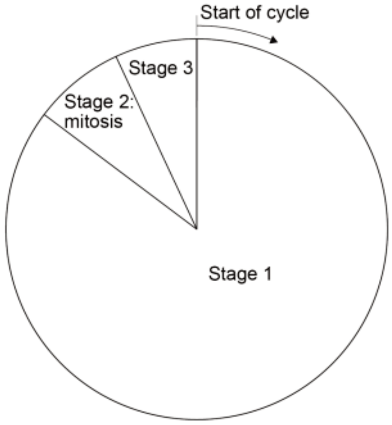
17. Coronary Heart Disease

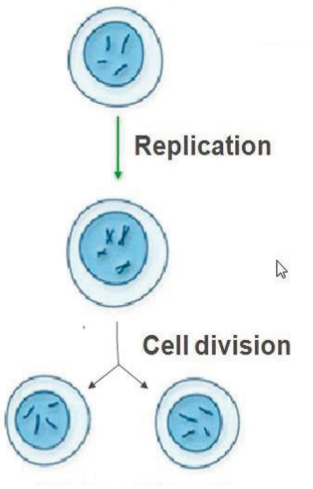
Term	Definition
Disease	dis-ease (not at ease; something in our body or mind is not working correctly)
Coronary Heart Disease	a non-communicable disease (you can't catch it)
Coronary arteries	supply the heart muscle with oxygen and glucose
Coronary heart disease	The coronary arteries have layers of fatty material building up in them. They get narrower. Less blood can flow through the coronary arteries, so the heart muscle lacks oxygen.

Treatment	Description
Statins	Tablets used to reduce blood cholesterol. They slow down the rate of fatty material build up.
Stents	Used to keep the coronary arteries open.
Heart valve replacement	Valves keep blood flowing through the heart in the right direction. Sometimes the valves don't open fully or become leaky. This prevents blood flowing through the heart properly. The patient becomes out of breath and lacks energy. Faulty heart valves can be replaced with new biological valves (from a donor) or mechanical valves.
Heart failure	Can be treated with a new heart and lungs. The heart would come from a donor. Mechanical hearts can be used to keep the patient alive whilst waiting for a heart transplant.

18. Cell Cycle: Mitosis

Stage of the cell cycle	Events
1	The cell grows. The DNA replicates to form two copies of each chromosome. New mitochondria and ribosomes are made.
2	**Mitosis**: one set of chromosomes is pulled to each end of the cell. The nucleus divides.
3	The cytoplasm and cell membranes divide. There are now two identical cells.





Uses of cell division by mitosis

1. Growth
2. Repair of tissues
3. Asexual reproduction

19. Cell Cycle: Mitosis and Cancer

Stage of the cell cycle	Events
1	The cell grows. The DNA replicates to form two copies of each chromosome. New mitochondria and ribosomes are made.
2	Mitosis: one set of chromosomes is pulled to each end of the cell. The nucleus divides.
3	The cytoplasm and cell membranes divide. There are now two identical cells.

Uses of cell division by mitosis

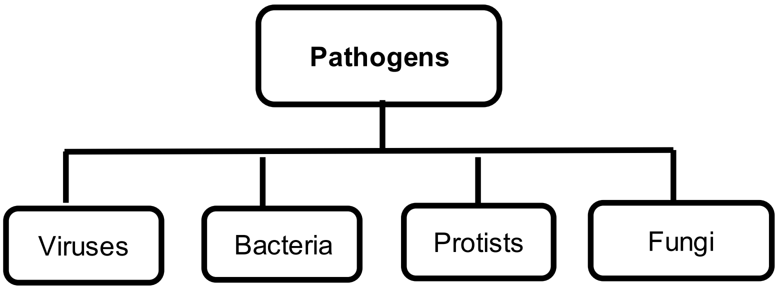
1. Growth
2. Repair of tissues
3. Asexual reproduction

Cancer is the result of uncontrolled growth and division of cells. This is caused by a change in the genetic material of the cell.

Benign tumours are growths of abnormal cells.
They are contained in one area, usually within a membrane. They do not invade other parts of the body.

Malignant tumour cells are cancers.
They invade neighbouring tissues and spread around the body in the blood, where they form secondary tumours.
Lifestyle factors and genetic factors can be risk factors for cancers.

20. Communicable diseases: pathogens



Communicable diseases are diseases caused by pathogens – they can spread from one organism to another.

Pathogens are organisms that cause infectious disease.
They can be viruses, bacteria, protists or fungi.
Pathogens may infect plants or animals.
Pathogens can spread by direct contact, water or by air.

Bacteria reproduce rapidly inside the body.
Bacteria produce poisons/toxins that damage tissues and make us feel ill.

Viruses reproduce rapidly inside the body.
Viruses live and reproduce inside cells, causing cell damage.

21. Communicable diseases: viruses

Pathogen	Disease	Transmission	Symptoms	Treatment or prevention
Virus	Measles	Sneezing and coughing produces droplets containing the virus; these droplets can be inhaled by others.	Fever and red skin rash. It can be fatal if there are complications.	Most young children are vaccinated against measles.
Virus	HIV/AIDs	Sexual contact or exchange of body fluids such as blood.	Flu-like illness, which then attacks the body's immune cells. Late stage HIV, known as AIDS, happens when the immune system is so damaged that it cannot deal with infections or cancers	treated with antiretroviral drugs.
Virus	Tobacco mosaic virus (TMV)	By direct contact	A distinctive mosaic pattern of discoloration on the leaves. The leaves can't photosynthesise as well, which affects the growth of the plant.	Remove infected plants; wash hands when handling plants to prevent transfer from one to another

22. Communicable diseases: bacteria, fungi and protists

Pathogen	Disease	Transmission	Symptoms	Treatment or prevention
Bacterium	Salmonella (food poisoning)	Undercooked chicken, or contamination of surfaces from raw chicken	Fever, abdominal cramps, vomiting and diarrhoea, caused by the bacteria and the toxins from the bacteria.	Poultry (chicken, turkey and ducks) are vaccinated against salmonella to control the spread
Bacterium	Gonorrhoea	sexually transmitted disease	Thick yellow or green discharge from the vagina or penis; as well as pain when urinating.	Antibiotics, although there are many resistant strains. Barrier methods of contraception can reduce the spread.
Fungus	Rose black spot	by wind or water	Purple or black spots develop on leaves. The leaves turn yellow and drop off. The leaves don't photosynthesise well, which affects the growth of the plant.	Fungicides and removing and destroying the affected leaves.
Protist	Malaria	Spread by mosquito bites.	Recurrent (repeating) episodes of fever. It can be fatal.	Prevented by stopping mosquitos from breeding, and by avoiding being bitten e.g. with a mosquito net.

23. Human defences against pathogens

Humans have several **non-specific defences** against pathogens.

These defences are general i.e. they work on most pathogens.

Primary line of defense:

Skin is a physical barrier.

Nose, trachea, bronchi contains mucus and hairs to trap pathogens.

Stomach contains acid which kills pathogens.

Secondary line of defense:

If a pathogen enters the body, the **immune system** tries to destroy it.

White blood cells kill pathogens by:

1. Phagocytosis (absorbing the pathogen and destroying it. This is non-specific)
2. Antibody production (they make pathogens stick together. This is specific)
3. Antitoxin production

A **vaccine contains** small quantities of dead or inactive pathogen, which are injected into the body

↓

Stimulates the white blood cells to produce antibodies.

↓

Memory cells remain in the body.

↓

If the same pathogen re-enters the body, the white blood cells produce antibodies **quickly and in greater numbers**, preventing infection. The person shows no symptoms.

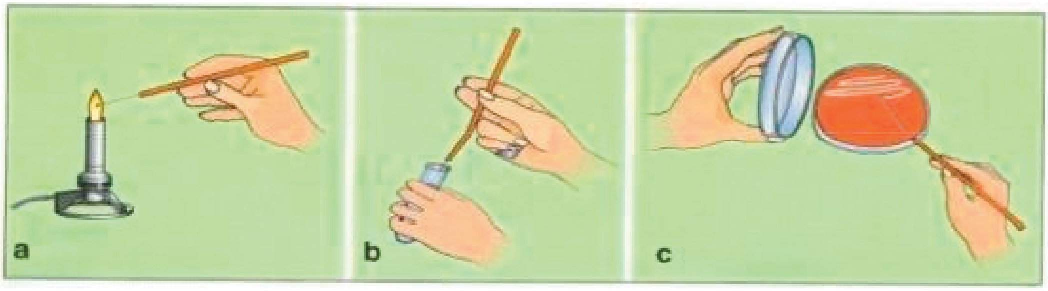
Benefits of Vaccinations:

Prevent infection in individuals (see above).

Prevent the spread of infection from one person to another.

24. Preparing uncontaminated cultures of bacteria

1. Sterilise Petri dishes and culture media before use.
2. Sterilise an inoculating loop by passing through a flame.
3. Dip the cool inoculating loop into the bacterial culture.
4. Lift the lid of the dish as little as possible and for as short a time as possible.
5. Zigzag the loop over the surface of the agar in the Petri dish.
6. Secure the lid with adhesive tape in strips (not all the way around). This allows oxygen into the plate for aerobic bacteria. It also discourages the growth of harmful anaerobic bacteria.
7. Incubate upside down (to prevent condensation) at 25^0C (to prevent growth of microbes harmful to people).



25. Medical Drugs

Antibiotics are medicines that help to cure bacterial disease. They kill infectious bacteria inside the body. An example is penicillin. It is important that the right antibiotic is used for the right bacteria. Antibiotics cannot be used to kill viruses. Resistant strains of bacteria have evolved – e.g. MRSA – these are not affected by antibiotics.

Painkillers do not kill pathogens, but they do treat the symptoms of disease.

Antivirals are difficult to produce. They tend to damage body tissues as well as kill the virus.

Drug	Source	Purpose
Digitalis	Foxgloves	Heart disease
Aspirin	Willow	Painkiller
Penicillin	Penicillium mould	Antibiotic (discovered by Alexander Fleming)

New drugs

Traditional drugs came from plants and microorganisms.

New drugs are synthesised by chemists in the pharmaceutical industry. However, the starting point may still be a chemical extracted from a plant.

Testing new drugs

New medical drugs must be tested and trialled to check that they are safe and effective.

They are tested for **toxicity**, **efficacy** (does it work), and **dose.**

Preclinical trials use cells, tissues and animals

Clinical trials use healthy volunteers and patients

1.Very low doses are given at the start.

2.If it is safe, further clinical trials are done to find the optimum dose.

3.In double blind trials, some patients are given a placebo.

A **placebo** looks like the drug but contains no drug.

In a **double blind trial**, neither the scientist nor the patient knows if they have been given the drug, or the placebo.

26. Monoclonal Antibodies

What are monoclonal antibodies?

Monoclonal antibodies are produced from a single clone of cells.
The antibodies are specific to one binding site on one protein antigen, and so are able to target a specific chemical or specific cells in the body.

To produce monoclonal antibodies

1. A protein antigen is injected into a mouse.
2. The mouse produces lymphocytes (a type of white blood cell), which make antibodies against this particular antigen.
3. The lymphocytes are extracted from the mouse.
4. The lymphocyte is fused with a tumour cell to make a hybridoma cell.
5. Single hybridoma cells are cloned to make large numbers of identical cells, making identical antibodies.
6. A large quantity of antibody can then be collected and purified.

Problems:

They create more side effects than expected, so have not yet been used as widely as everyone hoped.

How monoclonal antibodies work in the body

1. Monoclonal antibody is specific to the antigen e.g. HIV
2. Monoclonal antibodies attach to the (HIV) antigens
3. Virus (HIV) genetic material cannot enter cell

Uses of monoclonal antibodies

- In pregnancy testing
- To measure the levels of hormones and other chemicals in blood
- To locate or identify specific molecules in a tissue or a cell, by binding them with a fluorescent dye
- To treat some diseases – for cancer, the monoclonal antibody can be bound to a radioactive substance, a toxic drug or a chemical, which stops cells growing and dividing. It delivers the substance to the cancer cells, without harming other cells.

27. Health Issues

Health is the state of physical and mental wellbeing.
Health may be affected by diet, stress and life situations.

Diseases often interact:

Defects in the immune system increase the chance of infectious disease.

Viruses living in cells can trigger cancers.

Pathogens can cause immune reactions; the immune reactions can then trigger allergies, such as asthma and skin rashes.

Severe physical illness can lead to mental illness e.g. depression.

Lifestyle has an effect on some non-communicable diseases
Many diseases are caused by the interaction of a number of risk factors.

Examples include:

- Poor diet, smoking and lack of exercise are risk factors for cardiovascular disease.
- Obesity is a risk factor for type 2 diabetes.
- Alcohol can affect liver and brain function.
- Smoking is a risk factor for lung disease and lung cancer.
- Smoking and alcohol have effects on unborn babies.
- Carcinogens, including ionising radiation, are risk factors for cancer.

28. Plant diseases

Causes of plant disease

Viruses, bacteria, fungi, insects

Nitrate deficiency causes stunted growth (as nitrate ions are needed to make amino acids, and amino acids are needed to make proteins. Proteins are needed for growth)

Magnesium deficiency causes chlorosis (yellow leaves) as they are needed to make chlorophyll

Detection of plant disease

Stunted growth

Spots on leaves

Areas of decay (rot)

Growths

Malformed stems or leaves

Discolouration

Presence of pests

Identification of a disease

Refer to a gardening manual or website

Take infected plant to a lab to identify the pathogen

Using testing kits that contain monoclonal antibodies

Plant defence responses

Physical defences

Cellulose cell walls

Tough waxy cuticle on leaves

Layers of dead cells around stems (bark on trees) which fall off

Chemical defences

Antibacterial chemicals

Poisons to deter herbivores

Mechanical adaptations

Thorns and hairs deter animals

Leaves which droop or curl when touched

Mimicry to trick animals

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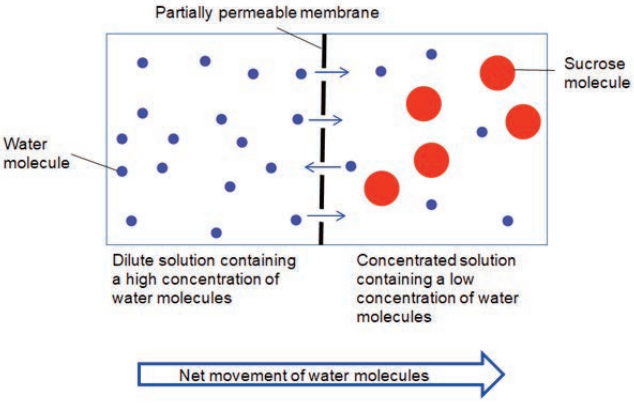
29. Transport across membranes – osmosis and active transport

Osmosis is the **diffusion** of **water** through a partially permeable membrane.

Water moves from a **dilute solution to a concentrated solution.**

Cell membranes are partially permeable.

This means that they allow some things to cross e.g. water, but not other things e.g. sugar.

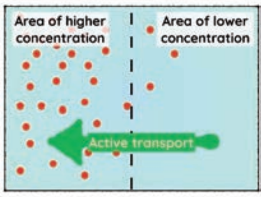


Active Transport is the movement of substances from a **low concentration to a high concentration.**

This is the opposite of diffusion.

Active transport needs **energy** from respiration.

This is because it moves substances against the concentration gradient; from **low to high** concentration.



Active transport is used by plant root hairs to move mineral ions from the soil to the plant. The mineral ions are needed for growth.

Active transport is used in the small intestine to move sugar molecules into the blood. Sugar molecules are used for cell respiration.

30. Photosynthesis

Photosynthesis

carbon dioxide + water → glucose + oxygen

We remember it as COW → GO

$6CO_2 + 6H_2O \rightarrow C_6H_{12}0_6 + 6O_2$

Light is needed to provide the energy for photosynthesis.
Photosynthesis is endothermic.
During photosynthesis, energy is transferred from the environment to chloroplasts.

Rate of photosynthesis

The rate of photosynthesis is **increased** when:

1. The light intensity increases
2. The carbon dioxide concentration increases
3. The amount of chlorophyll increases
4. The temperature increases*

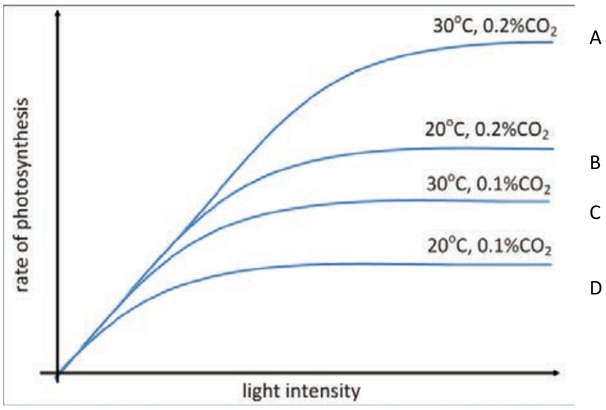
*if the temperature increases too much, enzymes that control photosynthesis are denatured, and the rate decreases.

Uses of glucose from photosynthesis

The glucose produced in photosynthesis may be:
Used for **respiration**
Converted into insoluble **starch** for storage
Used to produce amino acids for **protein** synthesis
Used to produce **cellulose**, to strengthen the cell wall
Used to produce **fat** or oil for storage
(RSPCF)

To produce amino acids, plants also use nitrate ions.
Nitrate ions are absorbed from the soil.
They are absorbed by root hair cells by active transport.

31. Limiting Factors in Photosynthesis: Higher only



Why does this matter?

Limiting factors are important in the economics of enhancing the conditions in greenhouses to gain the maximum rate of photosynthesis while still maintaining profit.

Carbon dioxide concentration, temperature, light intensity and the amount of chlorophyll all affect the rate of photosynthesis.
Any of these factors may be the factor that limits the rate of photosynthesis. For example, if there is plenty of carbon dioxide, but light intensity is low, then light intensity will be the limiting factor.

You will need to be able to tell from a graph which factor is the limiting factor.
At first, as light intensity increases, the rate of photosynthesis increases, meaning that light intensity is the limiting factor.
Then, light intensity continues to increase, but photosynthesis does not. This means that there is another limiting factor.
By comparing line C and D, or line A and B, we can see that when the temperature increases, the rate of photosynthesis increases. This means that temperature is a limiting factor.
By comparing line A and C, or line B and D, we can see that when the concentration of carbon dioxide increases, the rate of photosynthesis increases. This means that concentration of carbon dioxide is a limiting factor.

32. Respiration

Cellular respiration happens continuously in living cells.
It is exothermic.
It transfers all the energy needed for living processes.
It can be aerobic (using oxygen) or anaerobic (without oxygen).

Organisms need energy for
•Chemical reactions to build larger molecules
•Movement
•Keeping warm

Aerobic respiration
Glucose + oxygen → carbon dioxide + water
Remember it as GO → COW
$C_6H_{12}0_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Anaerobic respiration in muscles
Glucose → lactic acid
Anaerobic respiration transfers much less energy than aerobic respiration, as oxidation is incomplete.

Anaerobic respiration in plants and yeast cells
Glucose → ethanol and carbon dioxide
Anaerobic respiration in yeast cells is called fermentation.
It is important in the manufacture of bread and alcoholic drinks.

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33. Response to exercise and metabolism

Response to exercise
During exercise, the body needs more energy.
The heart rate, breathing rate, and breath volume increase to supply the muscles with more oxygenated blood.
If muscles do not get enough oxygen, anaerobic respiration occurs.

Problems:
Incomplete oxidation of glucose means that less energy is released.
Lactic acid is produced.
An oxygen debt is caused.
Muscles become fatigued and stop contracting efficiently.

After exercise (Higher only)
Lactic acid is transported by the blood from the muscles to the liver
It is converted back to glucose
This conversion requires oxygen.
The amount of oxygen required to convert the lactic acid back to glucose is called the **oxygen debt.**

Metabolism
Metabolism is the total of all the reactions in a cell, or in the body.

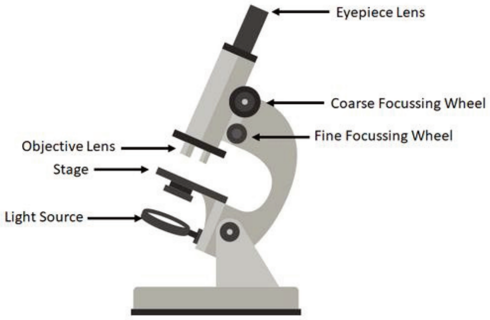
The energy transferred by respiration in cells is used by the organism for the constant enzyme-controlled reactions that synthesis new molecules. These reactions are known as metabolism.

Metabolism includes:
respiration
glucose → starch/ glycogen/ cellulose
glucose + nitrate ions → amino acids → proteins
glycerol + fatty acids → lipids
breakdown of excess proteins → urea for excretion

34. Required Practicals 1 – Microscopy and Food Tests

Using a Microscope

1. Light on
2. Platform (stage) high
3. Lowest magnification objective lens first
4. Coarse focus first, then fine focus



Rules for Biological Drawings

- Sharp pencil
- Smooth lines
- Ruler for label lines
- No arrowheads
- Add magnification (multiply eyepiece lens by objective lens)

Food tests

Food	Test	Positive result
Starch	add iodine solution	turns black
Sugars	add Benedict's solution → heat	makes (orange) precipitate
Protein	add Biuret solution	turns purple
Fats (lipids)	add ethanol → shake → add water → shake	cloudy white emulsion

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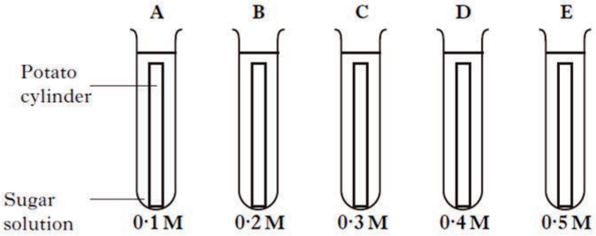
35. Required Practical 2 - Osmosis

Investigate the effect of concentration of salt or sugar solutions on mass of potato

IV: concentration of salt (or sugar) solution (need at least 5 different concentrations)

DV: change in mass of potato cylinders

CV: volume of salt solution; surface area of potato; time in solution; all potato skin removed; method of drying the potato



Method

1. Use a cork borer to cut 5 pieces of potato; make them the same length.
2. Place a known volume of each salt solution into each of 5 boiling tubes.
3. Weigh each potato cylinder.
4. Add one potato to each boiling tube, recording the mass for each.
5. After 30 minutes, remove each piece of potato; dry by rolling three times on a paper towel.
6. Reweigh each potato piece.
7. Calculate the change in mass of the potato and the % change in mass.
8. Plot a graph of salt concentration against % change in mass.

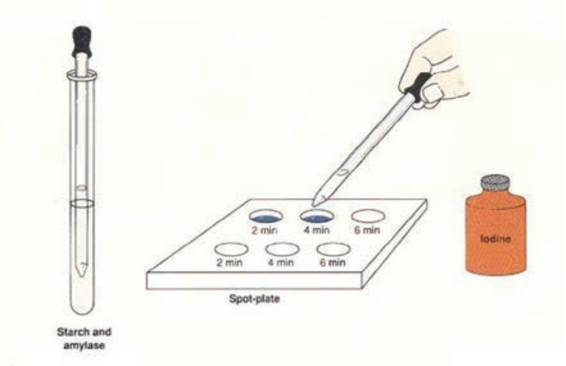
36. Required Practical 3 - Enzymes

Investigate the effect of pH on the reaction of amylase enzyme

IV: pH (change using at least 5 different buffer solutions)

DV: time taken to digest starch (measured as the time it takes for a sample of the mixture **not** to turn black when mixed with iodine solution)

CV: volume and concentration of amylase solution; volume and concentration of starch solution; temperature; time for samples



Method:

1. Place known volume of starch solution into a boiling tube.
2. Place known volume of amylase solution into the boiling tube.
3. Stir using a glass rod.
4. Take a sample of mixture and place onto a spot tile.
5. Add a drop of iodine solution to the spot tile; repeat every 30s; record the time taken for the mixture not to turn black.
6. Repeat steps 1 – 5 for at least 5 different pHs.

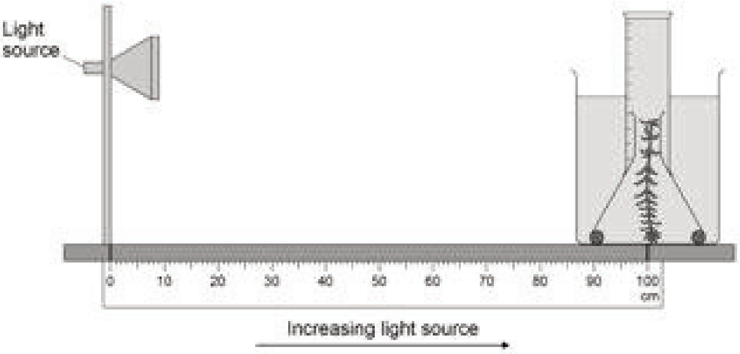
37. Required Practical 4 - Photosynthesis

Investigate the effect of light intensity on the rate of photosynthesis

IV: light intensity (using at least 5 different distances from lamp to pondweed)

DV: number of bubbles released from pondweed per minute

CV: concentration of carbon dioxide; power of the bulb; no background light; time; length of pondweed



Method:

1. Cut a piece of pondweed, with a diagonal cut.
2. Place cut end uppermost into a boiling tube.
3. Immerse in water or a dilute solution of sodium hydrogen carbonate (to provide carbon dioxide).
4. Place a lamp 10cm away from the boiling tube; turn off all other lights.
5. When bubbles appear, start to count bubbles for one minute.
6. Using same pondweed, repeat the experiment, increasing the distance from the lamp by 10cm each time, for at least 5 distances.
7. Plot a graph of distance from the lamp against number of bubbles produced per minute.

38. Required Practical 5: Microbiology

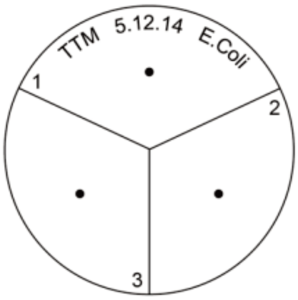
Preparation of Uncontaminated Cultures of Bacteria

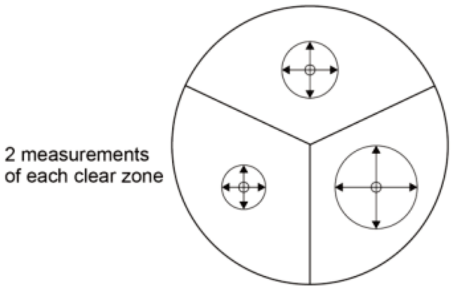
1. Sterilise Petri dishes and culture media before use.
2. Sterilise an inoculating loop by passing through a flame.
3. Dip the cool inoculating loop into the bacterial culture.
4. Lift the lid of the dish as little as possible and for as short a time as possible.
5. Zigzag the loop over the surface of the agar in the Petri dish.
6. Secure the lid with adhesive tape in strips (to allow oxygen into the plate, whilst ensuring that other contaminants can't enter).
7. Incubate upside down (to prevent condensation) at 25^{0}C (to prevent growth of microbes harmful to people).

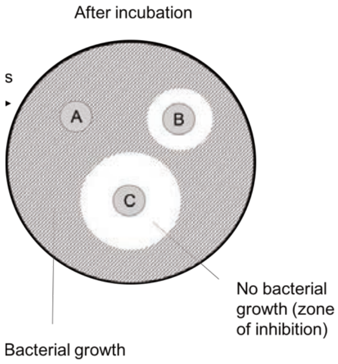
Effectiveness of Antibiotics

1. Prepare an uncontaminated plate of bacteria.
2. Sterilise forceps by dipping in ethanol, then passing through a flame.
3. Allow to cool, then pick up a disc pre-soaked in antibiotic.
4. Place the disc on the agar; repeat for two other antibiotics and a disc dipped in sterilised water (a control).
5. Incubate at 25^{0}C for 48 hours.
6. Measure diameter of the clear area around the disc.

The larger the clear zone, the more effective the antibiotic for that type of bacteria.







Biology Paper 2 (Triple)

39. Homeostasis

Homeostasis is maintaining constant internal conditions, so that cells can survive.

Cells in the body can only survive within narrow physical and chemical limits. Outside of these limits, enzyme action and all cell functions stop.

Homeostasis maintains optimal conditions.
This includes
Blood glucose concentration
Body temperature
Water levels.

Homeostasis is **automatic.**
There are two automatic control systems in the body.

1. The nervous system
2. The endocrine system (chemicals called hormones).

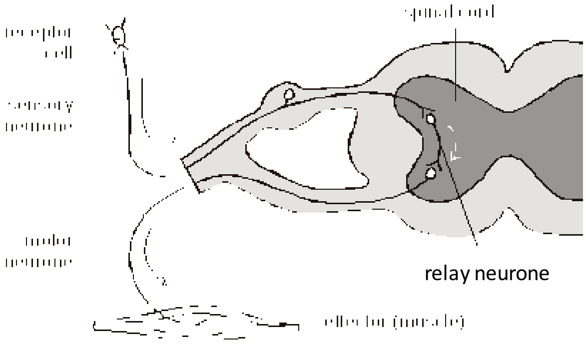
The nervous system enables humans to react to changes in surroundings and to coordinate behaviour.
Automatic control systems have three parts.

1. **Receptors**: cells that detect stimuli, and pass this information along neurones as electrical impulses.
2. **Coordination centre** is the central nervous system, which receives and processes information from receptors. The CNS sends instructions to…
3. **Effectors** that make changes to restore optimum levels, e.g. muscles or glands.

40. Reflex Actions

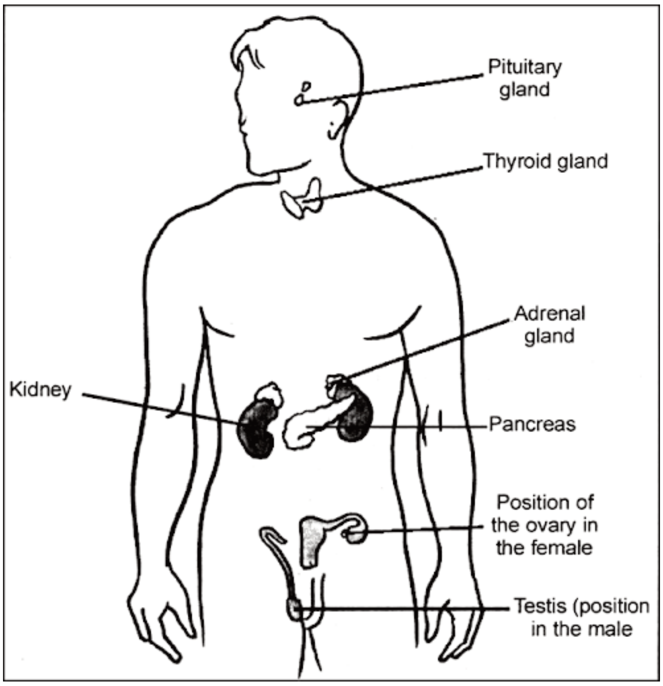
Reflexes are quick and short lasting.
They do not involve the conscious part of the brain.

Gaps between neurones are called synapses.



stimulus
⬇
receptor
⬇
sensory neurone
⬇
synapse
⬇
relay neurone
⬇
synapse
⬇
motor neurone
⬇
effector
⬇
response

41. The Endocrine System



Examples of endocrine glands

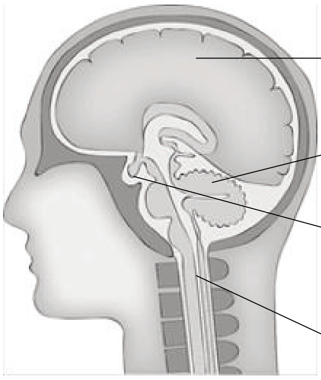
- Pituitary gland
- Thyroid
- Pancreas
- Adrenal gland
- Ovary
- Testes

The Endocrine System

The endocrine system is made of glands.
Glands secrete (release) chemicals called hormones.
Hormones are secreted straight into the blood stream.
The blood carries the hormone to a target organ where it produces an effect.

Compared to the nervous system, the effects are slower but last longer.

42. The Brain



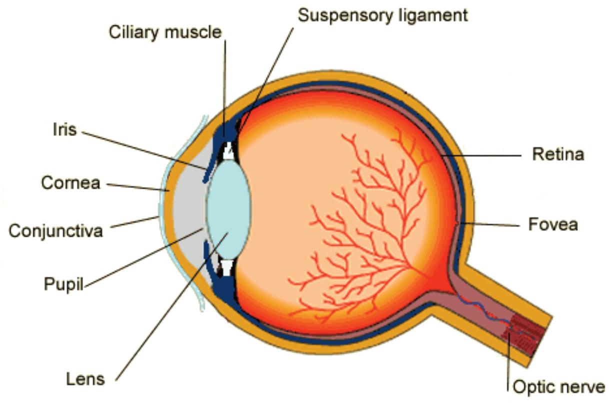
Part of brain	function
Cerebral cortex	Thought, language
Cerebellum	Movement
Pituitary gland	The 'master gland'. Secretes several hormones into the blood in response to body conditions. These hormones act on other glands. These glands release other hormones, bringing about more effects.
Medulla	Involuntary control of breathing, swallowing, digestion

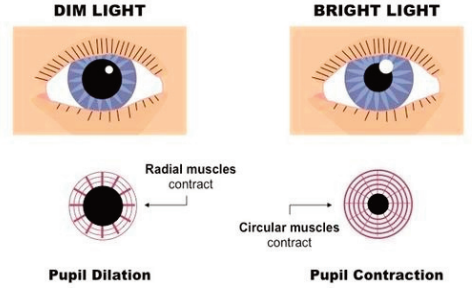
The Brain

Made of billions of interconnected neurones that control complex behaviour.
Neuroscientists map regions to functions by studying patients with brain damage, electrically stimulating parts of the brain, using MRI scanning.
The complexity makes investigation and treatment difficult.

43. The Eye

The eye is a sense organ containing receptors to light intensity.





Part	Role
cornea	transparent layer at the front of the eye; refraction occurs here
Iris	coloured part of eye; contains radial and circular muscles
pupil	gap which allows light into the eye
lens	refracts the light onto the retina
ciliary muscles	control the shape of the lens
suspensory ligaments	support the lens
retina	contains receptors; rods detect light, cones detect colour
optic nerve	sensory neurones that transmit impulses from eye to brain
sclera	tough outer covering

Adaptation to different light conditions uses the muscles of the iris

Dim light: radial muscles contract, circular muscles relax, pupil gets bigger

Bright light: radial muscles relax, circular muscles contract; pupil gets smaller.

44. Accommodation in the eye

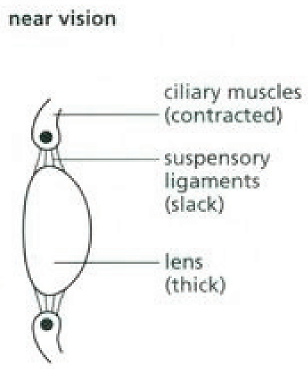
Accommodation: changing the shape of the lens to focus on near or distant objects.

Near objects:

Ciliary muscles contract

Suspensory ligaments loosen

Lens is thicker and refracts light more strongly

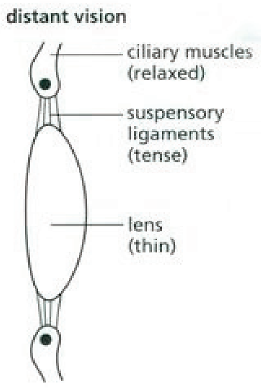


Distant objects:

Ciliary muscles relax

Suspensory ligaments are pulled tight

Lens is thinner and refracts light less strongly

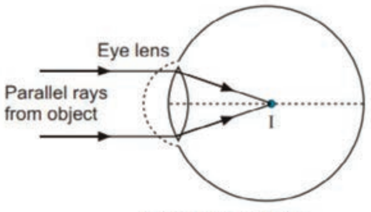


45. Correction of eye problems

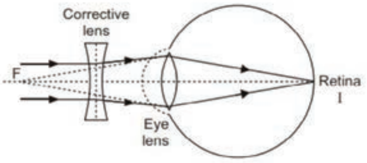
Correction of myopia (short sightedness)

Problem: light rays focus before the retina (for example the eyeball is too long)

Solution: use concave spectacle lenses to refract the light outwards before the cornea.



(a) Image formation by myopic eye

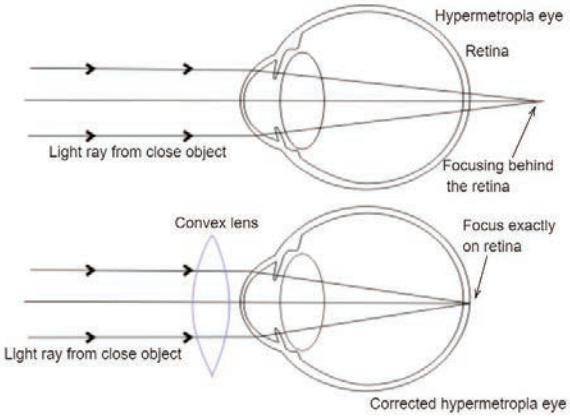


(b) Corrected myopia

Correction of hyperopia (long sightedness)

Problem: light rays focus after the retina (for example the eyeball is too short)

Solution: use convex spectacle lenses to refract the light inwards before the cornea.



New technologies include:

Hard and soft contact lenses

Laser surgery to change the shape of the cornea

Replacement lenses in the eye

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46. Control of blood glucose

Blood glucose concentration is monitored and controlled by the pancreas.

*Glucagon is higher only

Negative feedback: when the body responds to a change in a factor (temperature, glucose concentration, salt concentration) by correcting it.

Steady blood glucose concentration

Pancreas detects high blood glucose concentration

Pancreas releases **insulin**

Insulin causes glucose to move from blood into cells

Insulin causes liver and muscle cells to convert glucose into glycogen

Blood glucose levels fall again

Steady blood glucose concentration

Pancreas detects low blood glucose concentration

Pancreas releases **glucagon***

Glucagon causes glycogen (which was stored in cells) to be converted into glucose

Glucose is released into the blood

Blood glucose levels rise again

Steady blood glucose concentration

47. Diabetes

Type 1 diabetes is a disorder.

The pancreas does not produce enough insulin.

People with type 1 diabetes have uncontrolled high blood glucose levels.

Type 1 diabetes is treated with insulin injections.

Type 2 diabetes is a disorder.

Cells do not respond to insulin.

Obesity is a risk factor for type 2 diabetes.

Type 2 diabetes is treated with a carbohydrate-controlled diet (e.g. starch rather than sugar) and exercise regimes.

---

48. Control of body temperature

The regulation of body temperature is another example of negative feedback.

The skin contains temperature receptors and sends impulses to the **thermoregulatory centre in the brain.**

➡

The thermoregulatory centre also contains receptors sensitive to the temperature of the blood.

Body temperature gets **too high**

There must be an increased transfer of energy from the skin to the environment.

1. Blood vessels dilate (vasodilation)
2. Sweat glands produce sweat; as the sweat evaporates it cools the body.

Body temperature gets **too low**

There must be a decreased transfer of energy from the skin to the environment.

1. Blood vessels constrict (vasoconstriction)
2. Sweating stops
3. Skeletal muscles contract

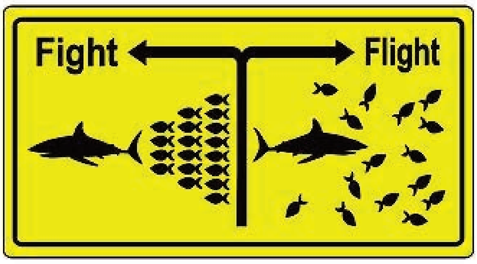
Blood temperature returns to **normal**

49. Adrenaline and thyroxine

Adrenaline is produced by the adrenal glands.

Adrenaline is produced in times of fear or stress.

Adrenaline increases the heart rate.
It increases the delivery of oxygen and glucose to the brain and muscles, preparing the body for fight or flight.



Thyroxine is produced by the thyroid gland.

Thyroxine stimulates the basal metabolic rate.

Thyroxine plays an important role in growth and development.

When thyroxine levels increase, signals sent to the thyroid gland turn off thyroxine production, so that levels decrease again.
This is another example of negative feedback.

---

50. Control of water and nitrogen balance in the body 1

If the blood plasma becomes **too dilute**, water will move by osmosis from the plasma into the cells; they might burst.
If the blood plasma becomes **too concentrated**, water will move by osmosis from the cells into the plasma; they might shrivel.

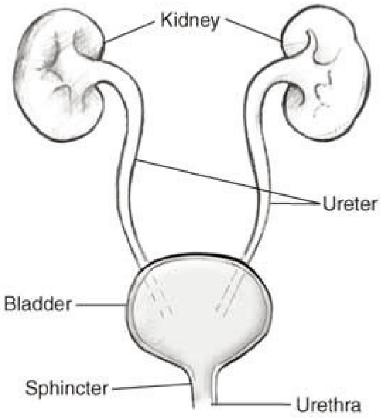
Excess amino acids are **deaminated** in the liver to make ammonia.
Ammonia is toxic and so it is immediately converted into urea.

Water leaves the body via the lungs during exhalation.
Water, ions and urea are lost from the skin in sweat.

There is no control over the loss of water, ions or urea by the skin or the lungs.

Excess water, ions and urea are removed via the kidneys in the urine.

The kidneys make urine by:
Filtering the blood
Reabsorbing **all** of the glucose
Reabsorbing as much water and ions as needed.
Excreting all of the urea
Urine contains excess water, excess ions and urea.



51. Control of water and nitrogen balance in the body 2

Effect of ADH (anti-diuretic hormone)
The water level in the body is controlled by the hormone ADH.

ADH is released by the pituitary gland when the blood is too concentrated.

ADH makes the kidney tubules more permeable to water.

ADH causes more water to be reabsorbed back into the blood from the kidney tubules.

This is controlled by negative feedback.

Kidney failure is treated by organ transplant or by kidney dialysis.

If someone has an **organ transplant**:
the tissue type must match
all operations have some risk of infection
the patient must take immunosuppressant drugs for the rest of their life to reduce the risk of rejection.

If someone is on **dialysis**:
it is very time consuming and requires many hours of hospital treatment every week.

52. Hormones in Human Reproduction

Secondary sex characteristics include the changes that take place at puberty.
During puberty reproductive hormones cause secondary sex characteristics to develop.

Testosterone is the main male hormone.
It is produced by the testes.
It stimulates sperm production.

Female hormone	Produced by	Function
Follicle stimulating hormone (FSH)	pituitary gland	causes an egg in the ovary to mature
Luteinising hormone (LH)	pituitary gland	causes the mature egg to be released into the oviduct – **ovulation**
Oestrogen	ovary	involved in thickening the lining of the uterus inhibits FSH
Progesterone	ovary	involved in maintaining the thickened lining of the uterus

53. Hormones to treat infertility

The use of hormones to treat infertility

The woman may be given a ‘fertility drug’.

This drug contains FSH and LH.

She may become pregnant in the normal way.

The couple may have **IVF treatment (in vitro fertilisation**).

1. The woman is given FSH and LH to stimulate the maturation of several eggs.
2. The eggs are collected from the mother and fertilised by sperm from the father in the laboratory.
3. The fertilised eggs develop into embryos.
4. When they are tiny balls of cells, one or two embryos are inserted into the mother’s uterus (womb).

Positives of fertility treatment

Gives a woman/couple a chance to have a baby of her/their own.

Negatives of fertility treatment

It is very emotionally and physically stressful.

The success rate is not high.

It can lead to multiple births, which are a risk to the babies and mother.

54. Contraception

Contraception can be used to control fertility.

Contraceptives may be classified as hormonal or non-hormonal.

Type	Method	How it works
Hormonal	Oral contraceptives	contain hormones to inhibit FSH production, so that no eggs mature
	Injection, skin patch or implant of slow-release progesterone	inhibit the maturation of eggs for a number of months or years
	Intrauterine devices (IUD)	prevent the implantation of an embryo or release a hormone
Non-hormonal	Barrier methods such as condoms and diaphragms	prevent the sperm reaching an egg
	Spermicidal agents	kill or disable sperm
	Abstaining from intercourse when an egg may be in the oviduct	prevents fertilisation
	Surgical methods of male and female sterilisation	eggs cannot move along oviduct; sperm cannot move along sperm ducts

55. Plant Hormones

Plants produce hormones to coordinate and control growth and responses to light (**phototropism**) and gravity (**geotropism or gravitropism**).
Unequal distribution of auxin causes unequal growth rates in plant roots and stems.

Positive Phototropism in stems
Auxin is produced from the stem tip.
Auxin diffuses down the stem, causing cells to elongate and divide (by mitosis).
In uniform light, auxin remains evenly distributed in the stem, so growth is uniform.
In unidirectional light (light from one side only), auxin moves to the shaded side of the stem, so the shaded side grows more quickly; the stem bends towards the light.

Positive Geotropism in roots
If a root is horizontal, auxin accumulates on the lower side.
Auxin restricts cell division in roots.
The lower side of the root grows more slowly than the upper surface of the root, so the root grows downwards.

Auxins are used in agriculture and horticulture:
As weed killers
As rooting powders
For promoting growth in tissue culture

Gibberellins are important in initiating (starting) seed germination.
Gibberellins are used in agriculture and horticulture:
To end seed dormancy
Promote flowering
Increase fruit size

Ethene controls cell division and ripening of fruits.
Ethene is used in the food industry to control ripening of fruit during storage and transport.

56. Adaptation and interdependence

Ecosystem	The interaction of a community of living organisms with the non-living parts of their environment.
Community	A group of species that live in the same place. A change in an abiotic or a biotic factor can affect the community.
Interdependence	Each species in a community depends on other species for food, shelter, pollination, seed dispersal etc. If one species is removed it can affect the whole community.
Stable community	All the biotic and abiotic factors are in balance. Population sizes remain fairly constant.

Adaptation
Organisms have features (adaptations) that enable them to survive in their natural environment.

Adaptations can be:
structural
behavioural
functional

Some organisms are adapted to very extreme environments – high temp, pressure or salt concentration. They are known as **extremophiles** e.g. bacteria in deep sea vents.

57. Competition

To survive and reproduce, organisms require materials – from biotic and abiotic sources.

These materials are limited; this leads to competition between individuals.

Competition in plants
Light
Space
Water
Mineral ions

Competition in animals
Food
Mates
Territory

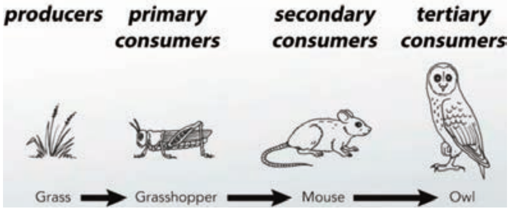
Abiotic factors caused by non-living things:
light intensity
temperature
moisture levels
soil pH
soil mineral content
carbon dioxide (for plants)
oxygen (for aquatic animals)
wind intensity and direction

Biotic factors: caused by living organisms
availability of food
new predators
new pathogens
one species outcompeting another, leaving too few individuals to breed

58. Organisation of an ecosystem

Feeding relationships are shown in food chains.
Every food chain starts with a producer.
Producers synthesise (make) molecules.
Usually, the **producer** is a green plant or alga that makes glucose by photosynthesis.
Photosynthetic organisms are the producers of biomass for life on Earth.

Producers are eaten by **primary consumers.**
Primary consumers may be eaten by **secondary consumers** and then **tertiary consumers.**
In a food chain, the arrow shows the direction of energy or biomass movement – from producer to consumer.



Predators kill and eat other animals.
Animals that are eaten are **prey.**

In a stable community the numbers of predators and prey rise and fall in cycles.

Environmental changes affect the distribution of species in an ecosystem.
These changes include:
temperature
availability of water
composition of atmospheric gases (abiotic factors)

The changes may be seasonal, geographic or caused by human interaction.

59. Trophic levels in an ecosystem

Trophic levels can be represented by numbers, starting at level 1 with plants and algae. Further trophic levels are numbered subsequently according to how far the organism is along the food chain.

Level 1: Plants and algae make their own food and are called producers.

Level 2: Herbivores eat plants/algae and are called primary consumers.

Level 3: Carnivores that eat herbivores are called secondary consumers.

Level 4: Carnivores that eat other carnivores are called tertiary consumers.

Apex predators are carnivores with no predators.

Decomposers break down dead plant and animal matter by secreting enzymes into the environment.

Small soluble food molecules then diffuse into the microorganism.

Pyramids of biomass can be constructed to represent the relative amount of biomass in each level of a food chain.

Trophic level 1 is at the bottom of the pyramid.

Producers are mostly plants and algae which transfer about 1 % of the incident energy from light for photosynthesis.

Only approximately 10 % of the biomass from each trophic level is transferred to the level above it.

Losses of biomass are due to:

Not all the ingested material is absorbed, some is egested as faeces

Some absorbed material is lost as waste, such as carbon dioxide and water in respiration and water and urea in urine.

Large amounts of glucose are used in respiration.

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60. Recycling materials: carbon

All materials in the living world are recycled to provide the building blocks for future organisms. Two examples are the carbon and the water cycle.

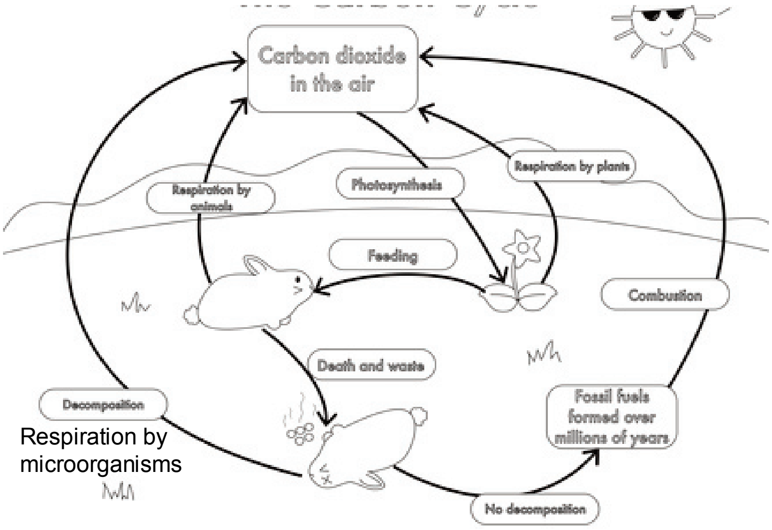
Carbon Cycle

Carbon moves from the atmosphere into organisms through photosynthesis.

It is released from organisms to the atmosphere through respiration.

When living things die and decay, microorganisms (bacteria and fungi) break chemicals down.

They return carbon dioxide to the atmosphere and mineral ions to the soil.



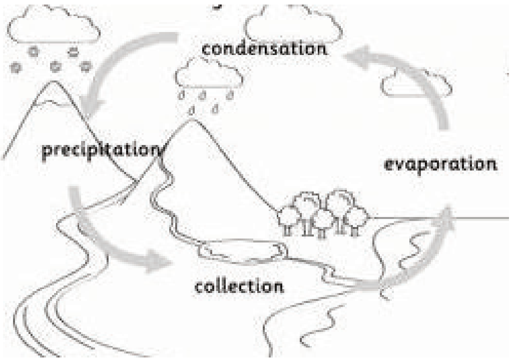
61. Recycling materials: water and decomposition

Water cycle

Rain provides fresh water for plants and animals on land.
The water drains into the sea through rivers.

There is continuous evaporation of water from land and sea.

There is continuous precipitation of water onto the land and into the sea.



Decomposition (Triple only)

Gardeners and farmers try to provide optimum conditions for rapid decay of waste biological material (warmth, oxygen, moisture) to make compost.
The compost is used as a natural fertiliser for growing garden plants or crops.

Anaerobic decay produces methane gas.

Biogas generators can be used to produce methane gas as a fuel.

62. Biodiversity and human interaction 1

Biodiversity: the variety of all the different species of organism on earth, or within an ecosystem.
High biodiversity is good for the stability of ecosystems.
It reduces the dependence of species on one another for food and shelter.
Biodiversity is good for humans too – for food, for medicines, for materials.
Human activities have reduced biodiversity.
Only recently have humans made efforts to stop this reduction.

Pollution is increasing.
There are more humans and an increase in the standard of living, so we are using more resources and producing more waste.
Pollution kills plants and animals; this reduces biodiversity.
Pollution can occur:
In water – from sewage, fertiliser or toxic chemicals
In air – from smoke and acidic gases
On land – from landfill and toxic chemicals

Global warming is happening.
This is the consensus of scientists all over the world, based on thousands of peer-reviewed publications.

We have increased the levels of carbon dioxide and methane in the atmosphere.

Global warming impacts:
loss of habitat
loss of food
the spread of disease

This will lead to extinctions and the loss of biodiversity.

63. Biodiversity and human interaction 2

Land use
Humans use land for building, quarrying, farming and dumping waste.
This reduces the land available for animals and plants.

We have destroyed **peat bogs** to produce cheap compost.
This reduces the habitat and reduces biodiversity. Compost increases food production.
When peat decays or burns, it releases carbon dioxide into the atmosphere.

Deforestation is the reduction in size of forests.
Deforestation is a big problem in tropical areas.
People want the land for cattle and rice fields, and to grow crops for biofuels.

Stopping the decline in biodiversity
There are breeding programmes for endangered species.

Rare habitats are protected and regenerated.

Farmers have reintroduced hedgerows to promote biodiversity.

Some governments have passed laws to reduce deforestation and carbon dioxide emissions.

Some governments have passed laws to increase recycling resources instead of dumping waste in landfill.

64. Food production

Food security is having enough food to feed a population. Sustainable methods must be found to feed all people on Earth.
Biological factors which are threatening food security include:

- the increasing birth rate has threatened food security in some countries
- changing diets in developed countries means scarce food resources are transported around the world
- new pests and pathogens that affect farming
- environmental changes that affect food production, such as
- widespread famine occurring in some countries if rains fail
- the cost of agricultural inputs
- conflicts that have arisen in some parts of the world which affect the availability of water or food.

The **efficiency** of food production can be improved by restricting energy transfer from food animals to the environment. This can be done by limiting their movement and by controlling the temperature of their surroundings**.** Some animals are fed high protein foods to increase growth.

Fish stocks in the oceans are declining. It is important to maintain fish stocks at a level where breeding continues, or certain species may disappear altogether in some areas.
Control of net size and the introduction of fishing quotas play important roles in conservation of fish stocks at a sustainable level.

Modern biotechnology techniques enable large quantities of microorganisms to be cultured for food.
The fungus ***Fusarium*** is useful for producing mycoprotein, a protein-rich food suitable for vegetarians. The fungus is grown on glucose syrup, in aerobic conditions, and the biomass is harvested and purified.
A **genetically modified bacterium** produces human insulin. When harvested and purified this is used to treat people with diabetes.
GM crops could provide more food or food with an improved nutritional value such as golden rice.

65. Variation

There is usually extensive genetic variation within a population of a species.

Variation means differences in the characteristics of individuals in a population.

Causes of variation:
The genes they have inherited (genetic causes)

The conditions in which they have developed (environmental causes)

A combination of genes and the environment.

66. Chromosomes

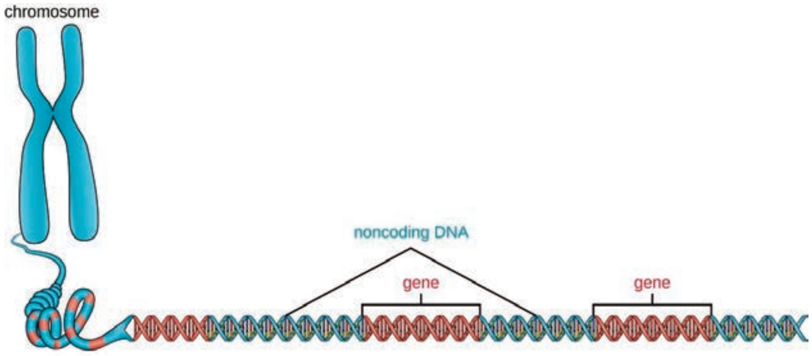
Refer back to paper 1 page 6

A **genome** is the entire genetic material of an organism. The whole human genome has been studied.

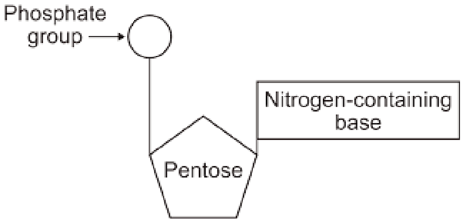
In a eukaryotic cell, genetic material is found in the nucleus, and contained in chromosomes.
Humans have 23 pairs of chromosomes in their body cells.
Genetic material is made of a chemical called DNA.

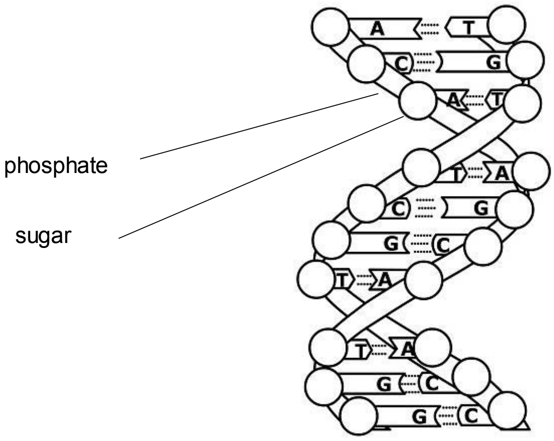
A **gene** is a short section of DNA on a chromosome
A gene codes for a sequence of amino acids, making a specific protein.

Not all parts of DNA code for proteins.
Non-coding parts of DNA can switch genes on and off, so variations in these areas of DNA may affect how genes are expressed.



67. DNA





DNA is a polymer made from four different **nucleotides.**
A **nucleotide** consists of a sugar, a phosphate group and one of four different bases.
The 4 bases are A, C, G and T.

DNA is made of 2 strands of nucleotides wound around each other in a **double helix.**
The long strands of DNA consist of alternating sugar and phosphate sections.
Attached to each sugar is one of the four bases.
In the complementary strands a C is always linked to a G on the opposite strand, and a T to an A.

68. Coding for Proteins

Each sequence of three bases of DNA is the code for a particular amino acid.

The order of bases on the DNA controls the order in which amino acids are assembled to produce a particular protein.

Proteins are synthesised on ribosomes, according to a template.

Carrier molecules bring specific amino acids to add to the growing protein chain in the correct order.

When the protein chain is complete it folds up to form a unique shape.

This unique shape enables the proteins to do their job as enzymes, hormones or forming structures in the body such as collagen.

Mutations
Any errors in the sequence of bases may result in a different protein being assembled.

A **mutation** is a change in the sequence of bases in the DNA.
Mutations occur continuously.
Most do not alter the protein, or only alter it slightly so that its appearance or function is not changed.

A few mutations code for an altered protein with a different shape.

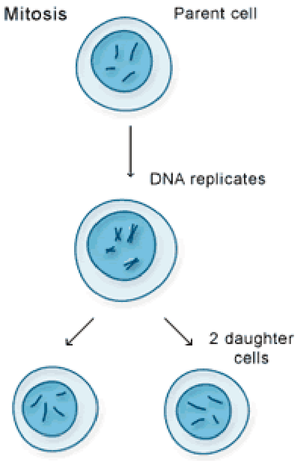
An enzyme may no longer fit the substrate binding site or a structural protein may lose its strength.

69. Cell Division: Mitosis (reminder from paper 1)

Mitosis happens in body cells.

In mitosis, the number of chromosomes remains the same.

Stage of the cell cycle	Events
1	The cell grows. The DNA replicates to form two copies of each chromosome. New mitochondria and ribosomes are made.
2.	**Mitosis**: one set of chromosomes is pulled to each end of the cell. The nucleus divides.
3	The cytoplasm and cell membranes divide. There are now two identical cells.



Uses of cell division by mitosis

1. Growth
2. Repair of tissues
3. Asexual reproduction

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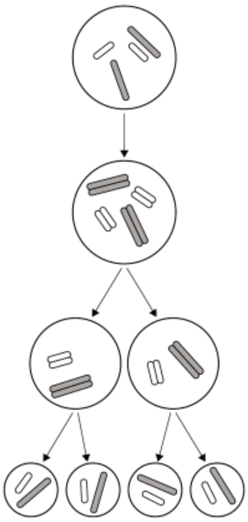
70. Cell Division: Meiosis

Meiosis happens in reproductive organs: ovaries and testes.

In meiosis, the number of chromosomes is halved.

The full number of chromosomes is restored when the male and female gametes fuse during fertilisation.

Stage of the cell cycle	Events
1	The cell grows. The DNA replicates to form two copies of each chromosome. New mitochondria and ribosomes are made.
2.	**Meiosis**: the chromosomes are pulled to opposite poles twice.
3	The cytoplasm and cell membranes divide twice. There are now four genetically different gametes (sex cells) Each gamete has just one set of chromosomes.



At fertilisation

Male and female gametes join.

The new cell has two sets of chromosomes.

The new cell divides by mitosis.

After fertilisation

The cells continue to divide by mitosis.

The cells begin to differentiate.

71. Reproduction: Asexual and Sexual

Asexual reproduction involves only one parent.
There is no fusion of gametes.
There is no mixing of genetic information.
The offspring are genetically identical.
They are clones.
Only mitosis is involved.

Advantages of asexual reproduction (Triple only)
Only one parent is needed
More time and energy efficient as they do not need to find a mate
Faster than sexual reproduction
Many identical offspring can be produced when conditions are favourable

Sexual reproduction involves the fusion of male and female gametes (sex cells)
In animals, these are sperm and egg cells.
In flowering plants, these are pollen and egg cells.
Sexual reproduction involves the mixing of genetic information.
This leads to variety in the offspring.
Gametes are made through **meiosis.**

Advantages of sexual reproduction (Triple only)
Produces variation in the offspring
If the environment changes, variation gives a survival advantage by natural selection
Natural selection can be speeded up by humans in selective breeding to increase food production

Some organisms reproduce by **both methods** depending on the circumstances.
Malarial parasites reproduce asexually in the human host, but sexually in the mosquito.
Many fungi reproduce asexually by spores but also reproduce sexually to give variation.
Many plants produce seeds sexually, but also reproduce asexually by runners such as strawberry plants, or bulb division such as daffodils.

72. Genetic Crosses: definitions and inheritance

Term	Meaning
gene	part of a chromosome that codes for a protein e.g. codes for eye colour
allele	version of a gene e.g. blue eyes, brown eyes
genotype	the alleles that an organism has e.g. AA, Aa or aa
phenotype	the characteristics that an organism has e.g. tall, dimples, red flowers
dominant	A dominant allele is always expressed, even if there is only one copy
recessive	two copies of a recessive allele are required for it to be expressed
homozygous	two of the same alleles for a gene e.g. AA or aa
heterozygous	two different alleles for a gene e.g. Aa

Polydactyly causes extra fingers or toes.
It is caused by a dominant allele.

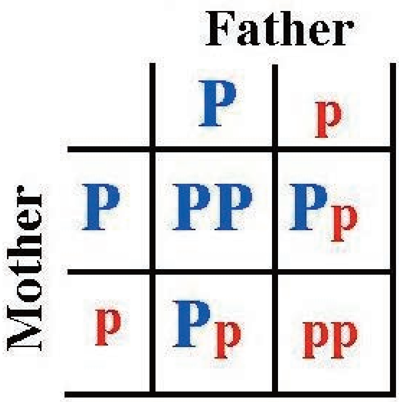
Cystic fibrosis is a disorder of cell membranes, causing mucus to block narrow passages such as the bronchioles.
It is caused by a recessive allele.

Sex determination
Humans have 23 pairs of chromosomes in each nucleus but only one pair determines sex.
Human females have XX.
Human males have XY.

73. Genetic Crosses: Punnett Squares

Parents: Pp x Pp

Gametes: P, p P, p



Father

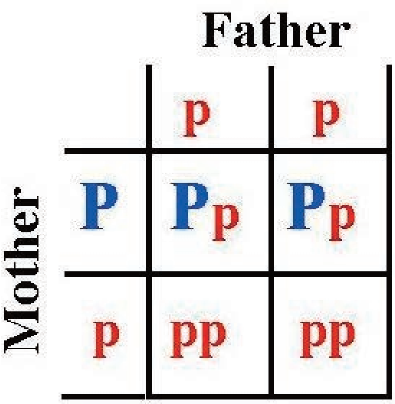
Mother

	P	p
P	PP	Pp
p	Pp	pp

The chance of any one offspring being pp is 1 in 4 or 25%

Parents: pp x Pp

Gametes: p, p P, p



Father

Mother

	p	p
P	Pp	Pp
p	pp	pp

The chance of any one offspring being pp is 50% or 1 in 2

74. Evolution

Evolution is a change in the inherited characteristics of a population over time through a process of natural selection. This may result in the formation of a new species

The theory of evolution by natural selection states that all species of living things have evolved from simple life forms that first developed more than three billion years ago.

Natural Selection

Mutation causes variation in the population

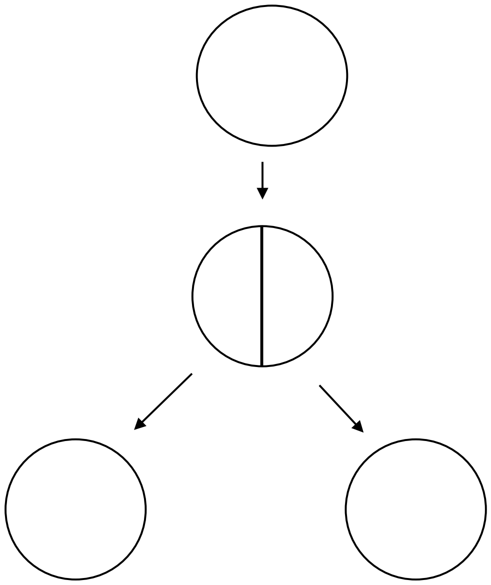
Individuals with characteristics most suited to the environment are more likely to survive to breed successfully.

These characteristics are then passed on to the next generation.

Over many generations, the proportion of the population with this characteristic increases.

75. Speciation

Speciation is the formation of new species.



One population, which can breed together

A new geographical barrier divides the population – the population can no longer breed together.

Natural selection continues in both new populations.
Over many generations the two populations become so different in phenotype, that they can no longer breed together to produce fertile offspring – they have formed two new species.

76. Evidence for evolution: fossils, extinction, resistant bacteria

Charles Darwin was criticised in the 1800s as he didn't have sufficient evidence for his theory of natural selection. There is now lots of evidence for natural selection.

Fossils are evidence for natural selection.
Fossils are the remains of organisms from millions of years ago, found in rocks.
We can learn from fossils about how life changed over time.

Fossils show us that extinctions happen.
Extinction is due to :
New disease
New predator
Climate change
Habitat loss
Single catastrophic events e.g. an asteroid

Formation of fossils:
Replacement of hard parts of organisms with minerals as they decay
Imprints of organisms e.g. footprints, burrows, rootlet traces
Preserved parts of organisms that have not decayed, due to lack of oxygen, water or warmth
Problems with the fossil record
Many early life forms were soft bodied. They have left few traces behind. These have mainly been destroyed by geological activity. So we can't be certain about how life began.

Resistant bacteria are evidence for natural selection
Mutation causes variation in the population – some bacteria are more resistant to antibiotics than others. Resistant bacteria have an advantage as they are less likely to be killed by antibiotics. These individuals survive and reproduce. The genes for the resistance are passed on. The resistant strain becomes more common.
To combat resistant strains:
Doctors should not give antibiotics for mild infections or viral infections
Patients should complete the whole course of antibiotics so all bacteria are killed and none survive to mutate and become resistant
Antibiotics should be used less by farmers in pigs, cows, sheep etc.

77. History of ideas: Darwin and Wallace

Charles Darwin proposed the theory of evolution by natural selection.
He developed his ideas as a result of:

- observations on a round the world expedition
- years of experimentation and discussion
- the developing knowledge of geology and fossils,

Darwin published his ideas in **On the Origin of Species (1859).**
There was much controversy surrounding these revolutionary new ideas.
The theory of evolution by natural selection was only gradually accepted because:
The theory challenged the idea that God made all the animals and plants that live on Earth
There was insufficient evidence at the time the theory was published to convince many scientists
The mechanism of inheritance and variation was not known until 50 years after the theory was published.

Alfred Russel Wallace independently proposed the theory of evolution by natural selection.
He published joint writings with Darwin in 1858 which prompted Darwin to publish On the Origin of Species (1859) the following year.
Wallace worked worldwide gathering evidence for evolutionary theory.
He is best known for his work on warning colouration in animals and his theory of speciation.
Alfred Wallace did much pioneering work on speciation but more evidence over time has led to our current understanding of the theory of speciation.

Other theories, including that of **Jean-Baptiste Lamarck**, are based mainly on the idea that changes that occur in an organism during its lifetime can be inherited.
We now know that in the vast majority of cases this type of inheritance cannot occur.

78. History of ideas: Mendel

In the **mid-19th century Gregor Mendel** carried out breeding experiments on plants.

One of his observations was that the inheritance of each characteristic is determined by ‘units’ that are passed on to descendants unchanged.

Why weren't Mendel's ideas accepted?
The importance of his ideas was not recognised in his lifetime, due to a lack of evidence.

Why were Mendel's ideas accepted?
In the **late 19th century** behaviour of chromosomes during cell division was observed.

In the **early 20th century** it was observed that chromosomes and Mendel’s ‘units’ behaved in similar ways.
This led to the idea that the ‘units’, now called genes, were located on chromosomes.

In the **mid-20th century** the structure of DNA was determined, and the mechanism of gene function worked out.

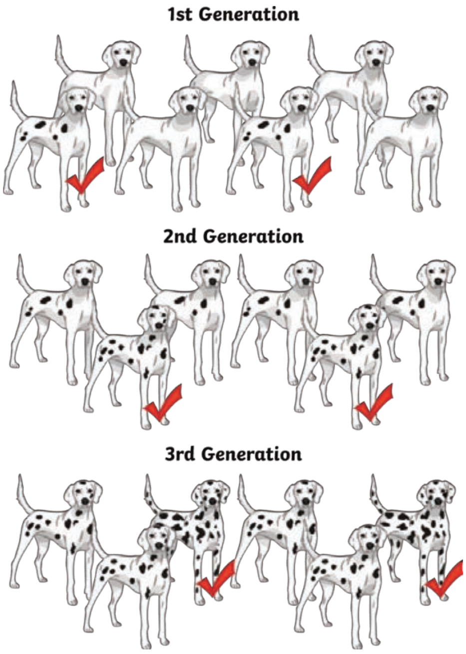
This scientific work by many scientists led to the gene theory being developed.

79. Selective breeding

Selective breeding is the process where humans breed plants and animals for particular characteristics.
People have been doing this for thousands of years to produce food crops and domesticated animals.

Mutations cause variation in the population.
Individuals with a particular characteristic are chosen by humans.
These individuals are allowed to reproduce.
The genes for the characteristic are passed on and become more common over time.

Examples include:
Disease resistance in crops
Animals that produce more meat or milk
Domestic dogs with a gentle nature
Large or unusual flowers

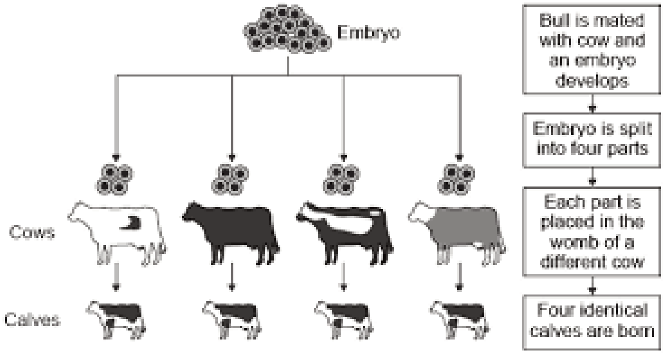


Disadvantages:
Selective breeding can lead to inbreeding.
Some breeds are prone to disease.

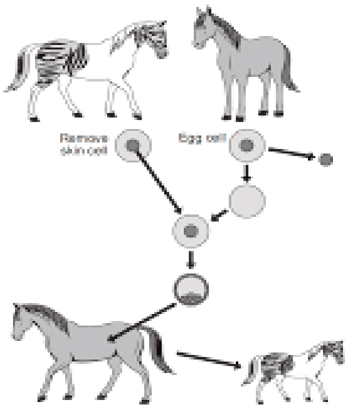
80. Cloning

Tissue culture: small groups of cells from part of a plant are used to grow identical new plants.
This is important for preserving rare plant species or commercially in nurseries.
Cuttings: an older, but simple, method used by gardeners to produce many identical new plants from one parent plant.

Embryo transplants: split apart cells from a developing animal embryo before they become specialised, then transplant the identical embryos into host mothers.



Adult cell cloning:
The nucleus is removed from an unfertilised egg cell.
The nucleus from an adult body cell is inserted into the egg cell.
An electric shock stimulates the egg cell to divide to form an embryo.
These embryo cells contain the same genetic information as the adult skin cell.
When the embryo has developed into a ball of cells, it is inserted into the womb of an adult female to continue its development.



81. Genetic Engineering

Genetic engineering is where a genome of an organism is changed by technology.

A gene is taken from one organism and given to another to produce a desired characteristic.

Examples:

Plants have been genetically engineered to produce a bigger yield and be resistant to disease.

Bacteria have been engineered to produce useful chemicals e.g. insulin.

The method (higher only)

Enzymes are used to cut out the useful gene from one organism.

The useful gene is inserted into a vector

The vector inserts the useful gene into the required cell

This is done at an early stage of development

Objections

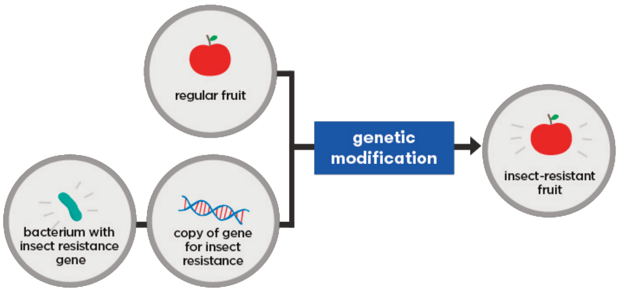
Some people object to genetic engineering.

There may be risks to human health that we don't yet understand.

There may be an effect on wild populations of flowers and insects.

Benefits

Genetic engineering could be used to cure diseases.



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82. Classification

Classification

Originally **Carl Linnaeus** classified organisms by their structure and characteristics into the following system:

Animal Example	Taxonomic Rank
Animalia	**Kingdom**
Chordata	**Phylum**
Mammalia	**Class**
Primate	**Order**
Hominidae	**Family**
Homo	**Genus**
sapiens	**Species**
Human	Common Name

The genus and the species gives the binomial name, e.g. *Homo sapiens*

The genus always starts with a capital letter, and the species with a small case letter.

Our understanding of internal structures, biochemistry and genetics meant that some organisms were reclassified.

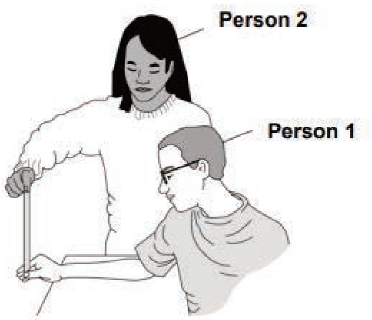
Three new groups called domains were proposed by **Carl Woese.**

Archaea – bacteria living in extreme environments

Bacteria – true bacteria

Eukaryota – animals, plants, fungi and protists.

83. Required Practical 6 – Human Reaction Time



Plan and carry out an investigation into the effect of a factor on human reaction time.

IV: number of times a ruler is dropped

DV: measuring the distance where it is caught (we get faster, up to a point)

CV: same person

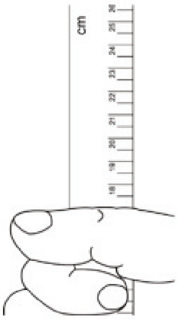
CV: same hand

CV: rest elbow on the table

CV: hold ruler in same position

Method

1. Place your weakest hand on a table with your hand over the edge.
2. Your partner holds a metre ruler at 0 cm above your hand so the top of your thumb is at the zero mark.
3. Without any notice, your partner drops the ruler and you catch it.
4. Read metre ruler from the top of the thumb.
5. Repeat steps 1-4 four more times.
6. Convert the distance on the ruler into reaction time in seconds using a table of data.



To improve the method

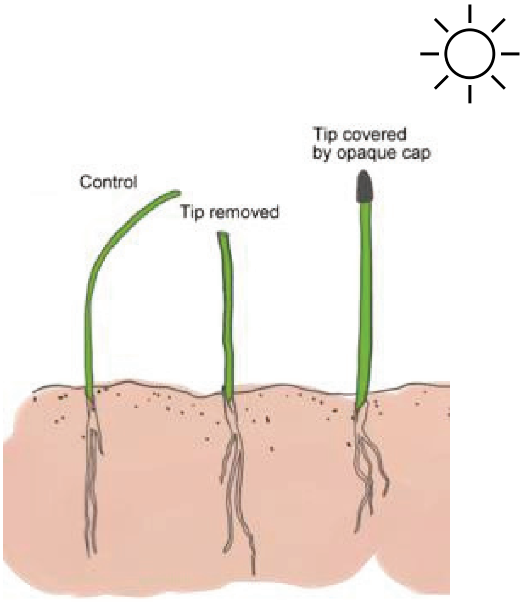
- To be more confident of the results, carry out 3 replicates on different people to identify anomalies; remove any anomalous results; calculate a mean.
- Use a computer to give a more precise reaction time because they remove the possibility of human error and it is more accurate.

84. Required Practical 7 – Plant Responses

Investigate the effect of light or gravity on the growth of newly germinated seedlings.

Set up the three groups of seedlings as follows:

1. Carefully remove the tip using the fine dissecting scissors
2. Carefully cover the tip with foil
3. Leave the seedling alone (control).
4. Place a light source to one side of the shoots, water the plants and leave for a few days.
5. Record the angle of growth away from the vertical.



Rules for biological drawings:

Sharp pencil

Label lines (no arrow heads) touch object and drawn with a ruler

Add a scale bar

Add annotation

No shading or colour

85. Required Practical 8 - Decay

Investigate the effect of temperature on the rate of decay of fresh milk by measuring pH change.

IV: temperature

DV: time for pH to change

CV: milk volume

CV: bile salts volume and concentration

CV: sodium carbonate solution volume and concentration

CV: number of drops of indicator

CV: lipase solution volume and concentration

Method

1. Add 20 cm^3 of milk to a beaker.
2. Using a clean measuring cylinder, add 5 cm^3 of bile salts solution.
3. Using a clean measuring cylinder, add 10 cm^3 of sodium carbonate solution.
4. Add 10 drops of phenolphthalein to the beaker, the mixture should be pink.
5. Put the beaker into a water bath at 20^{o}C and stir. Leave for 5 minutes for the beaker to reach the correct temperature.
6. Add 5 cm^3 lipase solution and start the stop clock.
7. Stir the contents of the beaker until the mixture loses the pink colour. At this point the mixture has become acidic.
8. Record how long it takes the pink colour to go.
9. Repeat steps 1 to 8 at 30^{o}C, 40^{0}C, 50^{0}C, 60^{0}C
10. Record the results in a suitable results table

Problems with the design of the method

The main problem will be maintaining the temperature.

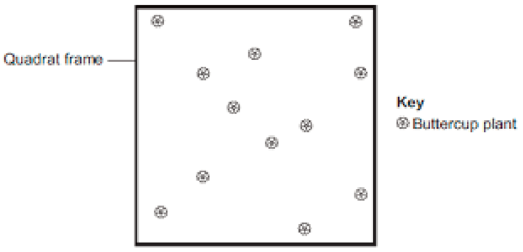
To improve the method

Several repeats are needed so that anomalies can be identified.

86. Required Practical 9 – Field Investigations 1

Measure the population size of a common species in a habitat.
Use sampling techniques to investigate the effect of a factor on the distribution of this species.

Quadrats are square shapes that are placed on the ground; the numbers of organisms in the square can be counted.
Transects are lines that are placed on the ground; quadrats can be placed at regular intervals along the transect to find out if the number of organisms changes along the line.



Method to estimate population size

1. Choose one area to investigate.
2. Divide the area into an imaginary grid.
3. Use a random number generator to select points in the area e.g. 4m in one direction, and 3m at right angles to this point.
4. Place the quadrat down so that the left-hand bottom corner is on the identified point.
5. Count the number of dandelion plants in the quadrat.
6. Record the number in your results table.
7. Repeat at least 10 times.
8. Calculate the mean number of dandelions per quadrat.
9. Calculate the total area of the field.
10. Divide the area by the area of one quadrat, then multiply this number by the mean number of dandelions per quadrat.

To improve the method

Dependent on random sampling, so will be more valid if more quadrats are used, or larger quadrats are used.
Repeat at different times of the year.

87. Required Practical 10 – Field Investigations 2

Use sampling techniques to investigate the effect of a factor on the distribution of this species.

Quadrats are square shapes that are placed on the ground; the numbers of organisms in the square can be counted.

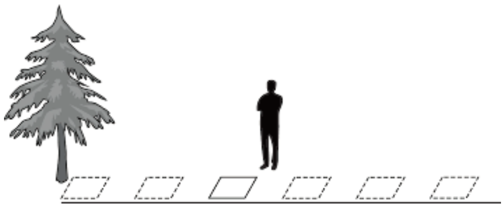
Transects are lines that are placed on the ground; quadrats can be placed at regular intervals along the transect to find out if the number of organisms changes along the line.

IV: light intensity

DV: number of daisies per quadrat

CV: size of quadrat

CV: sample every 1m along transect



Method to investigate the effect of light intensity

1. Choose two areas where dandelions grow; one in a sunny area and one in the shade.
2. Measure the light intensity in the sunny area.
3. Put down a transect line in the sunny area – do not look at the grass as you lay the line down.
4. Place the quadrat down next to the line at the start.
5. Count the number of dandelion plants in the quadrat.
6. Record the number in your results table.
7. Move the quadrat 1m further along the transect and repeat at least 8 times.
8. Repeat in the shady area.

Problems with the design of the method

Other variables are not controlled in this method. The soil pH, temperature, water availability and trampling may all affect the distribution of plants.

To improve the method

Complete three transects in each area.

Record observations.

Repeat at different times of the year.

---

88. Maths in Science 1

Anomalous result	A number that does not fit the pattern
Mean	Adding up a list of numbers and dividing by how many numbers are in the list. Exclude the anomalous result.
Median	The middle value when a list of numbers is put in order from smallest to largest
Mode	The most common value in a list of numbers. If two values are tied then there are two modes. If more than two values are tied then there is no mode.
Range	The largest number take away the smallest value in a set of data or written as X-Y.
Uncertainty	range ÷ 2
Surface area of a cube	(area of 1 side) x 6 sides
Volume of a cube	Width x height x depth
Area of a circle	∏ x (radius)^2

Prefixes

1 kJ = 1 x 10^3 J = 1000 J

1 pm = 1 x 10^{-12} m

1 mm = 1 x 10^{-3} m= 0.001 m

kilo	10 ^{3}
centi	10 $^{-2}$
milli	10 $^{-3}$
micro	10 $^{-6}$
nano	10 $^{-9}$
pico	10 $^{-12}$

5607.376

Standard form: 5.607 x 10^3

2 decimal places: 5607.38

3 significant figures: 5610

0.03581

Standard form: 3.581 x 10^{-2}

2 decimal places: 0.04

3 significant figures: 0.0358

89. Maths in Science 2

Calculating percentage: (part ÷ whole) x 100

e.g. Out of 90 insects, 40 of them were ladybirds. What is the % of ladybirds?

(40 ÷ 90) x 100 = 44 %

Calculating percentage change:

(difference ÷ starting value) x 100

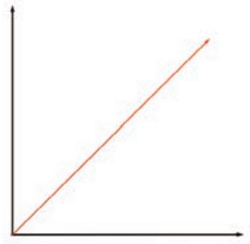
(0.59 ÷ 2.22) x 100 = 26.6 %

Conc of Sucrose (M)	**Mass of potato at start (g)**	**Mass of potato at end (g)**	**Change in mass (g)**
0	2.22	2.81	0.59

Graphs

Proportional (α)

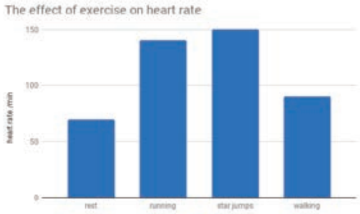
When the line passes through the origin



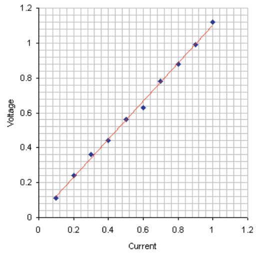
x axis = independent variable = left hand column of results table

y axis = dependent variable = right hand column of results table

Categoric data: data put into groups e.g. colour of eyes
Draw a bar chart

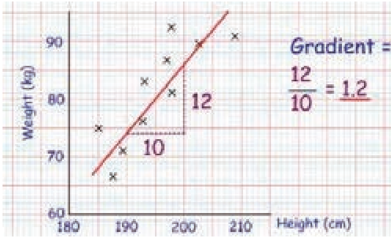


Continuous data: data that can take any value e.g. current
Draw a line graph



Gradient and Graphs

Gradient = $\frac{\text{Change in y}}{\text{Change in x}}$



Chemistry Paper 1 (Triple)

CONTENTS

1. Atoms, Elements, Compounds and Mixtures

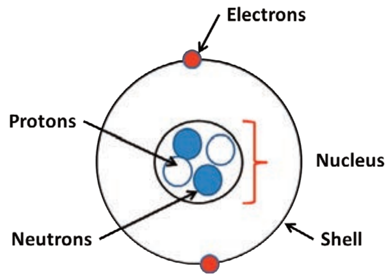
Keyword	Definition
Atom	smallest part of an element
Element	made up of only one type of atom
Compound	made from at least two elements, chemically combined
Mixture	made of two or more elements or compounds not chemically combined together

Radius of an atom = 0.1nm (1 x 10^{-10}m).

Radius of a nucleus is less than 1/10 000 of that of an atom.
This is 1 x 10^{-14}m.

Atoms are **neutral** (no electrical charge) because: -The number of protons and electrons are the same. -The charges cancel out
Atomic number = Proton number
Mass number = Number of protons and neutrons
Number of electrons = Number of protons

Structure of the atom (Nuclear model)



Subatomic particle	Relative charge	Relative mass
Proton	+1	1
Neutron	0	1
Electron	-1	1/1840

2. Structure of the Atom

7 **Top number**
Li
3 **Bottom number**

Proton = bottom number
Electron = bottom number
Neutron = top number – bottom number

Electronic Configuration

Electrons are arranged in shells.
1st shell – maximum of 2 electrons
2nd shell – maximum of 8 electrons
3rd shell – maximum of 8 electrons

Isotopes:

Atoms of the same element that have different numbers of neutrons but the same number of protons and electrons.

They have the same chemical properties but different physical properties.

$^{39}_{18}Ar$	$^{38}_{18}Ar$
18 protons 18 electrons 21 neutrons	18 protons 18 electrons 20 neutrons

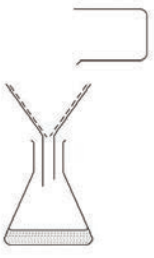
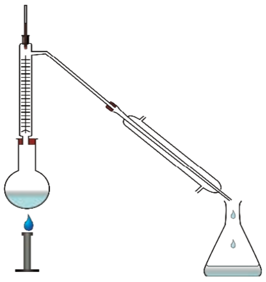
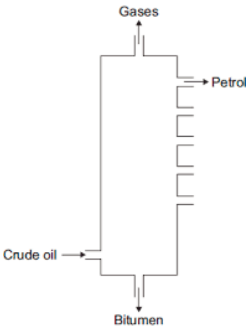
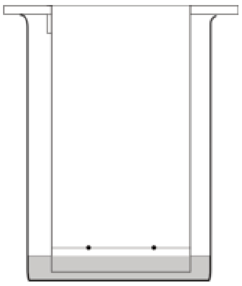
Calculating Relative Isotopic Abundance

Mass number	Abundance (%)
39	93.1
41	6.9

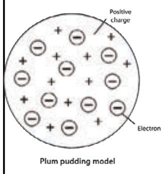
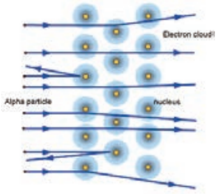
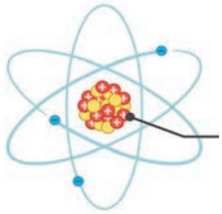
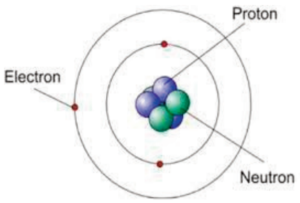
$$= \frac{(39 \times 93.1) + (41 \times 6.9)}{93.1 + 6.9}$$

$$= 39.1$$

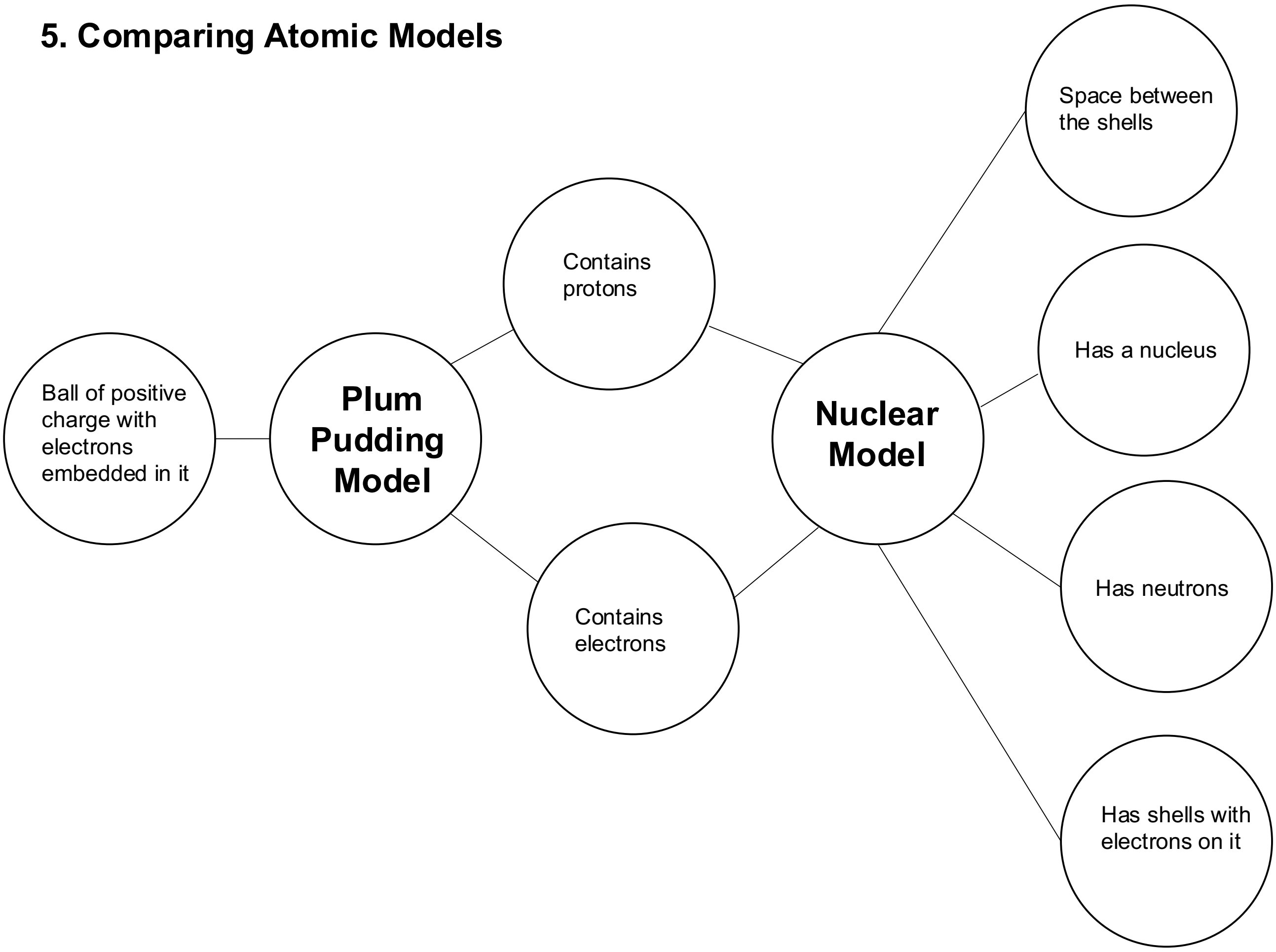
3. Separating Mixtures

Process	**Filtration**	**Distillation**	**Fractional distillation**	**Chromatography**
Diagram				
Physical property	Difference in solubility	Difference in boiling points	Difference in boiling points	Difference in solubility
Example	Sand and salt	Ink and water	Ink, water and oil Crude oil	Different colours in dyes

4. History of the Atom

Atomic model	**Plum pudding model**		**Nuclear model**		
Diagram					
Discovery	Electron	Positive nucleus in the centre of the atom	Electrons occupy shells Electrons are at specific distances from the nucleus	Neutrons	- Atomic radius: 1×10^{-10} m - Radius of a nucleus is less than 1/10 000 of the radius of an atom. - Most of the mass of an atom is concentrated in the nucleus. - The electrons are arranged at different distances from the nucleus.
Description	The atom is a ball of positive charge with negative electrons embedded in it.	Positively charged alpha particles were fired at thin gold foil. Most alpha particles went straight through the foil. A few were scattered in different directions by the atoms in the foil. It showed that the mass of an atom was in the centre (the nucleus) and the nucleus was positively charged.		Proved the existence of isotopes	
Discovered by	Thompson	Rutherford	Bohr	Chadwick	

5. Comparing Atomic Models



6. Ionic and Covalent Bonding

Ionic Bonding (metal & non-metal)

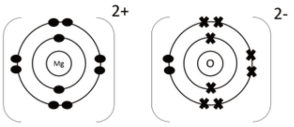
Structure: Giant ionic lattice

Electrons are lost or gained to achieve a full outer shell.

Ionic bond: Electrostatic attraction between oppositely charged ions.

Ions held in a fixed lattice.

Charge of ion: +2 (loses 2 electrons) and -2 (gains 2 electrons)



Describing the formation of an ionic compound

Example 1: NaF

Na atom loses 1 electron to form Na^{1+} ion.

F atom gains 1 electron to form F^{1-} ion

Example 2: Na_2O

Two Na atoms each lose 1 electron to form two Na^{1+} ions.

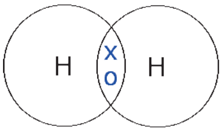
One O atom gains 2 electrons to form O^{2-} ion.

Covalent Bonding (2 x non-metals)

Covalent bond: Pairs of electrons are shared between the atoms.

Sharing one pair of electrons = single bond

Sharing two pairs of electrons = double bond



Simple Molecules

(2 x non-metals, covalent bonding)

Simple molecules (small molecules)

e.g. H_2, Cl_2, O_2, N_2, HCl, H_2O

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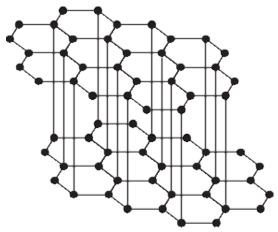
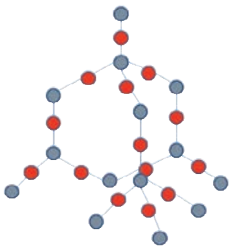
7. Giant Covalent Bonding

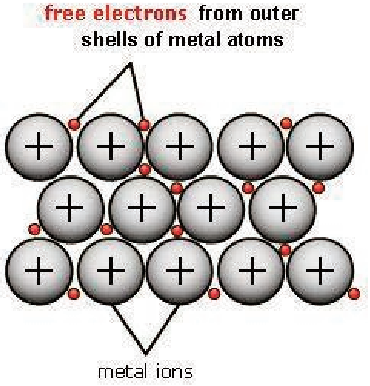
	Diamond	**Graphite**	**Silicon dioxide**
Bonding	Giant covalent	Giant covalent	Giant covalent
Made of	Carbon	Carbon	Silicon and oxygen
Structure	Each carbon atom forms four C-C covalent bonds.	Each carbon atom forms three covalent bonds with three other carbon atoms, forming layers of hexagonal rings . The 4th electron is delocalised	Each silicon atom forms four covalent bonds with oxygen atoms
Diagram			

8. Metallic Bonding and Alloys

Metallic Bonding

Metallic bond: Attraction between the positive metal ion and delocalised electrons.

Structure: Layers of metal positive ions surrounded by delocalised electrons

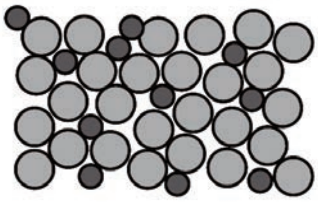


Alloy

Mixtures of metals with metals or a non-metal

e.g. stainless steel is a mixture of iron and carbon

Structure: Irregular layers



9. Quantitative Chemistry

Relative formula mass (RFM or M_r)

This is the mass in grams of 1 mole of the substance.

To calculate M_r (top number) you need to add up the atomic mass (Ar) of all of the atoms in the molecule.

Example1. NaCl = Na + Cl = 23 + 35.5 = 58.5

Example 2. $MgF_2 = Mg + (2 \times F) = 24 + (2 \times 19) = 62$

% Mass of an Element in a compound

$$\text{\% mass of an element} = \frac{\text{Atomic mass of element x number of atoms}}{\text{Relative formula mass of compound}} \text{ X } 100$$

Remember: $\frac{\text{part}}{\text{whole}} \times 100$

Conservation of Mass

During a chemical reaction, no atoms are made, no atoms are destroyed.

Decrease in mass:

$CaCO_3\,(s) \longrightarrow CaO\,(s) + CO_2\,(g)$

Carbon dioxide is a gas which is a product

Carbon dioxide escapes into the air.

Increase in mass:

$2Mg(s) + O_2\,(g) \longrightarrow 2MgO\,(s)$

Mg reacts with oxygen in the air

Oxygen has added to the magnesium

Concentration of a solution

$$\text{dm}^3 \xrightleftharpoons[\div 1000]{\text{X } 1000} \text{cm}^3$$

Concentration (g/dm^3) = mass (g) ÷ volume (dm^3)

10. Acids and Alkalis

Acid	Chemical formula
Sulfuric acid	H_2SO_4
Nitric acid	HNO_3
Hydrochloric acid	HCl

Alkali	Chemical formula
Sodium hydroxide	NaOH
Potassium hydroxide	KOH

Acid	Salt name ending
Hydrochloric	-chloride
Nitric acid	-nitrate
Sulfuric	-sulfate

The pH Scale

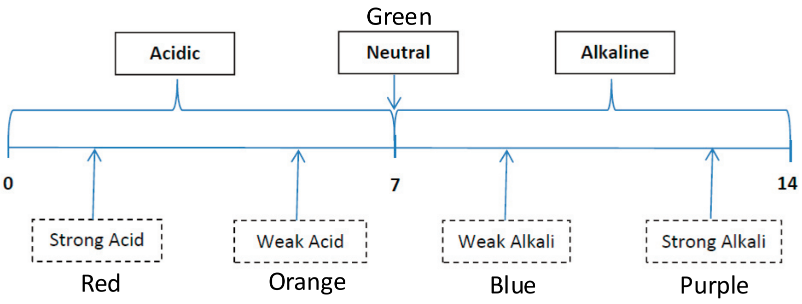
It can be measured with a pH probe, or universal indicator.

Acid: pH 0-6

Neutral: pH 7

Alkali: pH 8-14

The pH Scale



Neutralisation

Acids contain hydrogen ions (H^+)

Alkalis contain hydroxide ions (OH^-)

acid + alkali → water

Ionic equation: H^+ (aq) + OH^- (aq) → H_2O (l)

11. Reactions of Acids to Make a Salt (Neutralisation)

Reaction 1	**Reactions of Acids with Metals (Neutralisation)**
Rule	acid + metal → salt + hydrogen
Example	hydrochloric acid + magnesium → magnesium chloride + hydrogen

Reaction 2	**Reactions of Acids with Metal Oxide (Neutralisation)**
Rule	acid + metal oxide → salt + water
Example	sulfuric acid + magnesium oxide → magnesium sulfate + water

Reaction 3	**Reactions of Acids with Metal Hydroxide (Neutralisation)**
Rule	acid + metal hydroxide → salt + water
Example	nitric acid + magnesium hydroxide → magnesium nitrate + water

Reaction 4	**Reactions of Acids with Metal Carbonate (Neutralisation)**
Rule	acid + metal carbonate → salt + water + carbon dioxide
Example	nitric acid + magnesium carbonate → magnesium nitrate + water + carbon dioxide

12. Strong and Weak Acids

Strong acid

Completely ionised (breaks down) in aqueous solution.

$HCl \rightarrow H^+ + Cl^-$

Examples: Hydrochloric acid (HCl), nitric acid (HNO_3) and sulfuric acid (H_2SO_4).

Lower pH numbers (pH 1-3)

The stronger the acid, the more it ionises in solution, and the more hydrogen ions there are in the solution.

Concentrated acid

More hydrogen ions (H^+) per volume

Weak acid

Partially ionised (breaks down) in aqueous solution.

$CH_3COOH \rightarrow CH_3COO^- + H^+$

Examples: Ethanoic acid, citric acid and carbonic acid.

Higher pH numbers (pH 4-6)

pH

If the hydrogen ion concentration in a solution increases by a factor of 10, the pH of the solution decreases by 1.

Volume of acid (cm^3)	pH
10	3
1000	5

13. Energy Changes

Exothermic Reaction. Energy is transferred from particles to the surroundings. Temperature increases.

Examples: Combustion, many oxidation reactions, neutralisation.

Every day uses: self-heating cans and hand warmers.

Endothermic reaction. Energy is transferred from the surroundings to the particles. Temperature decreases.

Example: Thermal decomposition and the reaction between citric acid and sodium hydrogencarbonate.

Every day uses: sports injury packs.

Activation energy: minimum amount of energy required for the reaction to start.

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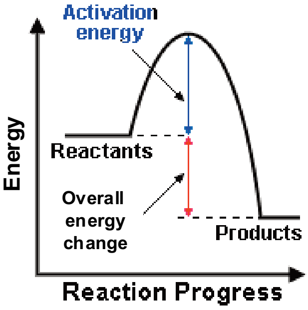
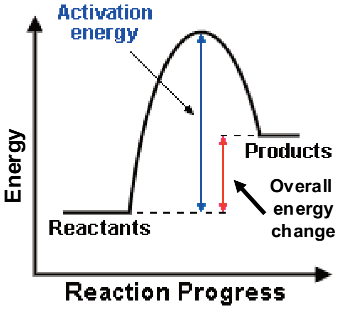


Exothermic reaction



Endothermic reaction

Exothermic energy profile:

Reactants are **higher** in energy than the products.

Energy is released to the surroundings.

.

Endothermic energy profile:

Reactants are **lower** in energy than the products.

Energy is absorbed by the surroundings.

.

14. Calculating Bond Enthalpy

Energy IN
Total energy needed to break the bonds in the reactants

—

Energy OUT
Total energy needed to form the bonds in the products

=

Energy CHANGE
Overall energy change

Exothermic reaction.

Negative value

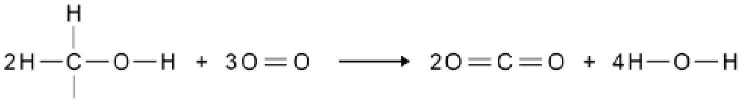
Total energy needed to break the bonds in the reactants ≪ Total energy needed to form the bonds in the products

Endothermic reaction.

Positive value.

Total energy needed to break the bonds in the reactants ≫ Total energy needed to form the bonds in the products

	C–H	C–O	O–H	O=O	C=O
Bond energy in kJ / mol	412	360	464	498	805



$$\mathrm{2H{-}\overset{H}{\underset{H}{C}}{-}O{-}H + 3O{=}O \longrightarrow 2O{=}C{=}O + 4H{-}O{-}H}$$

6 x (C-H) = 6 x 412 = 2472
2 x (C-O) = 2 x 360 = 720
2 x (O-H) = 2 x 464 = 928
3 x (O=O) = 3 x 498 = 1494
TOTAL = 5614

4 x (C=O) = 4 x 805 = 3220
8 x (O-H) = 8 x 464 = 3712
TOTAL = 6932

5614 – 6932= -1318

15. The Development of the Periodic Table

Newland's Periodic Table	**Similarities**	**Mendeleev's Periodic Table**
Included only the elements known at the time	Ordered elements by atomic **weight**	Left gaps for elements he predicted would be discovered later so that elements can be placed together
Maintained a strict order of atomic weights	Missing noble gases because they are unreactive so not discovered until later	Swapped the order of some elements if that fitted their properties better e.g. Te and I
Mendeleev's version was **accepted** because: -he predicted properties of missing elements -the elements discovered filled the gaps -the properties matched Mendeleev's predictions		

Modern Periodic Table

It is called a **Periodic Table** because similar properties occur at regular intervals

Elements arranged in order of atomic **number** (proton number)

Groups (columns): Elements with similar chemical properties

Group number = number of outer shell electrons = similar chemical properties

Period (row): Elements have the same number of shells

16. Chemical Formulae

Group number	Charge of ion formed
1	+1
2	+2
3	+3
5	-3
6	-2
7	-1

Name of ion	Chemical formula of ion
Sulfate	$SO_4{}^{2-}$
Hydroxide	OH^{1-}
Ammonium	$NH_4{}^{1+}$
Nitrate	$NO_3{}^{1-}$
Carbonate	$CO_3{}^{2-}$

How to deduce chemical formulae

	Mg^{2+}	**Br^{1-}**
Identify the number	2	1
Swap the numbers	1	2
Chemical formula	$Mg\ Br_2$	

	$NH_4{}^{1+}$	**$SO_4{}^{2-}$**
Identify the number	1	2
Swap the numbers	2	1
Chemical formula	$(NH_4)_2SO_4$	

Chemical Formulae

NaCl – 1 x Na atom and 1 x Cl atom

H_2O – 2 x H atoms and 1 x O atom

$Mg(OH)_2$ – 1 x Mg atom, 2 x O atoms and 2 x H atoms

$CaCO_3$ – 1 x Ca atom, 1 x C atom and 3 x O atoms

17. Reactions of Group 1, Group 7 and Group 0

	Group 1	**Group 7**	**Group 0**
Name	Alkali Metals	Halogens (non-metal)	Noble gases
Reactivity	Increases down the group	Decreases down the group	Unreactive (inert). Full outer shell of electrons
Reactivity explanation	-more shells -outer electron is further away from the nucleus -less nuclear attraction between the nucleus and the outer electron -electron is lost more easily	-more shells -outer electron is further away from the nucleus -less nuclear attraction between the outer electron and the nucleus -electron is gained less easily	Already has a full outer shell of 8 electrons (except helium which has 2). No need to react.
Trend in melt. pt.	Decreases	Increases	Increases
Explanation for trend in melting point		-molecules increase in size -intermolecular forces increase -more energy is required	-atoms increase in size -intermolecular forces increase -more energy is required
Reactions	**Reaction with oxygen:** $4M + O_2 \rightarrow 2M_2O$	**Displacement:** A more reactive halogen can displace a less reactive halogen from its salt e.g. $2KBr + Cl_2 \rightarrow 2KCl + Br_2$ Chlorine more reactive than bromine. Displacement occurs. $2KBr + I_2 \rightarrow$ no reaction Iodine cannot displace bromine	
	Reaction with chlorine: $2M + Cl_2 \rightarrow 2MCl$ Vigorous reaction Na = silver solid; Cl_2 = green gas Reaction = orange flame Product = white solid NaCl produced		
	Reaction with water: $2M + 2H_2O \rightarrow 2MOH + H_2$ Hydroxide ions (OH^-) make solutions alkali. Metal floats and moves. Effervescence.		

18. Reactivity of Metals

Oxidation and Reduction (adding and losing oxygen)

Oxidation: When the metal gains oxygen to become a metal oxide.

Reduction: When the metal oxide loses oxygen to become a metal.

The Reactivity Series

- Potassium
- Sodium
- Calcium
- Magnesium
- Aluminium

Extracted by electrolysis of a molten ionic compound

- Carbon
- Zinc
- Iron
- Tin
- Lead
- Hydrogen
- Copper

Extracted from its oxide by reduction using carbon

- Silver
- Gold
- Platinum – least reactive

Extraction of metals

Metals above carbon in the reactivity series: Extracted by electrolysis

Metals below carbon: Extracted from their oxides by reduction with carbon.

iron oxide + carbon → iron + carbon dioxide

The iron has been **reduced** – it has lost oxygen. The carbon has been **oxidised**.

Silver, gold and platinum: Found in the Earth as the metal itself because they are unreactive.

Oxidation and Reduction (adding and losing electrons)

Oxidation: Loss of electrons.

Reduction: Gain of electrons.

Remember **OIL RIG**

For example:

$$Fe^{2+} + 2e^{-} \rightarrow Fe$$

The iron ion gains two electrons and becomes an iron atom.

The iron has been reduced – it has gained two electrons.

Redox: When oxidation and reduction occur at the same time

$$Cu + 2Ag^{+} \dashrightarrow Cu^{2+} + 2Ag$$

Cu has been oxidised – lost 2 electrons

Ag has been reduced – gained 1 electron for each Ag ion

19. Properties of Ionic Compounds and Simple Molecules

Property of Ionic Compounds	Explanation
High melting point	Giant ionic structure. Lots of energy needed to break strong electrostatic attraction between oppositely charged ions.
Conducts electricity in solution/molten (liquid)	Ions are mobile and carry charge.
Does not conduct electricity as a solid	Ions are in a fixed lattice. Ions are not mobile so cannot carry a charge

Simple Molecules

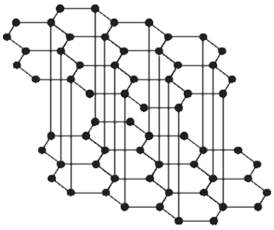
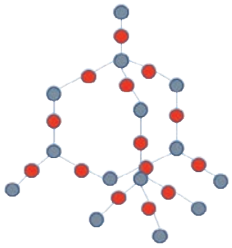
(2 x non-metals, covalent bonding)

Simple molecules (small molecules)

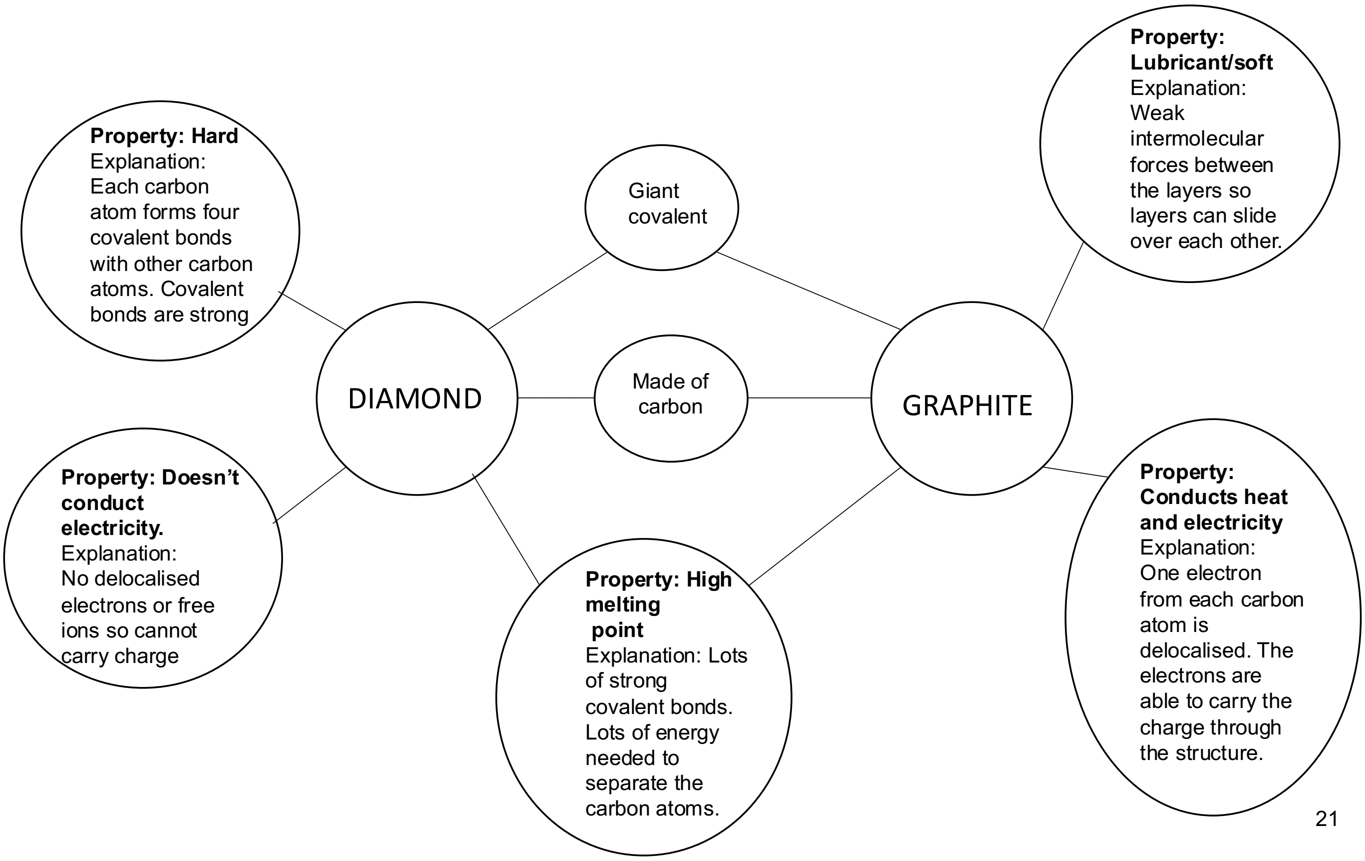
e.g. H_2, F_2, Cl_2, O_2, N_2, HCl, H_2O, CO_2

Property of Simple Molecules	Explanation
Low melting points and boiling points. (Gas at room temperature)	-Simple molecule -Weak intermolecular forces between the molecules. -Little energy needed to overcome these forces.
Does not conduct electricity	Molecules do not have any mobile ions or delocalised electrons

20. Structure of Giant Covalent Substances

	Diamond	**Graphite**	**Silicon dioxide**
Bonding	Giant covalent	Giant covalent	Giant covalent
Made of	Carbon	Carbon	Silicon and oxygen
Structure	Each carbon atom forms four C-C covalent bonds.	Each carbon atom forms three covalent bonds with three other carbon atoms, forming layers of hexagonal rings . The 4th electron is delocalised	Each silicon atom forms four covalent bonds with oxygen atoms
Diagram			

21. Comparing Properties of Giant Covalent Substances: Diamond and Graphite



Property: Hard
Explanation:
Each carbon atom forms four covalent bonds with other carbon atoms. Covalent bonds are strong

Giant covalent

Property: Lubricant/soft
Explanation:
Weak intermolecular forces between the layers so layers can slide over each other.

DIAMOND

Made of carbon

GRAPHITE

Property: Doesn't conduct electricity.
Explanation:
No delocalised electrons or free ions so cannot carry charge

Property: High melting point
Explanation: Lots of strong covalent bonds. Lots of energy needed to separate the carbon atoms.

Property: Conducts heat and electricity
Explanation:
One electron from each carbon atom is delocalised. The electrons are able to carry the charge through the structure.

22. Nanoparticles

Nanoparticles

Nanoparticles are bigger than an atom.

Nanoparticles have different properties due to a **higher surface area to volume ratio.**

Advantage: smaller quantities are needed which reduces cost.

Uses: medicine for controlled drug delivery and in synthetic skin, in electronics and in cosmetics and sun creams (better coverage and prevents cell damage)

Surface area: Volume ratio

Calculation of surface area of a cube: area of cube face x 6

Calculation of volume: width x depth x height

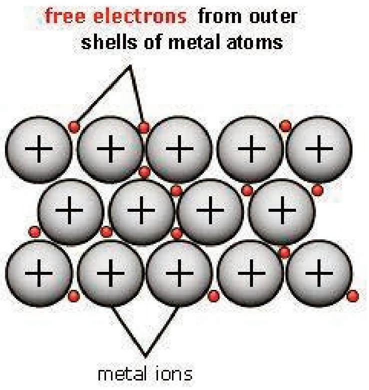
Graphene	
Single layer of graphite. Made of carbon atoms. One atom thick	
Structure	Each carbon atom forms three covalent bonds with three other carbon atoms, forming layers of hexagonal rings . The 4th electron is delocalised and carries the charge through the structure.
Property & Explanation	Conducts heat and electricity **Explanation**: One electron from each carbon atom is delocalised. The electrons are able to carry the charge through the structure.
Property & Explanation	High melting point **Explanation**: Lots of strong covalent bonds. Lots of energy needed to separate the carbon atoms.

23. Structure of Metals and Alloys

Metallic Bonding

Metallic bond: Attraction between the positive metal ion and delocalised electrons.

Structure: Layers of metal positive ions surrounded by delocalised electrons

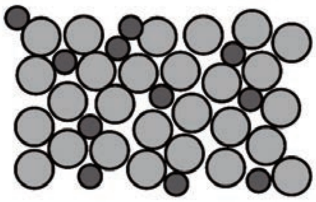


Alloy

Mixtures of metals with metals or a non-metal

e.g. stainless steel is a mixture of iron and carbon

Structure: Irregular layers



24. Properties of Metallic Bonding and Alloys

Property of metals	Explanation
Conduct electricity	Delocalised electrons are free to move and carry the charge through the metal.
Conducts thermal energy	Delocalised electrons move Energy transferred through the structure
Strong **High melting point**	Strong attraction between the metal positive ion and the delocalised electrons, so lots of energy needed to overcome attraction
Bent and shaped (malleable)	Layers of atoms are able to slide over each other.

Property of alloys	Explanation
Harder than pure metals	The atoms are different sizes. Layers are distorted and cannot easily slide over each other.
Does not conduct as well as pure metals	Alloys have different sized atoms and distort the layers Movement of delocalised electrons is restricted

25. Polymers

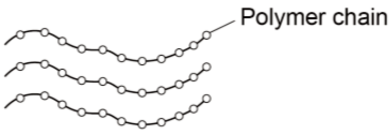
Keyword	Definition
Monomer	Made of a C=C bond. An alkene
Polymers	Large molecules linked to other atoms by strong covalent bonds.
n	Number of monomers/repeating units
Polymerisation	The C=C double bond in the monomer breaks open. Many monomers join together to form a long chain molecule (polymer.

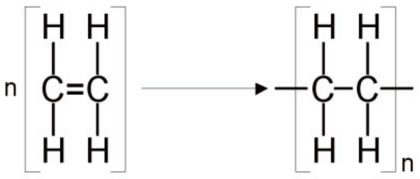
Property of polymers	Explanation of property
Solid at room temperature/ High melting point	The intermolecular forces between polymer molecules are relatively strong. Lots of energy needed to break bonds.

Structure and bonding in a polymer chain

Strong covalent bonds between the atoms

Weak intermolecular forces between the chains



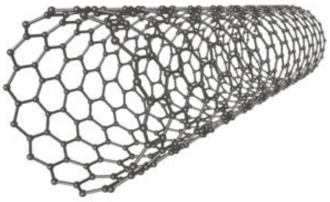


Name of monomer	Name of polymer
Vinyl chloride	Polyvinyl chloride
Styrene	Polystyrene
Ethene	Polyethene

26. Fullerenes and Transition Metals

Fullerenes

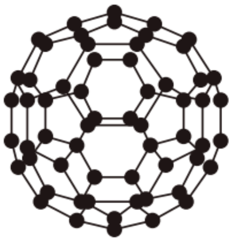
Fullerenes are molecules of carbon atoms with hollow shapes based on hexagonal rings of carbon atoms.



Properties: High tensile strength, electrical conductivity and conducts heat.

Uses:
Drug delivery into the body as it has a hollow structure.
Lubricants
Catalysts.

Buckminster fullerene:
Molecular formula: C_{60}
Spherical shaped
Uses: Lubricant as they can roll over each other



Transition Metals

Compared to group 1 metals, they are:
-harder
-have more than one oxidation state
- used as catalysts (lowers the activation energy by providing an alternative route)
- form coloured compounds

27. Electrolysis

Electrolysis: The splitting of an ionic compound into its elements using electricity.

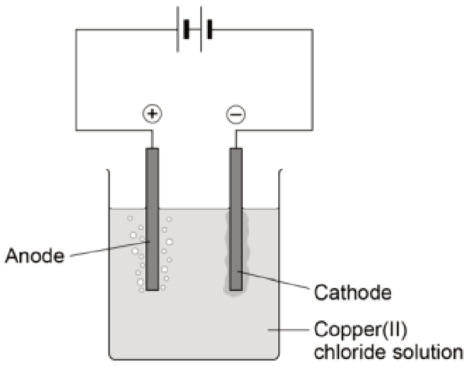
Electrolyte: A molten ionic compound or an ionic solution e.g. sodium chloride. They conduct electricity.

Reaction condition for electrolysis to occur:
In a solid, ions are not free to move.
In solution or molten, the ions are free to move and carry the charge.

Electrolysis Apparatus
Remember PANIC (Positive Anode Negative Is Cathode)

Positive ions move to the cathode (negative electrode)

Negative ions move to the anode (positive electrode)



28. Processes Occurring During Electrolysis

Reaction at the Anode
Non-metal ions (anions) move to the anode. Non-metal molecules are produced.

Half Equation:
$2Cl^- - 2e^- \rightarrow Cl_2$ $(2Cl^- \rightarrow Cl_2 + 2e^-)$
Each chloride ions lose 1 electron to form a chlorine molecule. It has been oxidised.
Remember OIL RIG (<u>O</u>xidation <u>I</u>s <u>L</u>oss Reduction <u>I</u>s <u>G</u>ain)

Processes at the anode
If the anion is sulfate (SO_4^{2-}) or a nitrate (NO_3^{1-}) oxygen gas (O_2) is produced
If the non-metal ion is a halide e.g. Br^-, the halogen molecule will be produced (Br_2)

How oxygen is produced from water during electrolysis
-water molecules break down
-H^+ and OH^- ions are produced
-OH^- attracted to the anode
-OH^- ions oxidised to O_2 molecules

Reaction at the Cathode
Metal ions (cations) move to the cathode. Metal atoms are produced.

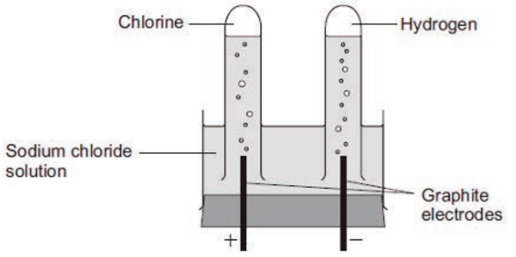
Half Equation: $Li^+ + e^- \rightarrow Li$
Lithium ion has gained 1 electron to form lithium atoms.
It has been reduced.
Remember OIL RIG (<u>O</u>xidation <u>I</u>s <u>L</u>oss Reduction <u>I</u>s <u>G</u>ain)

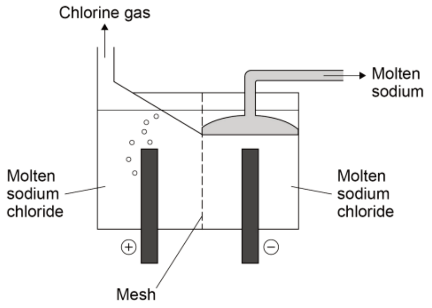
Competition between two positive ions at the cathode
A positive metal ion e.g. K^+, and a positive hydrogen ion, H^+ are both in solution.

At the cathode, hydrogen gas (H_2) is produced if the metal is more reactive than hydrogen e.g. K^+ and H^+ ions are in solution. Refer to reactivity series on page **18**

How hydrogen is produced from water during electrolysis
-water molecules break down, H^+ and OH^- ions are produced
-H^+ attracted to negative electrode
-H^+ is less reactive
-pH increases as there is a decrease in H^+ ions

29. Electrolysis as an industrial process (sodium chloride)





Half equation for the production of sodium
$Na^+ + e^- \rightarrow Na$

Mesh is used to keep the products of the electrolysis apart so the products do not react

Ions pass through the mesh

Why the pH of the solution increases:
- Water molecules break down to produce H^+ and OH^- ions
- H^+ attracted to cathode. H^+ ions discharged
- H is less reactive than Na
- Decrease in H^+ concentration
- pH increases as it becomes more alkali

Products discharged for the electrolysis of sodium chloride
Hydrogen gas (H_2), chlorine gas (Cl_2) and sodium hydroxide (NaOH) in solution

Ions present in solution
Na^+ and Cl^- (from NaCl),
H^+ and OH^- (from water)

How sodium hydroxide (alkali) solution is produced:
Sodium ions and hydroxide ions are left in solution
Hydrogen ions are released at the negative electrode to form hydrogen gas
$2 H^+ + 2 e^- \rightarrow H_2$
Chloride ions are released at the positive electrode to form chlorine gas
$2 Cl^- \rightarrow Cl_2 + 2 e^-$

30. Extraction of Aluminium Using Electrolysis

Electrolysis to extract metals

Metals above carbon in the reactivity series – extracted from their ores using electrolysis.

Metals below carbon in the reactivity series – extracted from their ores using carbon. This is called reduction.

Aluminium

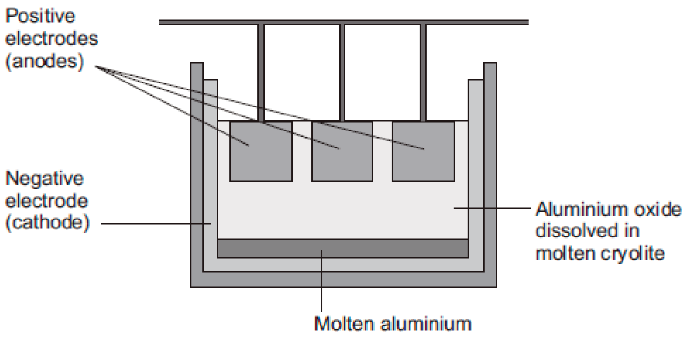
Aluminium ore – Bauxite (aluminium oxide, Al_2O_3)

Uses of aluminium: make cars and plane and tin foil

Reaction at the cathode

$Al^{3+} + 3e^- \rightarrow Al$ Reduction

Al^{3+} has gained 3 electrons to form Al atoms.



Expensive - Large amounts of energy are needed to melt the metal compound, and to produce electricity.

Molten mixture: Aluminium oxide and cryolite

Why a molten mixture of aluminium oxide is used:

Mixed with cryolite. This lowers the melting point, so less energy is needed.

Carbon anodes replaced because the carbon anode reacts with oxygen produced at the anode. The anode fizzles away as CO_2 is produced.

Reaction at the anode

$2O^{2-} \rightarrow O_2 + 4e-$ Oxidation

Two O^{2-} ions have lost 2 electrons each to form an O_2 molecule.

31. Batteries & Fuel cells

Simple cell

Most reactive metal will lose electrons (oxidation)

Least reactive will gain electrons (reduction)

Difference in reactivity creates electron flow which produces a voltage

Cell voltage

Magnesium
Zinc
Copper

↓ Increase in reactivity

The biggest voltage occurs when the difference in the reactivity of the two metals is the largest. A cell made from a magnesium electrode and a copper electrode has a higher voltage than either of the other two combinations.

Fuel cells

Use hydrogen gas (fuel) and oxygen (from the air).

Hydrogen is oxidised to form water releasing electrical energy.

Benefits: No toxic chemicals to dispose of; takes less time to refuel

Problem: Storing hydrogen. It is explosive.

Fuel cells Half Equations

Cathode: $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$
Anode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
Overall equation: $2H_2 + O_2 \rightarrow 2H_2O$

Battery – 2 or more cells together

Non-rechargeable cells and batteries - the chemical reactions stop when one of the reactants has been used up e.g. alkali batteries. Irreversible reaction

Benefits: Cheap to manufacture

Problem: Contains toxic metals which cause issues with disposal

Battery – 2 or more cells together

Rechargeable cells and batteries - Reversible reaction

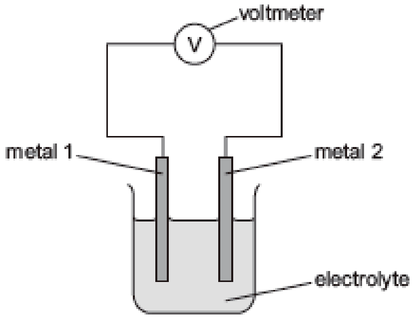
Benefits: recharged many times before being recycled, reducing the use of resources

Problem: Costs more to manufacture

Batteries vs Electrolysis

Electrolysis uses electricity to produce a chemical reaction

Chemical cells (batteries) use a chemical reaction to produce electric



32. Required Practicals 1: Making a salt and Electrolysis

Making a soluble salt

1. Add excess copper oxide to sulfuric acid in a beaker
2. Stir using a stirring rod
3. Filter using a funnel and filter paper into a conical flask.
4. Evaporate the water from the copper sulfate solution in an evaporating dish using gentle heat until half the volume is left.
5. Leave on windowsill to form crystals.
6. Pat dry crystals.

Reasoning for the steps

Step 1: Excess metal oxide used so that all the acid reacts.

Step 2: Reaction stirred so all the chemicals react.

Step 3: Removal of excess copper oxide. Excess copper oxide used as it is easier to remove than excess acid

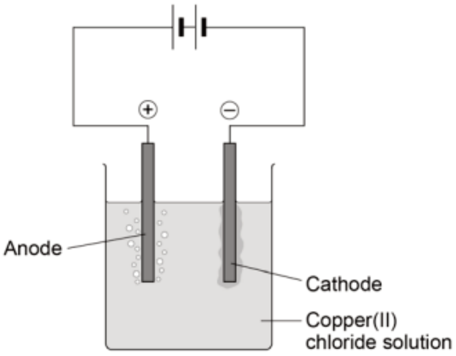
Step 4: Slow this step down by using a water bath

Observations:

Black solid (copper oxide) is left in the filter paper

Colour change

Electrolysis of aqueous solutions



Cathode: Metal attracted. Metal atoms are formed.

If the **metal is more reactive than hydrogen**, the metal ion will stay in solution and hydrogen ions will attract to the cathode, producing hydrogen gas

Anode: If the anion is sulfate (SO_4^{2-}) or a nitrate (NO_3^{1-}) oxygen gas (O_2) is produced

33. Required Practicals 2 – Energy Changes

Reacting two solutions, e.g. acid and alkali

1.Place the polystyrene cup inside the glass beaker

2.Using a measuring cylinder, measure 25 cm^3 of acid

3. Add to polystyrene cup.

4.Record the temperature of the acid using a thermometer.

5.Add 5cm^3 of alkali to the polystyrene cup and record the temperature obtained.

6.Repeat with 5cm^3 of alkali until 40 cm3 of alkali has been added

IV: Volume of alkali

DV: Temperature of reaction mixture

CV: Type of acid and alkali, volume of acid

To improve the accuracy

Use polystyrene cup

Add a lid

Repeat the experiment and calculate the mean ignoring anomalous results

Valid results: Repeat 3 times, identify the anomalous results, calculate the mean

Reacting a solid with a solution, e.g. metal and solution

1.Place the polystyrene cup inside the glass beaker to make it more stable.

2.Using a measuring cylinder, measure 25 cm^3 of copper sulfate solution

3.Place the solution in a polystyrene cup.

4.Record the temperature of the solution using a thermometer.

5.Using a balance, weigh out 1g zinc powder

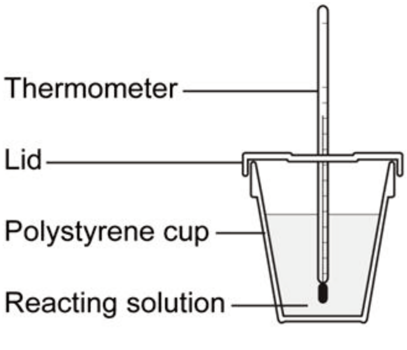
6.Add the zinc powder and record the temperature.

7.Repeat steps 1-6 with different masses of zinc powder

IV: Mass of metal

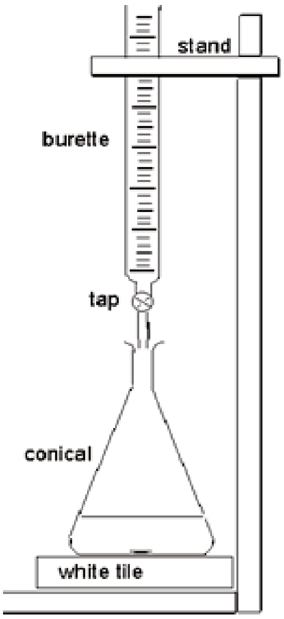
DV: Temperature of reaction mixture

CV: Concentration and volume of copper sulfate solution



34. Required Practicals 3 - Titration

Titration of a strong acid and an alkali



1.Set up equipment as shown in diagram.

2. In the conical flask add 25 cm^3 of the alkali using a pipette with a few drops of phenolphthalein indicator.

3. Add the acid from the burette into the conical flask, swirling the conical flask until the colour changes.

4. Record volume of acid.

5. Repeat steps 2-4 until you have 3 concordant titres (within 0.1 cm^3 of each other).

6. Calculate the mean titre.

The acid and the alkali can be in either glass vessel (burette or conical flask).

Pipette – exactly measures out 25 cm^3
Burette – volume varies
Concentration (mol/dm^3) = moles / volume

How to improve the accuracy:

- Swirl the solution.
- Use a white tile under the flask.
- Add the acid dropwise near the endpoint.
- Repeat and calculate mean.

Reasons why a burette is used:

- can add the acid in small increments
- can measure variable volumes
- more accurate than a measuring cylinder

Chemistry Paper 2 (Triple)

CONTENTS

35. Rates of Reaction

Collision theory	Chemical reactions can occur only when reacting particles collide with each other and with sufficient energy.
Activation energy	The minimum amount of energy that particles must have to react energy.
Factors that affect the rate of a reaction	Concentration; Temperature Pressure; Catalyst Surface area

Explaining the rate of reaction in terms of particles

The higher the **temperature**, particles move faster,…

The higher the **concentration/pressure**, more particles in a given volume,…

The higher the **surface area**, more area for the reactants to collide,…

…the faster the rate of reaction due to a higher frequency of successful collisions.

Measure the rate of reaction by:	**Equipment needed:** Stop clock Balance or measuring cylinder/gas syringe
	a) Loss of mass of the reactants (use a balance) b) Volume of gas produced (use a gas syringe or upturned measuring cylinder) c) Time taken for the solution to become cloudy (place conical flask on cross and watch it disappear)

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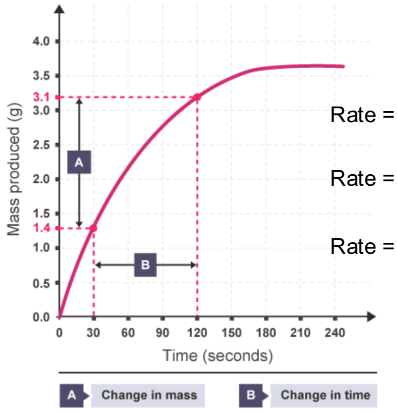
36. Rates of Reaction Graphs

Calculating average rate

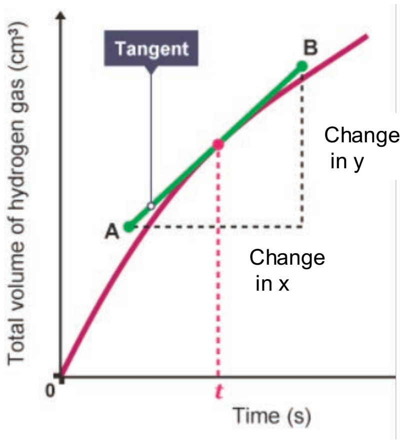


$$\text{Rate} = \frac{\text{change in mass}}{\text{change in time}}$$

$$\text{Rate} = \frac{3.1 - 1.4}{120\text{-}30}$$

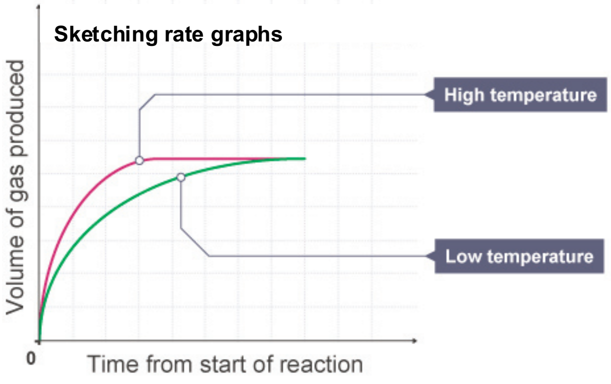
Rate = 0.0189 /s

Calculating the rate at a specific time



1. Draw a tangent at that point approximately 10 cm long.
2. Draw a triangle
3. Calculate change in y
4. Calculate change in x
5. Gradient = $\frac{\text{change in y}}{\text{change in x}}$

Sketching rate graphs



Steeper the curve	Faster the rate of reaction
Horizontal line on graph	Reaction is finished (reactants used up)
Why the rate changes (in terms of particles)	Fewer acid particles Less frequent collisions Reaction stops due to a limiting factor

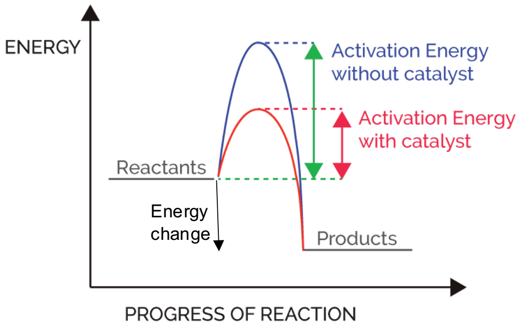
37. Rates of Reaction and Equilibrium

Catalysts increase the rate of reaction by providing a different pathway for the reaction that has a lower activation energy.

They reduce energy costs.

Catalysts are not included in the chemical equation for the reaction.

Biological catalyst: enzyme



Reversible reaction

Anhydrous copper sulfate (white) + water $\rightleftharpoons$ Hydrated copper sulfate (blue)

Closed system	When reactants or products cannot enter or leave the system
What does it mean by equilibrium?	The rate of the forward and reverse reaction is the same. The concentrations of reactants and products are constant. It is a closed system
How to use Le Chateliers principle	Use to explain the effect of changing the conditions on the position of equilibrium
Equilibrium and temperature	Increase in temperature – reaction moves in the endothermic direction. Decrease in temperature – reaction moves in the exothermic direction.
Equilibrium and pressure	Increase in pressure – reaction moves to the side of the fewer moles. Decrease in pressure – reaction moves to the side of the most moles.
Equilibrium and concentration	Increase in concentration of a chemical– reaction moves to the opposite side to use up excess chemical. Decrease in concentration of a chemical– moves to this side to create more of this chemical.
Equilibrium and a catalyst	No effect on the position of equilibrium. A catalyst allows the reaction to reach equilibrium faster. Increases the rate of the forward and the reverse reaction by the same amount.

38. Evolution of the Atmosphere

Volcanoes released water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), ammonia (NH_3).

Volcanoes were a source of nitrogen.

Not certain of exact % of each gas as there was no evidence

Temperature cooled down. Water vapour condensed to form oceans

Algae and plants used up carbon dioxide by photosynthesis to produce oxygen.

Methane reacted with oxygen to form carbon dioxide and water.

Ammonia reacted with oxygen to form nitrogen and water.

Today's atmosphere:

- 78 % Nitrogen (N_2)
- 21 % oxygen (O_2)
- 1 % other gases

Reasons why O_2 levels increased	• Algae and plants began to photosynthesise, producing oxygen • Oxygen levels increased, allowing animals to evolve.
Reasons why CO_2 levels decreased	•Absorbed by oceans. •Locked up as sedimentary rocks and fossil fuels. •Used in photosynthesis to produce oxygen

How coal was formed from carbon dioxide present in the early atmosphere:

- Carbon dioxide was used during photosynthesis by trees
- Trees die and are compressed over millions of years

39. Greenhouse effect

Greenhouse Gases

- Water vapour (H_2O)
- Carbon dioxide (CO_2)
- Methane (CH_4)

Effects of Global Climate Change
Sea level rise, which may cause flooding and increased coastal erosion
More frequent and severe storms
Changes to the distribution of wildlife species

Human Activities Which Increase Greenhouse Gases
Combustion of fossil fuels releasing more carbon dioxide
Deforestation leading to less trees so less photosynthesis occurring
More animal farming (digestion, waste decomposition) so more methane released
Decomposition of rubbish in landfill sites so more methane released)

How greenhouse gases cause global warming

Short wavelength radiation enters the atmosphere

Absorbed by Earth and re-emitted as a **longer** wavelength radiation

Absorbed by the atmosphere

Increases the temperature leading to global warming

How trees reduce global warming:

- Trees use carbon dioxide
- For photosynthesis
- Carbon dioxide causes global warming

40. Polluting our Atmosphere

Pollutant	How it is made	Effect on health/environment
Sulfur dioxide (SO_2)	Sulfur in fossil fuels reacts with oxygen to form sulphur dioxide.	Cause respiratory problems in humans and causes acid rain. Acid rain damages plants and buildings.
Carbon monoxide (CO)	Incomplete combustion of hydrocarbons.	A toxic gas which causes death. Difficult to detect as it is colourless and odourless.
Carbon particulates (unburned hydrocarbons)	Incomplete combustion of hydrocarbons.	Causes global dimming and damages lungs.
Oxides of nitrogen (NO_x)	Made from nitrogen and oxygen **in air** reacting at a high temperature in a car engine.	Causes respiratory problems in humans and cause acid rain.

Carbon Footprint	The total amount of carbon dioxide and other greenhouse gases emitted over the full life cycle of a product, service or event.
How to Reduce the Carbon Footprint	- Increased use of alternative energy supplies e.g. wind - Use energy efficient appliances - Carbon capture and storage (CCS)
Problems on Reducing the Carbon Footprint	- Lifestyle changes e.g. using public transport - Economic considerations e.g. can countries afford to build more wind turbines?

41. Further Quantitative Chemistry 1: Equations and definitions

Mole	Mole= mass (g) / relative formula mass Mole = mass (g) /relative atomic mass
Avogadro's Number	6.02×10^{23} The number of particles (atoms, ions or electrons) in one mole of substance.
Atom Economy	Atom economy = $\frac{\text{RFM of desired product}}{\text{RFM of ALL the reactants}} \times 100$
Percentage yield	% yield = $\frac{\text{actual mass (g)}}{\text{theoretical mass (g)}} \times 100$
Volume	$\text{cm}^3 \xrightarrow{\div 1000} \text{dm}^3$
Concentration	Concentration (mol/dm^3) = moles/ volume (dm^3) Concentration (g/dm^3) = mass (g) / volume (dm^3)
Gas volume	1 mole of gas occupies 24 dm^3 0.5 moles of gas occupies 24 x 0.5 dm^3= 12 dm^3 Use balanced symbol equation to deduce mole ratios.

High atom economy

Less wasted products and better economically

Percentage yield

Less than 100 % yield due to:

- •the reaction may not go to completion because it is reversible
- •some of the product may be lost when it is separated from the
- •reaction mixture

42. Further Quantitative Chemistry 2: Limiting reactants and Theoretical Yield

Limiting Reactants

The reactant that is completely used up is called the limiting reactant because it limits the amount of products.

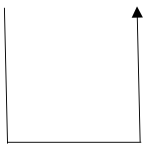
For example: 3 g of Mg react with 7 g of O_2. Which is the limiting reagent?

	2Mg	+	O_2	→ 2MgO
Mass	3 g			
Mr	24 (don't include big 2)			
Moles	3/24=0.125		0.125/2 = 0.0625	
Ratio	**2**Mg :**1**O_2			

O2 is the limiting reactant as there is only 0.0625 moles. Once the oxygen has reacted, the reaction is over.

Theoretical Yield Calculation

128 grams of hydrogen peroxide break down into water and oxygen. What mass of oxygen is produced?



	$2H_2O_2$	→	$2H_2O$ +	O_2
Mass	128 g			60.2g
Mr	34 (don't include big 2)			32
Moles	128/34=3.76			3.76/2 = 1.88
Ratio		**2**H_2O_2 :**1**O_2		

a) Underline the 2 substances from the question in the equation.

b) Add the information from the question under mass, Mr and moles.

c) Use ratios (the big numbers to calculate the new moles).

d) Follow the U-arrow to calculate new mass

43. Further Quantitative Chemistry 3: Balancing equations and Gas volumes

Example 1: Work out the balanced equation when 12 grams of magnesium reacts completely with 38.5g of HCl, to make 49.5 grams of $MgCl_2$ and 1 gram of H_2

:	Mg +	HCl →	$MgCl_2$ +	H_2
Step 1: work out the moles of each reactant and product.	12 g/ 24 = 0.5	38.5 g/ 38.5 = 1	49.5/99 = 0.5	1/2 = 0.5
Step 2: divide through by the smallest number	0.5/0.5=1	1/0.5 = 2	1/0.5=1	0.5/0.5=1
Step 3: write the balanced equation	Mg + 2HCl → $MgCl_2$ + H_2			

Example 2: Iron chloride is produced by heating iron in chlorine gas. The equation for the reaction is:

$$\underline{2Fe} + \underline{3Cl_2} \rightarrow 2FeCl_3$$

Calculate the volume of chlorine needed to react with 14 g of iron

:	**2Fe**	**$3Cl_2$**
Mass	14	
Mr	56	
Moles	14/56 = 0.25	(0.25/2) x 3=0.375
Ratio	2	3

0.375 moles of chlorine gas made

1 mole of gas occupies 24 dm^3

0.375 / 24 = 0.0156 dm^3 of chlorine gas produced

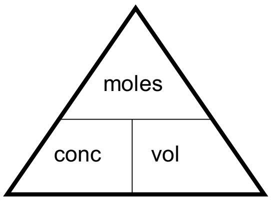
15.6 cm^3 of chlorine gas produced

44. Further Quantitative Chemistry 4: Titration Calculations

QUESTION: 13.3 cm^3 of 0.0500 mol/dm^3 citric acid solution was needed to neutralise 25.0 cm^3 of sodium hydroxide solution. The equation for the reaction is:

$$3NaOH + C_6H_8O_7 \rightarrow C_6H_5O_7Na_3 + 3H_2O$$

Calculate the concentration of the sodium hydroxide solution in mol/dm^3



1. Identify the 2 chemicals in the question
2. Plug in the numbers from the question.
3. Convert cm^3 to dm^3

	3NaOH	**$C_6H_8O_7$**
moles		
volume (dm^3)	0.025	0.0133
concentration (mol/dm^3)		0.05

$$cm^3 \xrightarrow{\div 1000} dm^3$$

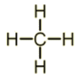
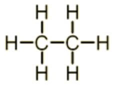
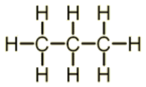
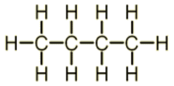
4. As we know TWO numbers for the citric acid, calculate the moles of the acid
5. Then continue working through the table via the arrows

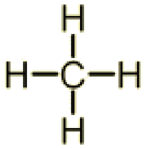
	3NaOH		**$C_6H_8O_7$**
moles	0.000665 x 3 =0.001995		0.0133 x 0.05 = 0.000665
volume (dm^3)	0.025		0.0133
concentration (mol/dm^3)	**0.0798**		0.05

45. Alkanes

Hydrocarbon	Made of **only** hydrogen and carbon
Alkane	A hydrocarbon made of C-C single bonds.
Alkane General Formula	$C_n H_{2n+2}$
Functional group of an alkane	C-C single bond Alkanes are saturated as all the C bonds are used up.
Homologous series	A family of hydrocarbons with similar chemical properties who share the same general formula

:

Alkane	**Molecular Formula**	**Displayed formula**
Methane	CH_4	
Ethane	C_2H_6	
Propane	C_3H_8	
Butane	C_4H_{10}	



Methane
A compound
A hydrocarbon
Covalent bonds between the C-H atoms
Homologous series: Alkanes

46. Fractional Distillation of Crude Oil

Keyword	**Definition**
Boiling point	The temperature at which a liquid turns into a gas
Combustion	Burning in oxygen
Flammability	How easily a substance ignites (catches on fire)
Fossil fuels	(non-renewable/finite fuels) Coal, oil, natural gas
Fraction	Molecules with a similar number of carbon atoms
Viscosity	The runniness of a liquid Higher the viscosity of the liquid, the longer it will take for the liquid to flow
Volatility	How easily a liquid changes into a gas

Physical property:
Fractional distillation relies of mixtures having different **boiling points** to enable the mixture to be separated

Fossil fuels: Coal, crude oil and natural gas

How coal is made: Trees die and are compressed over millions of years.

How crude oil is made: Made by the decomposition of plankton buried in mud over millions of years

Coal has more carbon than oil and natural gas

Fractional distillation of crude oil

1. Crude oil is heated and evaporated
2. Temperature decreases from the bottom to the top of the column
3. Fractions condense at different heights
4. Fractions have different boiling points

Properties of fractions as you go down the column

Boiling point - increase with increasing molecular size

Viscosity - increase with increasing molecular size

Flammability - decreases with increasing molecular size

47. Combustion and Cracking

	Complete combustion (FO COW)	**Incomplete combustion**
Reaction conditions	Lots of oxygen	Little oxygen
Reactants	Fuel and oxygen	Fuel and oxygen
Products	Carbon dioxide and water	Carbon monoxide (or carbon particulates /soot) and water
	Test for carbon dioxide: Bubble through limewater **Result**: Turns cloudy	Carbon monoxide is toxic

Cracking vs Distillation

Cracking Requires a catalyst

Distillation Does not require a catalyst

Cracking - Hydrocarbons can be broken down (cracked) to produce smaller, more useful molecules. Also known as thermal decomposition.

Thermal decomposition – breaking down a compound using heat.

Example:

$C_{30}H_{62}$	→	$C_{20}H_{42}$	+	$C_{10}H_{20}$
Long alkane		more useful shorter alkane		alkene (make plastics)

Reason for cracking: Turns long hydrocarbon chains into more useful shorter hydrocarbon chains.

Short alkanes are useful as they are flammable and used for fuels

Alkenes are used to make plastics via polymerisation (see page 24)

Catalytic Cracking

Reaction conditions: High temperature and a catalyst

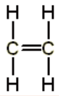
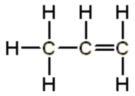
Steam Cracking

Reaction conditions: High temperature

---

48. Alkenes

Alkene	A hydrocarbon made of C=C double bonds.
Alkane General Formula	$C_n H_{2n}$
Functional group of an alkane	C=C double bond Alkanes are unsaturated
Chemical test for alkene	Add bromine water Alkene = Orange to colourless Alkane = stays orange

Alkene	**Molecular Formula**	**Displayed formula**
Ethene	C_2H_4	
Propene	C_3H_6	

Reactions of alkenes	
Combustion	Burn in air with smoky flames because of incomplete combustion. Makes carbon monoxide (toxic) and water.
Reaction with hydrogen	Addition reaction. It takes place in the presence of a catalyst to produce the corresponding alkane (saturated).
Reaction with water	Reaction with steam in the presence of a catalyst to produce an alcohol.
Reaction with a halogen	Addition of a halogen to an alkene produces a saturated compound with two halogen atoms in the molecule, for example ethene reacts with bromine to produce dibromoethane.

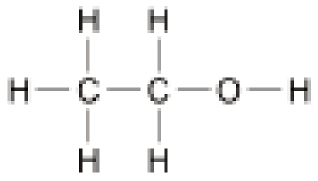
49. Alcohols

Alcohols

Functional group: –OH

Methanol, ethanol, propanol and butanol

Alcohols can be represented as: CH_3CH_2OH



Reactions of alcohols	
pH	Dissolve in water to form a neutral solution (pH 7, green)
Reaction with sodium	Hydrogen (H_2) gas and a sodium salt produced
Oxidation (type of reaction)	Use acidified potassium dichromate (oxidising agent) to make a carboxylic acid
Fermentation	sugar + yeast → ethanol (alcohol) Catalyst: yeast Conditions: anaerobic and warm

50. Carboxylic Acids and Esters

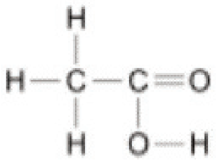
Carboxylic acids

Functional group: –COOH.

Methanoic acid, ethanoic acid, propanoic acid and butanoic acid.

The structures of carboxylic acids can be represented as:

CH_3COOH

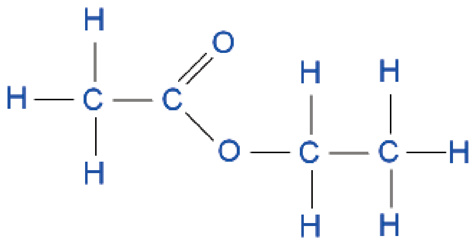


Esters

Functional group: –COOR

Ethyl ethanoate.

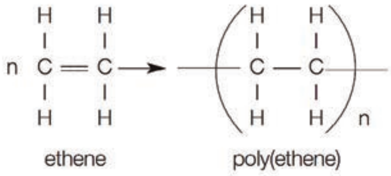
$CH_3COOCH_2CH_3$



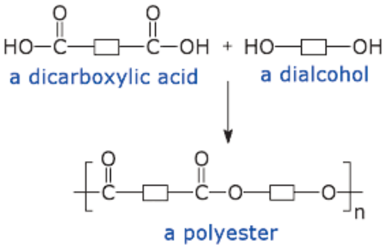
51. Polymerisation

Monomer	Made of a C=C bond
Polymers	Large molecules linked to other atoms by strong covalent bonds.
n	Number of monomers/repeating units
Polymerisation	The C=C double bond in the monomer breaks open. Monomers join together to form a long chain molecule (polymer.

Addition Polymerisation



Condensation Polymerisation



Addition polymerisation	Many small molecules, alkenes (monomers) join together to form very large molecules (polymers) e.g. poly(ethene).
Condensation polymerisation	Monomers with two functional groups react and join together, losing a small molecule e.g. water Dicarboxylic acid + diamine = polyamide e.g. nylon Dicarboxylic acid + diol = polyester
DNA	Two polymer chains, made from four different monomers called nucleotides, in the form of a double helix.
Amino acids	Contain 2 functional groups, -NH_2 and –COOH Amino acids (monomers) join together to make the polymer, proteins. Glucose (monomer) join together to make the polymer, starch and cellulose. Sugars, starch and cellulose are carbohydrates.

52. Mixtures, Test for Gases and Test for Water

Keyword	Definition
Boiling point	The temperature at which a liquid turns into a gas. Water has a boiling point of 100 °C
Formulation	A mixture that has been designed as a useful product e.g. shampoo Formulations include fuels, cleaning products, medicines, paints, alloys, fertilisers and foods. Crude oil is NOT a formulation as it is: -not a useful product -not mixed in measured quantities
Melting point	The temperature at which a solid turns into a liquid. Ice has a melting point of 0 °C
Pure substance	A single element or compound

Gas	**Chemical test**	**Result**
Hydrogen (H_2)	Lit splint	Pop sound
Oxygen (O_2)	Glowing splint	Splint relights in oxygen
Carbon Dioxide (CO_2)	Bubble through limewater	Turns milky/cloudy
Chlorine (Cl_2)	Damp litmus paper	Paper is bleached (white)

	Test	**Result**
Pure water	Boil it	Boils at exactly 100 °C
Water	Add anhydrous copper sulfate	Turns from white to blue

53. Chromatography

Chromatography can be used to separate mixtures and identify substances.
Relies on the difference in **solubility** (physical property) of the mixture

Mobile phase – the solvent e.g. water running up the chromatogram.
Stationary phase – the paper.

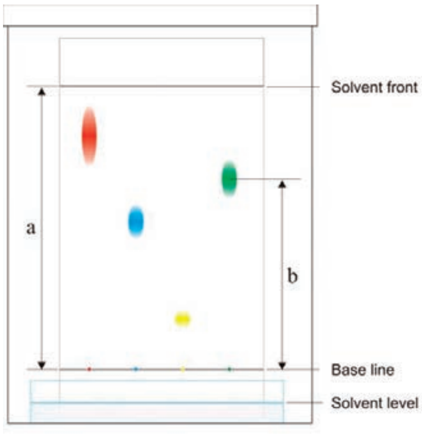
Evidence that the dye is a mixture

- More than 1 spot
- In a vertical column

Substances move between the phases. If a substance is more attracted to the mobile phase, it will move further up.
The R_f value tells you how far the substance has moved, relative to the solvent.

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

The R_f value can be used to identify the substance.
The R_f values would be compared to the known substance.
Rf value will always be **less than 1**



$R_f = b \div a$

54. Chemical Tests for Positive Ions

Flame test method
1.Dip a clean nichrome wire loop into a solid sample of the compound being tested
2.Put the wire loop into the edge of the **blue** flame from a Bunsen burner
3.Observe and record the flame colour produced
4.Nichrome wire dipped in acid to clean wire in between tests

Wooden splints vs using nichrome wire
Wooden splints don't need cleaning

Problem with this test:
Cannot use a mixture as cannot distinguish between flame colours.
One flame colour will mask another flame colour

Metal ion	Flame colour
Lithium compounds	crimson flame
Sodium compounds	yellow flame
Potassium compounds	lilac flame
Calcium compounds	red flame
Copper compounds	green flame

Testing for metals ions
Add sodium hydroxide to the metal solution to form a precipitate (insoluble solid)

Metal ion	Precipitate colour
Al^{3+}	white precipitate (dissolves when more NaOH added)
Ca^{2+}	white precipitate
Mg^{2+}	white precipitate
Cu^{2+}	blue precipitate
Fe^{2+}	green precipitate
Fe^{3+}	red/brown precipitate

Flame emission spectroscopy
Used to identify a metal ion.
Used to ow the concentration of an ion in a solution

55. Chemical Tests for Negative Ions

Ion	Chemical test	Result
Carbonate ions (CO_3^{2-})	Add hydrochloric acid to unknown carbonate.	Bubble gas through limewater Limewater turns cloudy
Halide ions	Add acidified silver nitrate solution	Cl^- = white precipitate Br^- = cream precipitate I^- = yellow precipitate
Sulfate ions (SO_4^{2-})	Add acidified barium chloride	White precipitate is formed

Instrumental analysis

Advantages:

Faster

More accurate

More sensitive (smaller samples needed)

Disadvantages:

Machines are expensive

Specialists training required

---

56. Potable Water

Finite resource (non-renewable):

A source from the Earth that is running out e.g. coal, crude oil

Renewable source:

A source that isn't running out e.g. wood

Potable water.

Safe to drink. Contains **low** levels of dissolved salts and microbes. Not pure.

	Potable water from salty water using distillation	Potable water from rainwater/groundwater	Potable water from the sea (desalination)	Potable water from waste water (sewage)
Method	1. Heat salty water. 2. Water evaporates. 3. Cool the water vapour 4. The vapour condenses to form potable water	1. Rainwater collected in reservoirs. 2. Passing the water through filter beds to remove any solids. 3. Sterilise to kill microbes. **Sterilising agents:** chlorine, ozone or ultra-violet light.	Distillation or by processes that use membranes such as reverse osmosis.	1. Removal of organic matter and harmful chemicals 2. Screening and grit removal 3. Sedimentation to produce sewage sludge and effluent 4. Anaerobic digestion of sewage sludge 5. Aerobic biological treatment of effluent.
Issues		Reliant on rainfall	These processes require large amounts of energy.	Expensive: Needs filtering and sterilising to remove harmful bacteria. Lots of steps

57. Saving Resources

Reduces	Limits the use of raw materials, energy consumption, waste and environmental impacts (quarrying and mining for raw materials).
Reuse	Use the item for another purpose e.g. a glass bottle is refilled.
Recycle	Turn the item into something else e.g. plastic bottles recycled to make fleeces, scrap steel is added to iron from a blast furnace. **Benefits**: conserves metal ores; uses less energy; reduces waste
Sustainable development	Development that meets the needs of current generations without compromising the resources for future generations.
Life Cycle Assessments (LCAs)	To assess the environmental impact (of the stages in the life of a product). • Extracting the raw material • Processing the raw material • Manufacturing • Disposal at the end of its useful life

58. Copper Extraction and Corrosion

Keyword	Definition
Bioleaching	Uses bacteria to produce leachate solutions that contain metal compounds. **Advantages**: Used to clean up toxic metals from industrial sites. Extracting copper from low grade ores. **Disadvantages**: Requires lots of energy in smelting and electrolysis process.
High grade copper ore	Rock that contains enough copper that makes it economically viable to extract it.
Low grade copper ore	Extract using phytomining or bioloeaching.
Phytomining	Grow plants on land containing copper ores. Plants are burnt to produce ash. Ash dissolved in acid to produce a solution of a copper compound. Electrolysis of solution containing the copper compound. **Advantages:** reduces the need to obtain new ore by mining. Conserves limited supplies of more valuable ores with higher metal content **Disadvantage**: Takes a long time. Large area of land required.

Corrosion	destruction of materials by chemical reactions with substances in the environment e.g. rusting.
Preventing corrosion	applying a coating that acts as a barrier, such as greasing, painting or electroplating

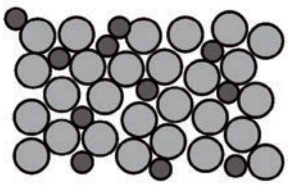
Aluminium has an oxide coating that protects the metal from further corrosion.

Zinc is used to galvanise iron and when scratched provides sacrificial protection because zinc is more reactive than iron.

Magnesium blocks can be attached to steel ships to provide sacrificial protection.

59. Alloys and their Uses

Alloys	Soft metals are mixed with other metals to make them harder.
Property	Hard.
Explanation	Metals are bendy as the layers of atoms can slide over each other easily. In alloys, the particles are different sizes. Layers are distorted and cannot slide over each other.



Alloy	Use
Bronze	Made of copper and tin. Used to make statues and decorative objects.
Gold	Used as jewellery. Usually an alloy with silver, copper and zinc. The proportion of gold in the alloy is measured in carats.
Brass	Made of of copper and zinc. Used to make water taps and door fittings.
Steels	Made of iron that contain specific amounts of carbon and other metals. High carbon steel is strong but brittle. Low carbon steel is softer and more easily shaped. Steels containing chromium and nickel (stainless steels) are hard and resistant to corrosion.
Aluminium	Alloys are low density and are used in aerospace manufacturing.

60. Different Materials

Material	How it is made
Glass (soda-lime glass)	Made by heating a mixture of sand, sodium carbonate and limestone.
Borosilicate glass	Made from sand and boron trioxide, melts at higher temperatures than soda-lime glass
Ceramic	Made by shaping wet clay and then heating in a furnace.
Composites	Made of 2 materials. Material 1: Matriix or a binder surrounding the fibres of the second material e.g. a polymer. Material 2: Reinforcement e.g. wood, concrete and fibre glass.

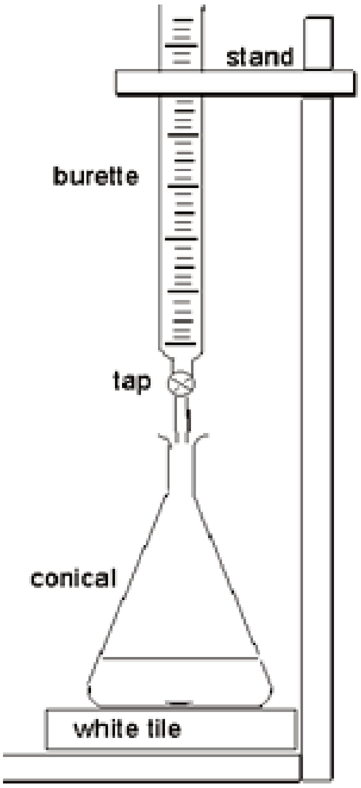
Polymer	Structure
Low density polyethene (LDPE)	Tangled chains. Lots of gaps between the chains. Low melting point
High density polyethene (HDPE)	Polymer chains are closer together so more atoms per unit volume. Higher melting point to LDPE
Thermosetting polymers	Polymer chains with cross-links between them and so they do not melt when they are heated. Cross links are covalent bonds.
Thermo-softening polymers	Individual, tangled polymer chains and melt when they are heated. No cross links. Can be remoulded. Easier to recycle as it can be melted and reshaped.

61. Fertilisers

Use of fertilisers	To make plants grow better and quicker
Fertilisers	Compounds of nitrogen, phosphorus and potassium NPK fertilisers contain compounds of all three elements. NPK fertilisers are formulations of various salts containing appropriate percentages of the elements.
Ammonia	Used to manufacture ammonium salts and nitric acid.
Potassium chloride	Potassium sulfate and phosphate rock are obtained by mining, but phosphate rock cannot be used directly as a fertiliser because it is insoluble. Phosphate rock is treated with nitric acid to produce phosphoric acid and calcium nitrate.
Ammonia phosphate	Phosphoric acid is neutralised with ammonia to produce ammonium phosphate.
Superphosphates	Phosphate rock is treated with sulfuric acid to produce single superphosphate (a mixture of calcium phosphate and calcium sulfate) or with phosphoric acid to produce triple superphosphate (calcium phosphate).

62. Making a Fertiliser

1. Set up equipment as shown in diagram.
2. In the conical flask add 25 cm^3 of the ammonia with a few drops of universal indicator.
3. Add the phosphoric acid from the burette into the conical flask, swirling the conical flask until the colour changes to green. Record volume
4. Repeat steps 1-3 without the indicator adding the correct volume of acid.
5. Evaporate half the solution in an evaporating dish.
6. Leave solution by windowsill.



The acid and the ammonia can be in either glass vessel (burette or conical flask).

Pipette – exactly measures out 25 cm^3

Burette – volume varies

White tile – see colour change clearly

How to improve the accuracy:

- Swirl the solution.
- Use a white tile under the flask.
- Add the solutipn dropwise near the endpoint.
- Repeat and calculate mean.

63. Haber Process

Used to manufacture ammonia (used to produce nitrogen-based fertilisers).

Raw materials: nitrogen and hydrogen.
Nitrogen is obtained from the air.
Hydrogen may be obtained from natural gas or other sources.

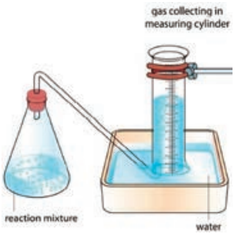
Catalyst: Iron
Temperature: High (about 450 °C)
Pressure: High (about 200 atmospheres).

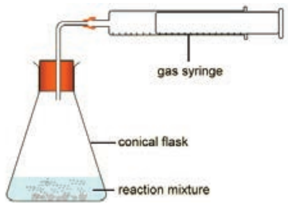
The **reaction is reversible** so some of the ammonia produced breaks down into nitrogen and hydrogen.
On cooling, the ammonia liquefies and is removed. The remaining hydrogen and nitrogen are recycled.

Reaction condition	$N_2 + 3H_2 \rightleftharpoons 2NH_3$
Equilibrium and temperature	Forward reaction is exothermic Increase in temperature, reaction moves to the left. Ammonia yield decreases. Decrease in temperature, reaction moves to the right. Ammonia yield increases.
Equilibrium and pressure	3 moles on the left and 2 moles on the right. Increase in pressure, reaction moves to the side of the fewer moles. Ammonia yield increases. Decrease in pressure, reaction moves to the side of the greater moles. Ammonia yield decreases.
Rates of reaction and temperature	Higher temperature – fast rate of reaction Expensive due to high energy costs Low temperature – slow rate of reaction. Slower turnover of product
Rates of reaction and pressure	Higher pressure – fast rate of reaction Expensive due to maintaining high pressure Low pressure – slow rate of reaction. Slower turnover of product

64. Required practicals 4: Rates of Reaction

Measuring the rate of reaction by collecting a gas



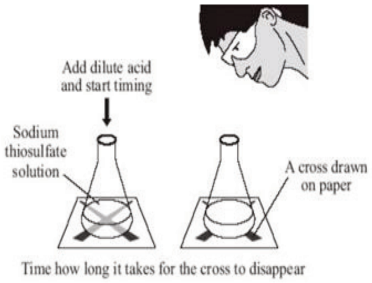


Method

1. Set up equipment as shown in diagram.
2. Add 5 cm magnesium strip and 30 cm^3 of a highly concentrated acid.
3. Collect gas for 1 minute.
4. Repeat steps 1-3 with different concentrations of acid

IV: concentration of acid
DV: volume of gas collected in 1 minute
CV: volume and type of acid, length of magnesium strip, time period of gas collection.

Measuring the rate of reaction by the formation of a precipitate



Method

1. Place conical flask on a black cross
2. Add sodium thiosulfate and hydrochloric acid to the flask.
3. Time how long it take for the cross to disappear.
4. Repeat steps 1-3 with different concentrations of sodium thiosulfate.

IV: concentration of acid
DV: time taken for cross to disappear
CV: volume and type of acid
Why there is mass loss:

- Sulfur dioxide gas is made
- Escapes into the air

Why the solution goes cloudy:
Solid sulfur is made

65. Required practicals 5: Chromatography, Test for Ions and Potable Water

Chromatography

Method:

1. Draw pencil start line on chromatography paper and place spot of dye on start line.
2. Place solvent in beaker and place chromatography paper in beaker so the paper is in solvent but solvent is below start line.
3. Wait for solvent to travel up the paper and mark solvent front.
4. Dry the paper
5. Calculate Rf of spots

Measurements to take:

Measure distance between start line and centre of spot.

Measure distance between start line and solvent front.

Use of measurements to determine Rf value

Use of pencil – pencil is insoluble. Does not interfere with ink.

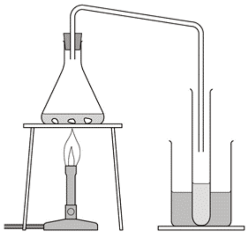
Line is above solvent level – so ink travels up the paper with the rising solvent

Test for unknown ions

An unknown ionic compound will be provided.

Test for positive ion – use flame test/adding sodium hydroxide

Test for negative ion – variety of tests



Method:

1. Heat seawater in conical flask.
2. Water evaporates
3. Water vapour condenses in delivery tube
4. Condenses in test tube

Chemical test	Test for seawater in conical flask	Test for pure water in test tube
Flame test to test for Na$^+$ ions. Dip wooden splint in each type of water and heat in blue Bunsen flame	Orange flame.	No change in colour
Test for Cl$^-$ ions. Add silver nitrate	White precipitate	No change in colour

66. Maths in Science 1

Anomalous result	A number that does not fit the pattern
Mean	Adding up a list of numbers and dividing by how many numbers are in the list. Exclude the anomalous result.
Median	The middle value when a list of numbers is put in order from smallest to largest
Mode	The most common value in a list of numbers. If two values are tied then there are two modes. If more than two values are tied then there is no mode.
Range	The largest number take away the smallest value in a set of data or written as X-Y.
Uncertainty	range ÷ 2
Surface area of a cube	(area of 1 side) x 6 sides
Volume of a cube	Width x height x depth
Area of a circle	∏ x (radius)^2

Prefixes

1 kJ = 1 x 10^3 J = 1000 J

1 pm = 1 x 10^{-12} m

1 mm = 1 x 10^{-3} m= 0.001 m

kilo	10 ^{3}
centi	10 $^{-2}$
milli	10 $^{-3}$
micro	10 $^{-6}$
nano	10 $^{-9}$
pico	10 $^{-12}$

5607.376

Standard form: 5.607 x 10^3

2 decimal places: 5607.38

3 significant figures: 5610

0.03581

Standard form: 3.581 x 10^{-2}

2 decimal places: 0.04

3 significant figures: 0.0358

67. Maths in Science 2

Calculating percentage: (part ÷ whole) x 100

e.g. Out of 90 insects, 40 of them were ladybirds. What is the % of ladybirds?

(40 ÷ 90) x 100 = 44 %

Calculating percentage change:

(difference ÷ starting value) x 100

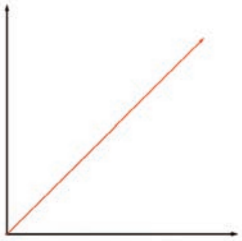
(0.59 ÷ 2.22) x 100 = 26.6 %

Conc of Sucrose (M)	Mass of potato at start (g)	Mass of potato at end (g)	Change in mass (g)
0	2.22	2.81	0.59

Graphs

Proportional (α)

When the line passes through the origin

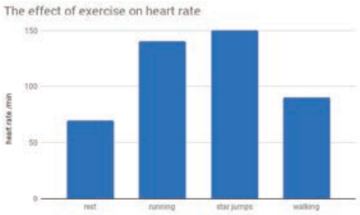


x axis = independent variable = left hand column of results table

y axis = dependent variable = right hand column of results table

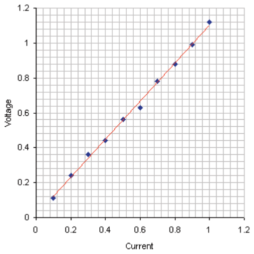
Categoric data: data put into groups e.g. colour of eyes

Draw a bar chart



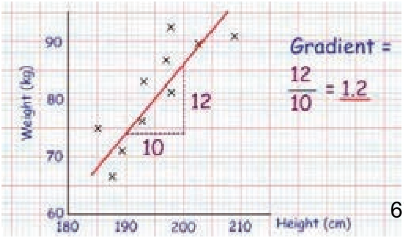
Continuous data: data that can take any value e.g. current

Draw a line graph



Gradient and Graphs

Gradient = $\frac{\text{Change in y}}{\text{Change in x}}$



Key

relative atomic mass
atomic symbol
name
atomic (proton) number

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] **Uut** ununtrium 113	[289] **Fl** flerovium 114	[289] **Uup** ununpentium 115	[293] **Lv** livermorium 116	[294] **Uus** ununseptium 117	[294] **Uuo** ununoctium 118

* The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Relative atomic masses for **Cu** and **Cl** have not been rounded to the nearest whole number.

Physics Paper 1 (Triple)

1. Energy stores and systems

Energy System

System:
An object or group of objects.
When a system changes there are changes in the way energy is stored within it.

Closed system:
Where neither matter nor energy enters or leaves.

Conservation of energy:
Energy is not created or destroyed but may be transferred between different energy stores.

The energy in a system can be transferred between different stores when work is done by:

- Heating
- Current flowing
- Mechanical by force
- Waves

Energy Store	Example
Thermal	Cup of hot tea
Kinetic	Moving car
Gravitational Potential	Water in a reservoir at the top of a mountain
Elastic Potential	Stretched bungee cord
Chemical	Battery, food
Magnetic	Two opposing north poles on bar magnet
Electrostatic	Two electrons repelling each other
Nuclear	The energy available to be released by fission when splitting an atom

2. Kinetic Energy and Elastic Potential Energy

Kinetic Energy

Kinetic energy of an object depends on the:
- mass
- speed

Kinetic energy (J) = 0.5 x mass (kg) x velocity^2 (m/s)

$E_k = 0.5mv^2$

Unit conversions:
kJ to J: x 1000
g to kg: ÷ 1000

Elastic Potential Energy

A force acting on an object may cause the shape of an object to change.

Elastic objects can store elastic potential energy if they are stretched or squashed. For example, this happens when a catapult is used or a spring is stretched.

Objects can also store elastic potential energy when they are squashed.

Elastic potential energy (J) = 0.5 x spring constant (N/m) x extension^2 (m)

Unit conversions:
kJ to J: x 1000
cm to m: ÷ 100

3. Work Done

A car braking to slow down
The friction force from the brakes does work. Energy is transferred from the car's kinetic store to the thermal store of its brakes, the brakes then transfer heat to the surroundings.

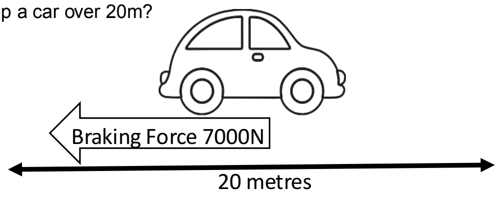
Energy transferred = work done

work done (J) = force (N) x distance (m)

W = Fs

Unit conversions:
kJ to J: x 1000
cm to m: ÷ 100
km to m: x 1000

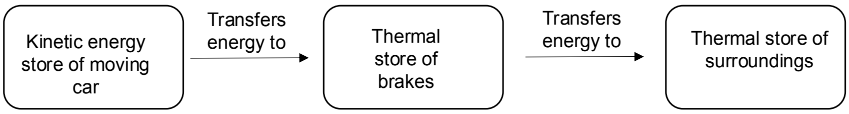
Example: How much work is done by the brakes if a 7000N braking force is used to stop a car over 20m?



Use the EVERY model to complete calculations:
E = equation
V = values
E = enter results
R = result
Y = units

E	W = F x s
V	F = 7000 N and s = 20 m
E	W = 7000 x 20
R	W = 140 000
Y	J

W = 140000J or 140 kJ



4. Gravitational Potential Store (E_p)

Raising an object off the ground increases its gravitational potential energy store.

The amount of energy depends on the mass and height of the object and strength of the gravitational field it is in.

Gravitational potential energy store (J) =	**mass (kg) x**	**gravitational field strength (N/kg) x**	**change in height (m)**

E_p = mgh

Unit conversions:
kJ to J: x 1000
cm to m: ÷ 100
km to m: x 1000
g to kg: ÷ 1000

Note: weight = mass x gravitational field strength

W = m x g

Therefore, we have a second formula for E_p

E_p = Weight x change in height

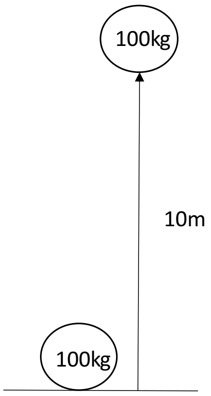
$E_p = W \times \Delta h$

Example: What is the gravitational energy required to lift a 100 kg mass up by 100 m?
Gravitational field strength = 9.81N/kg

Use the EVERY model to complete calculations:
E = equation
V = values
E = enter results
R = result
Y = units

E	$E_p = m \times g \times h$
V	m = 100 kg; g = 9.81; h = 100 m
E	$E_p = 100 \times 9.81 \times 100$
R	$E_p = 98100$
Y	J

E_p = 98100 J



5. Specific Heat Capacity (c) and Power

The amount of energy needed to raise the temperature of 1 kg of a substance by 1 °C.

Change in thermal energy (J) =	**mass (kg) x**	**specific heat capacity (J/kg°C) x**	**change in temperature (°C)**

$\Delta E = mc\Delta T$

Unit conversions:
kJ to J: x 1000
g to kg: ÷ 1000

Example: How much energy is released into the surroundings when a cup of tea holding 250g of fluid cools from 90°C to 20°C? c = 4200 J/kg°C

Use the EVERY model to complete calculations:
E = equation
V = values
E = enter results
R = result
Y = units

E	$\Delta E = m \times c \times \Delta\theta$
V	m = 250 g = 0.25 kg; c = 4200; $\Delta\theta$ = 90-20 = 70
E	$\Delta E = 0.25 \times 4200 \times 70$
R	73 500
Y	J

ΔE = 73500J or 73.5 kJ

Power

Power is the rate at which energy is transferred and is measured in watts.

1 watt = 1 joule of energy transferred per second.

Power (W) = energy transferred (J) ÷ time (s)

Power (W) = work done (J) ÷ time (s)

P = E ÷ t

Unit conversions:
kJ to J: x 1000
minutes to seconds: x 60
hours to seconds: x 3600
W to kW: ÷ 1000

Example. Calculate the power of a motor that uses 60,000 J of energy to lift an object in 20 seconds. Give your answer in kW.

E	P = E ÷ t
V	E = 60 000J; t = 20 s
E	P = 60 000 ÷ 20
R	3000
Y	W

P = 3000W or 3kW

A more powerful device can transfer more energy in a given time or will transfer the same amount of energy in a faster time.

6. Conservation of Energy

Dissipation of energy	Wasting energy. More energy needs to be put into appliance to account for dissipated energy. Useful dissipation of energy example: back of a fridge Example of dissipation of energy is bad: light bulbs, engines and TV's as heat
Conservation of energy	Energy can be transferred usefully, stored or dissipated, but it cannot be created or destroyed
Heat	When an object is heated, thermal energy is being transferred to it
Temperature	A measure of hot or cold something is

Reducing Wasted Energy (dissipated energy)	
Friction	Between two moving objects causes thermal energy to be dissipated. It can be reduced by lubrication.
Lubrication	• Friction between two moving objects causes energy to be dissipated as sound and to the thermal store.
Insulation	Reduces energy transfer by heating
Cavity wall insulation	Fills the air gap between the inner and outer wall reducing heat loss by convection.
Loft insulation	Reduces heat loss by convection.
Double glazing	• Creates an air gap between the two panes of glass to reduce energy loss by conduction. • Gases are good insulators
Draught excluders	Reduce energy loss by convection when placed around windows and doors.
Reflective material behind radiators	To keep infrared radiation in the room

7. Efficiency

Appliance	Useful Energy	Dissipated (wasted) Energy
Light bulb	Light	• Heating the bulb and surroundings
Hair Dryer	• Kinetic energy of the fan to push air • Heating of the air	• Sound of the motor. • Heating of the dryer and surroundings
Electric Motor	• Kinetic energy of objects driven by motor. • Gravitational potential energy of objects lifted by motor	• Heating of the motor and surroundings. • Sound of the motor turning

Efficiency

An efficient device wastes less energy than a less efficient device. It can be calculated as a decimal or multiplied by 100 to give a percentage.

$$\textbf{Efficiency} = \frac{\textbf{useful energy output}}{\textbf{total energy output}} \qquad \textbf{Efficiency} = \frac{\textbf{useful power output}}{\textbf{total power input}}$$

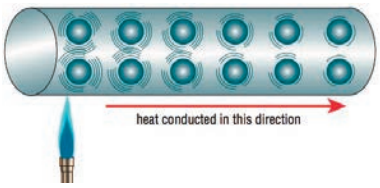
Example:. Calculate the wasted power and efficiency of a motor that has a rated power of 500W and transfers 300W usefully.

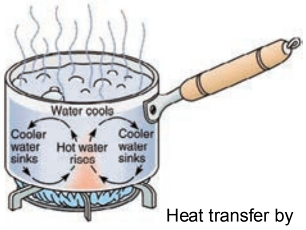
Wasted power = input power - output power = 500 – 300 = 200W

$$\text{Efficiency} = \frac{300}{500} = 0.6 \text{ 0r } 60\ \%$$

8. Methods of Heat Transfer

Heat Transfer Method	Description
Conduction (Occurs in solids)	When heated particles vibrate more with an increase in their kinetic energy. They collide more with surrounding particles transferring the heat
Convection (Occurs in liquids and gases)	Particles are free to move (in a liquid and gas). Increase in their kinetic store. Particles move faster. The space between the particles increases, so the density decreases. The warmer less dense region rises and the cooler, denser regions sink.
Infrared Radiation (Occurs in all objects)	The hotter an object the more infrared radiation it emits in a given time. An object at constant temperature emits and absorbs infrared radiation at the same rate A perfect black body absorbs all the infrared radiation that falls upon it and then emits it back at the same rate as it absorbs it.





Heat transfer by convection

Conductivity

How well a material transfers electricity or thermal energy.

Metals have a higher conductivity than non-metals as they have delocalised electrons which can move through the structure transferring energy

The best insulator has **low** conductivity

9. Non-Renewable Energy Resources

Renewable energy resources will never run out. It is an energy resource that can be replenished quickly.

Non-renewable resources will one day run out (fossil fuels). Fossil fuels are coal, oil and natural gas.

Energy Resource	Uses	Advantages	Disadvantages
Coal	Electricity generation, heating, steam trains in some countries	• Reliable energy resource • Low extraction costs • High energy per kg	All fossil fuels are running out. Burning fossil fuels releases carbon dioxide a greenhouse gas which causes global warming. SO_2 found in coal leads to acid rain when burned.
Oil	Electricity generation, heating, basis for petrol and diesel	• Reliable energy resource • Low extraction costs • High energy per kg	Burning fossil fuels releases carbon dioxide a greenhouse gas which causes global warming.
Gas	Electricity generation, heating, cooking	• Reliable energy resource • Gas fired power stations can be started quickly to meet changing energy demands	Burning fossil fuels releases carbon dioxide a greenhouse gas which causes global warming.
Nuclear	Electricity generation Fuel: Uranium or plutonium	• Reliable energy resource • It has the highest energy density per kg of any fuel. • Does not require combustion and therefore does not release carbon dioxide into the atmosphere	The waste products from nuclear plants is dangerous radioactive waste which needs to be stored safely for hundreds of years.

10. Renewable Energy Resources 1

Energy Resource	Uses	Advantages	Disadvantages
Solar Energy	• Heating domestic hot water. • Photovoltaic cells inside solar cells can create electricity to charge batteries. • Electricity generation in large scale solar power plants	• No atmospheric pollution due to burning of fossil fuels • In sunny countries it is more reliable (during the day) • Useful for remote places not supplied by the national grid. • No fuel costs and minimal running costs	• Cannot increase supply to match demand • High initial costs • Unreliable due to weather • Cannot use at night
Wind Power	Electricity generation	• No atmospheric pollution due to burning of fossil fuels • No fuel costs and minimal running costs No permanent damage to the landscape when removed. • Fast start-up	• Visual and noise pollution • Cannot increase supply to match demand • High initial costs • Cannot generate electricity if there is too little wind • Unreliable
Geothermal	• Electricity generation • Heating	• Reliable • No atmospheric pollution due to burning of fossil fuels	• Few suitable locations (only possible in volcanic areas) • High cost to build power station
Bio-fuels	• Electricity generation • Heating • Fuel for transport	• Carbon neutral (plants absorb carbon dioxide that is released when the fuel is burnt). • Reliable as crops grow quickly	• High costs to refine the fuel • Space for growing food taken up • Forests cleared to make space – decay and burned vegetation release CO_2 and methane.

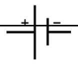
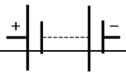
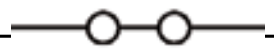
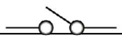
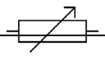
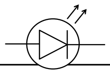
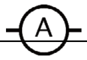
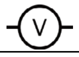
11. Renewable Energy Resources 2

Energy Resource	Uses	Advantages	Disadvantages
Hydro-Electric	Electricity generation	• Can respond immediately to increased demand, fast start-up. • Reliable (except if there is a drought) • No fuel costs and minimal running costs • Potential to be used as part of **pumped storage** scheme	• Requires land to be flooded to create a dammed reservoir • Loss of animal habitats • Relies on rainfall to keep reservoir full unless part of pumped storage system
Tidal barrage	Electricity generation	• No atmospheric pollution due to burning of fossil fuels • No fuel costs and minimal running costs	• Visual pollution • Difficulty providing access for boats / wildlife • Initial costs are high • Environmental impact during building phase due to multiple vehicles and large amounts of concrete being used
Wave power	Electricity generation	• No atmospheric pollution due to burning of fossil fuels • Smaller solution for limited populations	• Unreliable • Few suitable locations

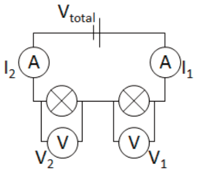
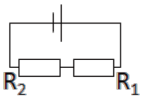
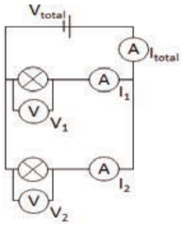
12. Electrical Terms

Keyword	Definition
Ampere (A)	Unit of electric current.
Current (I)	The flow of electrical charge. Measured in Amps (A)
Electric circuit	A collection of electronic components connected by a conductive wire that allows for electric current to flow.
Ohm (Ω)	Unit for resistance.
Potential difference (V)	A measure of energy, per unit of charge, transferred between two points in a circuit Measured in volts (V).
Resistance (R)	Reduces the flow of current. Measured in ohms (Ω).
Resistor	Component that prevents the flow of electric current.
Volt (V)	The standard unit of measure for electric potential (voltage).
Watt (W)	The standard unit of measure used for electric power.

13. Electrical Components

Component	Circuit symbol	Function
Cell		Provides electrons with energy to move around a complete circuit.
Battery		
Closed switch		Break and complete a circuit, so turn on and off.
Open switch		
Variable resistor		Allows the current in a circuit to be varied. Placed in series within the circuit.
Light emitting diode (LED)		Emits light when current passes through it. Placed in series within the circuit.
Ammeter		Used to measure current through a circuit. Placed in series within the circuit.
Fuse		A thin wire that melts if the current gets too high. Placed in series within the circuit.
Voltmeter		Used to measure potential difference (voltage) across a component. Placed in parallel within the circuit.

14. Series and Parallel Circuit Rules

	Series Circuit	**Parallel Circuit**
Number of loops	1	2+
Current	Same all the way round	Shared across the components $I_{total} = I_1 + I_2 + \dots$
Potential difference	Shared across the components $V_{total} = V_1 + V_2 + \dots$	Same across the components $V_1 = V_2 = \dots$
Resistance	Add together $R_{total} = R_1 + R_2 + \dots$	Total resistance will decrease if two or more resistors are added in parallel. Resistors in parallel have the **same pd** across them as the power supply. Adding another loop to the circuit means the current has more than one way it has to go.
	$V_{total} = IR_{total}$	$R_1 = V_{total} / I_1$ I_1 = current flowing through R_1 R_1 = Resistance of lamp 1
Example of a circuit	 	

15. Current, potential difference and resistance

The current (I) through a component depends on both the resistance (R) of the component and the potential difference (V) across the component.

The resistance of an electrical component can be found by measuring the electric current flowing through it and the potential difference across it.

Ohm's Law

At a constant temperature, the potential difference is **directly proportional** to the current.

Potential difference (V) = Current (A) x Resistance (Ω)

V = IR

Resistance is the opposite to current:

The higher the resistance of a circuit, the lower the current

Good conductors have a **low** resistance and insulators have a **high** resistance

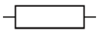
The current through a component depends on both the resistance *R* of the component **and** the potential difference *V* across the component

The **greater** the resistance *R* of the component, the **lower** the current for a given potential difference *V* across the component

The **lower** the resistance *R* of the component, the **greater** the current for a given potential difference *V* across the component

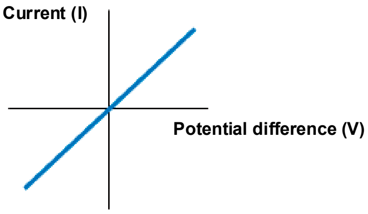
16. I-V Characteristics and Circuit Devices 1

Fixed Resistor



Purpose: Limits the current in a circuit.

At a constant temperature, the potential difference is **directly proportional** to the current.
If the potential difference increases, the current increases.
The resistance doesn't change when the current changes.
Obeys Ohm's law. It is an ohmic conductor.
Obeys V = IR



If the temperature changes, the resistance will change.

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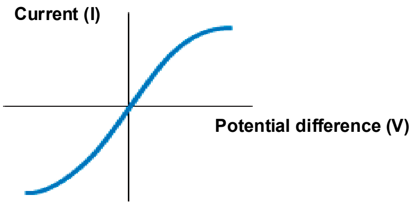
17. I-V Characteristics and Circuit Devices 2

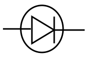
Filament bulb

Property: Emits light when current flows through it.

As the current increases, the filament wire gets hotter. The higher the current, the higher the temperature.
Resistance increases.
Harder for current to flow.
Graph gets less steep.
It is a non-ohmic conductor

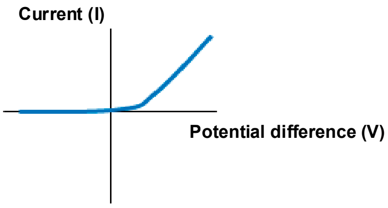


Diode



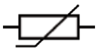
Property: allows current through in only one direction

The resistance depends on the direction of the current. As a diode only lets current flow in one direction, it has a very high resistance in the opposite direction, which makes it hard for the current to flow that way.
It is a non-ohmic conductor



18. I-V Characteristics and Circuit Devices 3

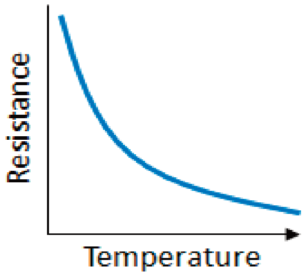
Thermistor



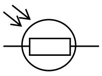
Use: central heating thermostats

High temperature– low resistance

Cold temperature – high resistance



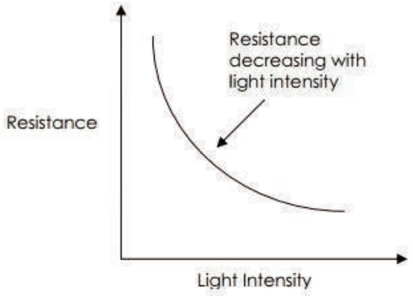
Light Dependent Resistor (LDR)



Used for: Automatic night lights

Bright light – low resistance

Darkness – high resistance



19. National Grid and AC DC supply

National Grid: A network of cables and transformers that connect power stations to consumers.

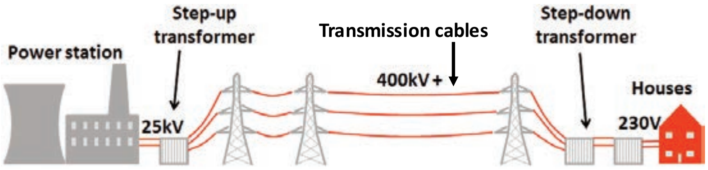
How step up transformers makes the National Grid efficient:

- Increases the potential difference
- Decreases the current
- Less energy loss

A huge amount of power is needed.

Increase efficiency: Use a high potential difference but a low current.

A high current would cause the wires to heat up, wasting a lot of energy (dissipated as heat).

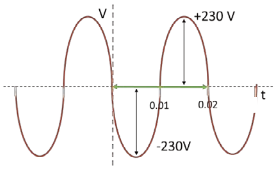


Alternating Current (AC)

The current constantly changes direction. It is produced by an alternating voltage where the positive and negative ends keep alternating.

The UK mains supply is AC at 230V.

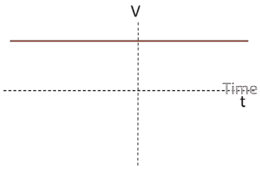
It has a frequency of 50Hz.



Direct Current (DC)

The current always flows in the **same direction**.

Batteries produce a DC voltage.



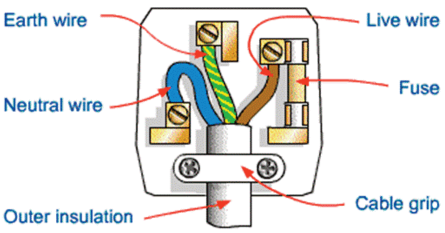
	Underground cables	Overground cables
Advantages	No visual pollution Less affected by the weather	No need to dig up the ground. Easy to repair
Disadvantages	Bigger disturbance to the land Difficult to access to repair	Visual pollution Affected by the weather

20. Electricity in the home

Electrical Wiring

Most electrical appliances are connected to the mains with a three-core cable (3 copper wires coated in insulating plastic).

Wire	Colour	Voltage (V)	Purpose
Live	Brown	230	Provides an alternating potential difference
Neutral	Blue	0	Completes the circuit carrying the current out of the appliance
Earth	Green and yellow	0	A safety feature. Prevents the appliance becoming live if there is a fault so does not normally carry a current.



Live Wire

If you touch the live a large pd is produced across your body and the current flows through you.

This electric shock can injure or kill you.

A connection between the live and earth creates a low resistance path to earth so a large current will flow.

This could cause a fire.

Fuses are placed in series with the live wire to limit the amount of current flowing in a circuit. If a fault occurs the current can be very high, so a fuse is used for safety.

A fuse is a thin piece of wire which all the current flows through, it gets hot and melts if too high a current flows through it, preventing any current flow.

Double Insulated Appliances

Some appliances have no earth wire.

They have a plastic non-conducting outer case and are designed so that the live and neutral wires cannot come into contact with the external casing.

This can be done by placing the wire terminals inside a plastic surrounding box.

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21. Electrical power and charge

Power

Energy in an electrical circuit is transferred by a moving charge. The charge has to work against resistance, so work is done. Work done is the same as energy transferred and depends upon power.

Energy transferred (J) = Power (W) x Time (s)

E = Pt

e.g. How much energy is transferred by a 3kW kettle in 2 minutes.

E E = Pt
V P = 3 kW = 3000W and t = 2 min = 120s
E E = 3000 x 120
R E = 360 000
Y J

E = 360 000J or 360 kJ.

Power Calculations

Power (W) = Current (A) x Potential difference (V)

P = IV

Power (W) = Current^2 (A) x Resistance (Ω)

P = I^{2}R

Charge

Energy transferred (J) = Charge (C) x Potential difference (V)

E = QV

Charge (C) = Current (A) x Time (s)

Q = It

An amp is the amount of charge flow per second.
1 amp = 1 coulomb per second.

Unit conversions

kJ toJ	x 1000
minutes to seconds	x 60
hours to seconds	x 3600

22. Static electricity and electric fields

Static electricity

- When certain insulating materials are rubbed against each other they become electrically charged. Negatively charged electrons are rubbed off one material and on to the other.
- The material that gains electrons becomes negatively charged.
- The material that loses electrons is left with an equal positive charge.
- Two objects that carry the same type of charge repel.
- Two objects that carry different types of charge attract.

Sparking (electric shock)

- Caused by the build-up of electrostatic charge
- Occurs when two objects which are charged by friction and become oppositely charged and have a surplus of electrons so large that the electrons 'jump' across to an object that is neutral.
- Causes a small current to flow between the objects, called a spark.

Electric Fields

•A charged object creates an electric field around itself

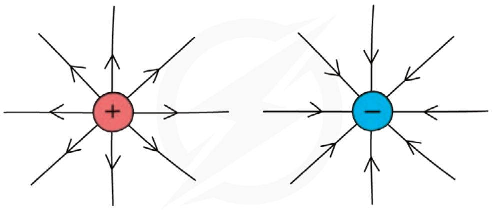
•Shown by electric field lines

•Fields lines always point **away** from **positive** charges and **towards negative** charges.

•The strength of an electric field depends on the distance from the object creating the field:

•The field is strongest close to the charged object - this is shown by the field lines being closer together

•The field becomes weaker further away from the charged object - this is shown by the field lines becoming further apart



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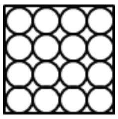
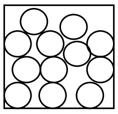
23. The particle model



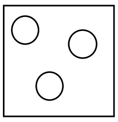
Solids

Have **strong forces** between particles or molecules, holding them close together in a **fixed**, **regular** arrangement. The particles can only vibrate around fixed positions.



Liquids

Have **weaker forces** between particles so although the particles are close together they can **flow** over each other at low speeds in random directions.



Gases

Have almost **no forces** between particles. Have **more energy** and are **free to move** in random directions and speeds.

Density

Closer the particles, the denser the material

Density (kg/m^3) = mass (kg) ÷ volume (m^3)

Density (g/cm^3) = mass (g) ÷ volume (cm^3)

***p* = m ÷ v**

e.g. What is the density of 1kg of water?

Volume of 1kg of water = 0.001m^3.

E	*p* = m ÷ v
V	m = 1kg and v = 0.001m^3
E	Density = 1 ÷ 0.001
V	1000
Y	kg/m^3

24. Internal Energy

If we increase the energy of the particles, it will either:
- Increase the temperature of the substance
- Change its state i.e. change from a solid to a liquid

Internal energy (energy stored by particles in a system) = Kinetic energy of particles (e.g. vibration of atoms) + Potential energy of particles (spacing between the particles)

Temperature is a measure of the average kinetic energy of the particles.
A temperature change depends on the mass of substance, what it is made from and the energy input (see specific heat capacity).
If the substance is heated sufficiently particles have enough energy in their kinetic stores to break the bonds holding them together and so a change in state occurs.
All changes of state do not affect the kinetic energy of the particles so are constant temperature processes.

Evaporation of a liquid: The particles at a liquid's surface sometimes gain enough energy to leave the surface as a gas

Increase rate of evaporation by:
-Increasing the surface area of liquid.
-Increasing the temperature of the liquid.
-Creating a flow of air across the liquid's surface.

Condensation of a gas: The water molecules that are in the air can hit a cool surface, cool down and therefore stay there.

Increase rate of condensation by:
-Increasing surface area
-Reducing surface temperature

25. Specific latent heat

Specific Latent Heat – the energy needed to change the state of 1kg of a substance

Thermal energy (J) = mass (kg) x specific latent heat (J/kg)

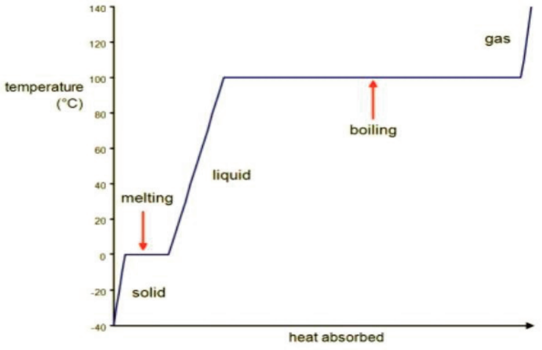
E = ml

e.g. How much energy is required to melt 1.5kg of ice. L_f water = 334 kJ/kg.

E	E = ml
V	mass = 1.5kg and specific latent heat of fusion = 334kJ/kg
E	E = ml = 1.5 x 334 000
V	E = 501 000
Y	J

E = 501 000J or 501 kJ

Specific latent heat of fusion (l_f) = change of state from solid to liquid at a constant temperature
Specific latent heat of vaporisation (l_v) = change of state from liquid to vapour at a constant temperature



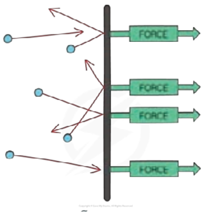
Gradient of the line = specific heat capacity of the substance.
Steeper the line, the higher the specific heat capacity of the substance

Horizontal line = specific latent heat
Longer the horizontal line = greater the specific latent heat of fusion/vaporisation

26. Particles in gases

Gas Pressure:

When the particles in a gas collide with the side of the container they exert a force on it. This force acts at right angles to the container walls.



Pressure = force exerted p a.

In a sealed container, the gas pressure is the total force of all the particles on the area of the container walls.

Increasing the temperature of the gas (whilst keeping the volume constant). Pressure and temperature are **directly proportional** to each other

- increases pressure
- Increases the average kinetic energy of the particles. Particles move faster so collide with the sides more often and with more momentum
- A larger total force is exerted
- The pressure increases.

Work Done

Work is done when energy is transferred by applying a force.

Work done on a gas increases its internal energy. This can increase the temperature of the gas.

Pumping up a bike tyre does work mechanically. The gas exerts a force on the plunger (due to pressure). To push the plunger down against this force, work must be done. Energy is transferred to the kinetic stores of the gas particles, increasing the temperature.

For a fixed mass of a gas held at a constant temperature:

Constant = Pressure (Pa) x volume (m^3)

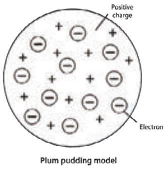
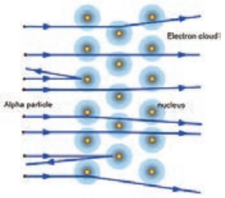
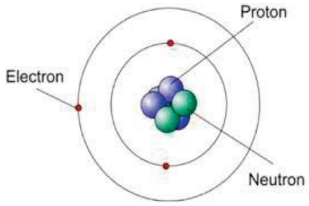
Pressure and volume are **inversely proportional** to each other

- When the volume **decreases** (compression), the pressure **increases**
- When the volume **increases** (expansion), the pressure **decreases**
- The key assumption is that the **temperature** and the **mass** (and number) of the particles remains the same

By increasing the volume:

- The particles will bump into the container walls less frequently
- Particles must travel further between each impact with the container
- Reduces the total force per metre of surface area
- Pressure reduces.

27. Atomic models

Atomic model	**Plum pudding model**		**Nuclear model**		
Diagram					
Discovery	Electron	Positive nucleus in the centre of the atom	Electrons occupy shells	Neutrons	• Atomic radius: 1 × 10^{-10} m • Radius of a nucleus is less than 1/10 000 of the radius of an atom. • Most of the atom is empty space
Description	The atom is a ball of positive charge with negative electrons embedded in it.	Positively charged alpha particles were fired at thin gold foil. Most alpha particles went straight through the foil. A few were deflected in different directions by the atoms in the foil. It showed that the mass of an atom was concentrated in the centre (the nucleus) and the nucleus was positively charged.	Shells are also known as energy levels	Proved the existence of isotopes	
Discovered by	Thompson	Rutherford	Bohr	Chadwick	

28. Isotopes and Radiation

Isotopes: Atoms of the same element that have different numbers of neutrons but the same number of protons and electrons.
They have the same chemical properties but different physical properties.

$^{16}_{8}O$	8 protons, 8 electrons and 8 neutrons
$^{18}_{8}O$	8 protons, 8 electrons and 10 neutrons

Isotopes that give out nuclear radiation are called radioactive isotopes.
Radioactive atoms have an unstable nucleus.
They give out (emit) radiation from their nucleus.
Doing this makes the atom more stable

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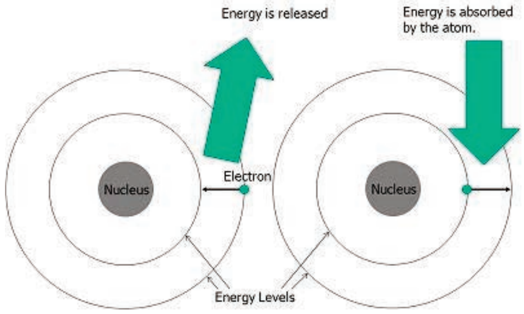


When an electron moves to a lower energy level, the electron releases electromagnetic radiation (left hand picture).

When an electron moves to a higher energy level, the electron absorbs electromagnetic radiation (right hand picture).
The further the energy level (shell) from the nucleus, more energy is required to move the electron **up** to that level.

29. Nuclear Radiation

	Alpha	Beta	Gamma
Symbol	$^{4}_{2}\alpha$	$^{0}_{-1}\beta$	$^{0}_{0}\gamma$
What is it?	Helium nuclei	Fast moving electron	Electromagnetic wave
Stopped by	Paper, thin sheet of aluminium and lead	Thin sheet of aluminium and lead	Lead
Ionising power (how easy it is to form an ion)	Strong	Weak	Very weak
Penetrating power	Low	Medium	High
Range in air	Few cm	Several metres	Many metres
Uses	Smoke alarms	Monitor thickness of paper and detect leaks in pipes.	Treat cancer. Sterilise medical equipment.

Keyword	**Definition**
Decay	A process by which a radioactive nucleus changes into a stable nucleus
Random	Impossible to predict when each individual nucleus will decay
Spontaneous	Impossible to make a decay any more/less frequent e.g. increasing temperature of pressure

30. Nuclear equations and half lives

Alpha decay causes the **charge** to decrease by 2 and **mass** to decrease by 4 as the nucleus releases the alpha particle

$${}^{219}_{86}\text{radon} \longrightarrow {}^{215}_{84}\text{polonium} + {}^{4}_{2}\text{He}$$

Beta decay causes the **charge** of the nucleus to **increase** but the mass remains the same. Within the nucleus a neutron is changed into a proton and releases an electron (beta particle)

$${}^{14}_{6}\text{carbon} \longrightarrow {}^{14}_{7}\text{nitrogen} + {}^{0}_{-1}\text{e}$$

Gamma rays do not change the mass or charge of the atom they are emitted from

Neutrons can also be an emitted form of non-ionising radiation

Half-Life:

The time taken for the number of radioactive nuclei in an isotope to halve.

Activity (the rate at which a source decays) is measured in Becquerel's Bq (1Bq = 1 decay per second).

e.g. if the initial activity of a sample is 600Bq what will it be after two half-lives?

1 half life = 600 ÷ 2 = **300Bq**

2 half lives = 300 ÷ 2 **= 150Bq**

e.g. What fraction remains radioactive after 40 years if the half-life of an isotope is 10 years?

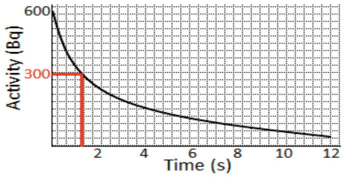
Number of half-lives = 40/10 = 4 half-lives.

After 1 half life – ½ remains

After 2 half lives - ¼ remains

After 3 half lives – ⅛ remains

After 4 half lives - 1/16 remains or 6.25%



Finding half-life from a graph:

- Mark where half the activity level is.
- Find the corresponding time (1.8s in this example)

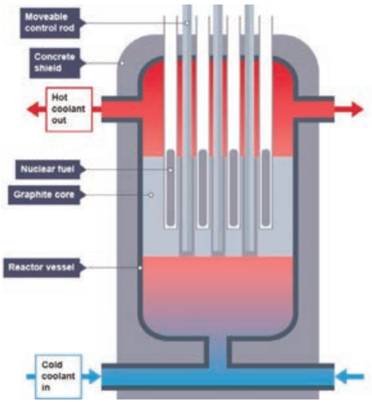
31. Applications of radiation, contamination and irradiation

Applications of radiation	**Radioactive contamination**	**Irradiation**
Destruction of unwanted tissue (cancer) or imaging internal organs. Radio-isotopes with a short half-life are used to limit any damage. Alpha radiation cannot be used for imaging because it cannot penetrate body tissue and it is highly ionising. Over exposure to ionising radiation can damage cells and lead to cancer	The unwanted presence of radioactive materials. The level of hazard depends on the type of radiation and the amount of time you are exposed. Nuclear power plant fuel rods and medical equipment with radioactive sources can have sources that we need to store safely for long periods of time at the end of their useful life.	Where an object is deliberately exposed to a radioactive source. Used to sterilise medical equipment and food. The irradiated object does not become radioactive, so it is safe.

Natural background radiation	It comes from either natural sources such as cosmic rays or radioactive rocks.
Man-made radiation	Medical x-rays or radiotherapy Nuclear testing or accidents e.g. Chernobyl
Dose	The amount of radioactivity we are exposed to. Measured in sieverts (Sv). 1000 mSv = 1Sv How big a dose you receive will depend on where you live and what your job is.
Why radioactive waste should have a short half-life	Activity decreases quickly Risk of harm decreases quickly

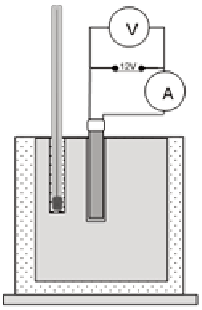
32. Nuclear fission and fusion

	Nuclear Fusion	Nuclear fission
How it occurs	Lighter nuclei join to form heavier nuclei Some of the mass of the nuclei is converted to energy	Neutron absorbed by a uranium nucleus Nucleus splits into two parts. Neutrons are released Gamma rays are emitted.
Requirements for the process to occur	Extremely high temperatures and high density	The unstable nucleus must absorb a neutron. As it splits into two, it emits 2 or 3 neutrons, plus gamma rays. These neutrons then split other unstable atoms creating a chain reaction. All the products of fission have kinetic energy.
Uses	Stars, including the Sun, use nuclear fusion to produce energy	**Nuclear power plants:** reliable source of energy **Nuclear reactor:** The energy released is used to heat water. The chain reaction is controlled to release energy as required. **Nuclear weapons:** The energy is released in an uncontrolled chain reaction. **Generation of electricity:** Fuel is deuterium which can be made from sea water. Does not create radioactive waste that needs to be stored.



Hot coolant out	Used to heat water to create steam and turn a turbine
Graphite core (moderator)	Used to slow down neutrons, so they are more easily absorbed by fuel rods.
Control rods	When lowered, prevent neutrons travelling between fuel rods, slowing down the rate of the chain reaction.

33. Required practical 1: Specific Heat Capacity



Method

1. Take a 1 kg block of copper.
2. Place an immersion heater in the larger hole in the block.
3. Connect the power supply to the joule meter (reset to read 0 Joules).
4. Connect the joule meter to the 12V immersion heater.
5. Place the thermometer into the other hole in the block.
6. Switch the power pack to 12 V. Turn it on.
7. After 1-minute record the temperature of the block and the reading from the joule meter.
8. Continue taking readings every minute until 10 minutes have passed.

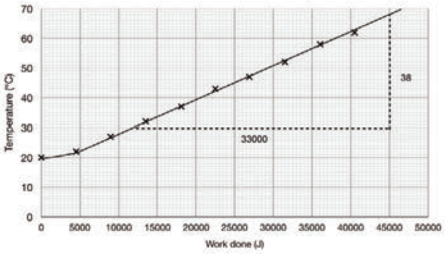
IV - Work done – (energy transferred to block measured by joulemeter)
DV - temperature
CV – Copper block of 1kg mass

Sources of Error

Heat is lost to the surroundings due to lack of insulation
The immersion heater is not fully immersed into the block
The graph may be curved at the start because it takes time for the heater and block to transfer the energy

Processing data

Plot graph work done against temperature
Specific heat capacity = 1 ÷ gradient

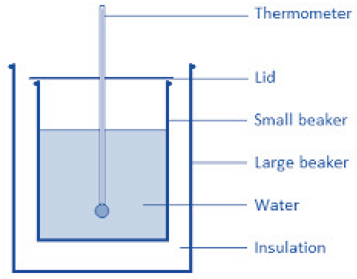


34. Required Practical 2: Thermal Insulation

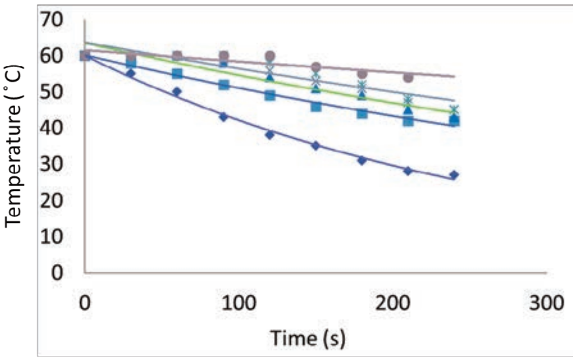
Method

1. Pour 200 cm^3 of hot water into a 250 ml beaker with a single layer of insulating material around it.
2. Use a piece of cardboard as a lid for the beaker.
3. Insert the thermometer through the hole in the cardboard lid
4. Record the temperature of the water and start the stopwatch.
5. Record the temperature of the water every 30 seconds for 5 minutes.
6. Repeat steps **1–5** increasing the number of layers of insulating material wrapped around the beaker until you reach 4 layers.
7. Repeat the experiment with no insulation around the beaker.
7. Plot a graph of temperature versus time.

IV – Time (s)
DV – Temperature change
CV – Volume of water, material of insulation, starting temperature.



The more layers of insulation the longer it takes for the temperature to drop, indicating a better insulator.



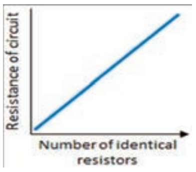
35. Required Practical 3: Resistance of a wire

Method:

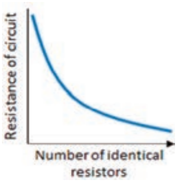
1. Set up equipment as shown in the diagram.
2. Connect the crocodile clips to the resistance wire, 100 cm apart.
3. Record the reading on the ammeter and on the voltmeter.
4. Move one of the crocodile clips closer until they are 90 cm apart.
5. Record the new readings on the ammeter and the voltmeter.
6. Repeat the previous steps reducing the length of the wire by 10 cm each time down to a minimum length of 10 cm.
7. Plot a line graph of length of wire (x axis) against resistance (y axis)

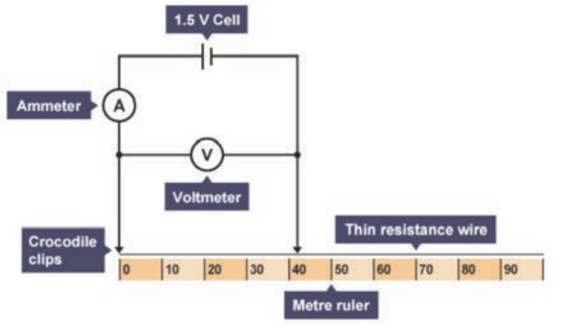
IV: length of the wire
DV: voltage and current
CV: type of wire, diameter of wire and the battery

Resistors in series



Resistors in parallel





Reason for inaccuracy of readings: The resolution of the length of wire is lower due to where the crocodile clips are attached to the wire
Improve accuracy of readings: Turn off the circuit between the readings. This will stop the wire heating up and the temperature changing

Possible errors: Wire heating up and increasing resistance, incorrect reading of ammeter and voltmeter and internal resistance of equipment

Conclusion: The length of the wire is **proportional** to the resistance of the wire.

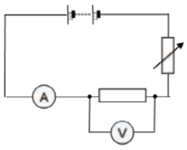
36. Required practical 4: Component IV characteristics

IV—Potential Difference (Volts)

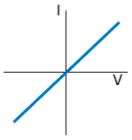
DV—Current (Amps)

CV— Same components, voltage from power pack, temperature – take the readings, immediately, Repeats to reduce the impact of outliers.

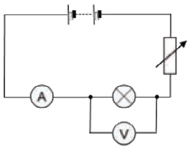
Fixed Resistor



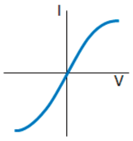
At a constant temperature, the current is **directly proportion** to the voltage. This means it obeys Ohm's Law.



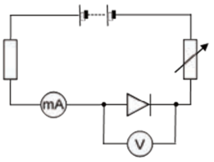
Filament Bulb



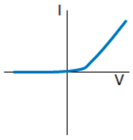
As the voltage increases the current increases. This causes the filament to get hotter, meaning the resistance increases. Therefore as the voltage continues to increase the current levels off.



Diode



The current can only flow in one direction because a diode has a very high resistance in the opposite direction.



Method

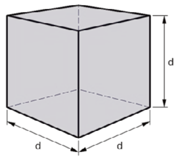
1. Measure the current in the resistor using the ammeter.
2. Measure the potential difference across resistor using the voltmeter.
3. Vary the resistance of the variable resistor
4. Record a range of values of current and potential difference.
5. Ensure current is low to avoid temperature increase.
6. Switch circuit off between readings
7. Reverse connection of the resistor to the power supply.
8. Repeat measurements of I and V in negative direction.
9. Plot a graph of current against potential difference

How to improve accuracy of readings:

- Circuit is switched off between readings
- Temperature does not change

37. Required practical 5: Calculating density

Regular shaped object



1. Measure the length, width and height using a ruler.

2. Calculate the volume (l x w x h)

2. Measure the mass using a balance.

3. Use the equation mass ÷ volume to calculate the density.

Irregular shaped object

1. Using a balance, measure the mass of the object.

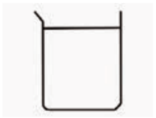
2. Fill a measuring cylinder with 100 cm^3 of water

3. Put object into measuring cylinder

4. Difference in volume of water is the volume of the object

5. Use the equation mass ÷ volume to calculate the density.

Liquid



1. Using a balance, record the mass of a beaker

2. Pour 100 cm^3 of liquid into the measuring cylinder.

3. Pour liquid into a beaker and record the mass of the beaker and its contents

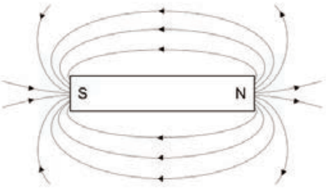
4. Difference in mass of (beaker + contents) from the beaker is the mass of the liquid.

5. Use the equation mass ÷ volume to calculate the density.

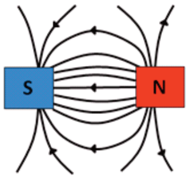
Physics Paper 2 (Triple)

38. Magnets

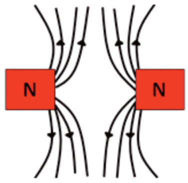
Magnetic metals	Iron (steel), nickel and cobalt
Permanent magnets	Magnetic all the time. Produce their own magnetic field.
Induced magnets	Made from magnetic materials. Only turns into a magnet when held in a magnetic field e.g. core of an electromagnet
North and south pole of a magnet	The part of the magnet where the magnetic field is the strongest
Magnetic field	A region where force is experienced by magnetic materials
Magnetism	A non-contact force from a magnetic to a magnetic field
Field lines	Point away from north and show the direction a north pole would point of it was placedin a field. Closer the field lines in a magnetic field = stronger the magnetic force. Field lines run from north pole to south pole.
Compass	A small bar magnet that is free to move. Always points north in a magnetic field
Evidence that the Earth's core is magnetic	The Earth's iron core creates a magnetic field. The north poles of magnets are attracted to the geographic North Pole of the Earth.



Opposite poles attract



Like poles repel



39. Compasses and magnets

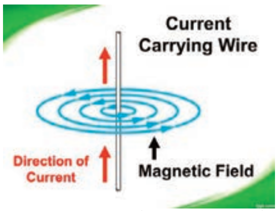
	Iron filings	Plotting compass
Method	Sprinkle iron filings on a piece of paper over the magnet	Use a plotting compass around the magnet with the needle showing the direction.
Advantage	Field lines easily seen	Direction of field lines shown
Disadvantage	Iron filings easily spilt and stick to magnet. Not permanent.	Compasses affected by magnets and do not always work so well. Takes longer.

Using a plotting compass to find the magnetic field of a bar magnet

1. Place magnet on a sheet of (plain) paper
2. Place the compass near the north pole of the magnet
3. Mark the position that the compass needle points to
4. Move the compass so the opposite end of the needle is at this position and mark the new position where the compass tip settles
5. Repeat above until you reach the south pole, then connect the marks together to construct a field line .
6. Add arrows to field lines (pointing north to south).

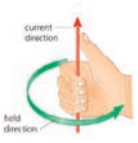
40. Electromagnetism

Magnetic Field around a Wire



- Arrows on the field line show the direction of the magnetic field.
- Reverse the direction of the current, the direction of the magnetic field reverses.
- If the field lines are closer, there is a larger the current.
- Further away from the wire, the weaker the magnetic field

Right Hand Grip Rule



Your thumb points in the direction of the current.

Your fingers point in the direction of the magnetic field.

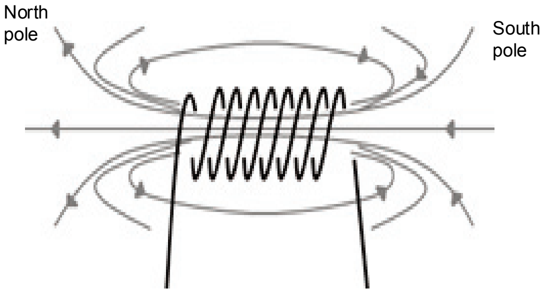
Solenoid: a coil of wire

Outside solenoid: Magnetic field lines are like a bar magnet

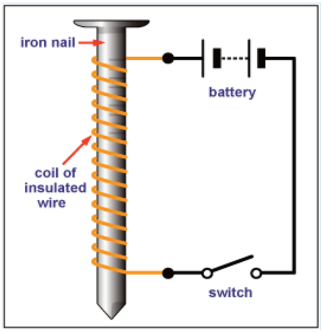
Inside solenoid Magnetic field is strong. Same strength and direction in all places. Field lines are parallel.

Electromagnet: a solenoid with an iron core

Advantages of an electromagnet:
Can be turned on or off. Strength of magnet can be increased or decreased.



41. Investigating electromagnetism



How to make an electromagnet

1. Set up equipment as shown in diagram
2. Wrap the wire around the nail
3. Connect the wire to the power supply
4. Switch on the power supply

How to test the electromagnet

- the more paperclips suspended, the stronger the electromagnet is
- clamp the electromagnet at different distances from the paperclip(s)
- the further the distance from which paperclips can be attracted the stronger the electromagnet is
- use de-magnetised paper clips

IV: Increase strength of electromagnet by (3 x Cs):

a) Increase the number of **coils**

b) Increase the **current**

c) Change the **core**

DV: Number of paperclips picked up

CV: Same type of paperclip.

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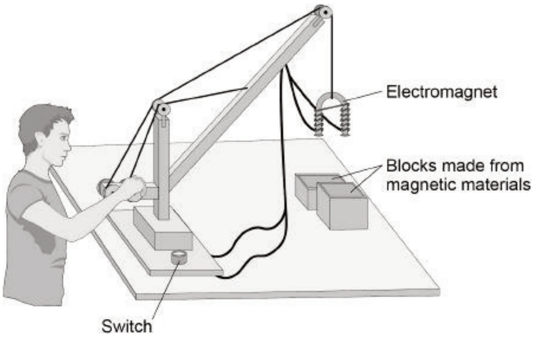
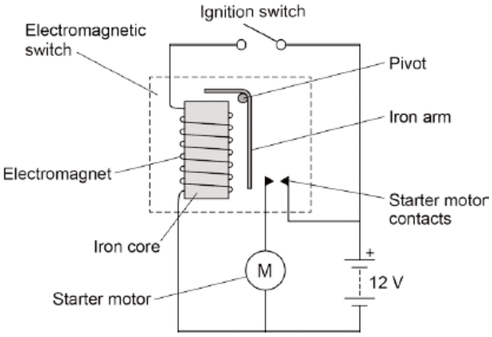
42. Uses for Electromagnets



1. Completing the circuit turns the electromagnet on
2. There is a current in the coil
3. A magnetic field is produced around the coil
4. The iron core becomes magnetised
5. Move electromagnet towards the blocks
6. The block is attracted to the electromagnet
7. Moving the crane moves the block
8. Switching off the current switches off the electromagnet
9. Releasing the block



1. Closing the switch causes a current to pass through the electromagnet
2. The iron core of the electromagnet becomes magnetised
3. The electromagnet attracts the short side of the iron arm
4. The iron arm pushes the starter motor together
5. The starter motor circuit is complete
6. A current flows through the starter motor

43. Fleming Left Hand Rule

When a wire carrying a current is exposed to the magnetic field of another magnet, then a force is produced on the wire at a right angle to the direction of the magnetic field produced.

This is called the motor effect.

force (N) = magnetic flux density (T) × current (A) × length (m)

$F = B\,I\,l$

- F is force in newtons (N)
- B is magnetic flux density (magnetic field strength) in tesla (T)
- I is current in amps (A)
- l is length in metres (m)

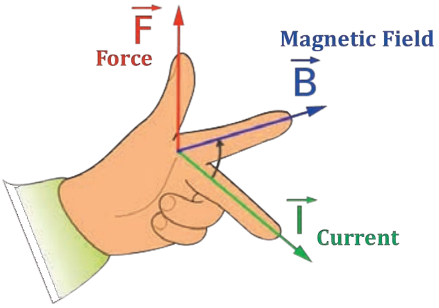
The force on a given length of wire in a magnetic field increases when:

- the current in the wire increases
- the strength of the magnetic field increases

The force is greatest when the direction of the current is 90° to the direction of the magnetic field.

There is **no** motor effect force if the current and magnetic field are parallel to each other.

Use Flemings "left hand rule" to find the direction of the force



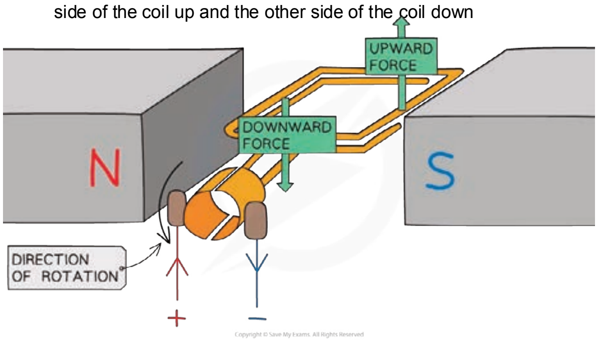
- Use your left hand
- The angle between your index finger and middle finger should be a right angle on the horizontal plane.
- The angle between your index finger and thumb should be a right angle on the vertical plane.
- Your thumb represents the direction of the force.
- Your index finger represents the direction of the magnetic field.
- Your middle finger represents the direction of the current flowing through the wire.

44. Motor Effect

- The motor effect can be used to create a simple d.c electric motor.
- Electricity is used to create motion
- The simple d.c. motor consists of a coil of wire (which is free to rotate) positioned in a uniform magnetic field.

When the current is flowing in the coil at 90º to the direction of the magnetic field:

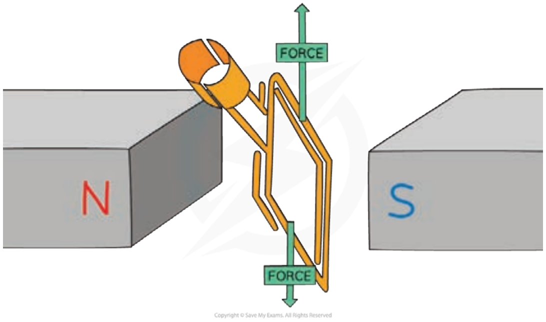
- The current creates a magnetic field around the coil
- The magnetic field produced around the coil interacts with the field produced by the magnets
- This results in a force being exerted on the coil
- As current will flow in opposite directions on each side of the coil, the force produced from the magnetic field will push one side of the coil up and the other side of the coil down



The **split ring commutator** swaps the contacts of the coil. This reverses the direction in which the current is flowing.

The two halves of the split ring commutator ensure that the current supplied to the wire changes direction each half-turn (or that the current supplied is the same direction on each side of the motor) and as a result, the force produced maintains a constant rotation in one direction overall.

Reversing the direction of the current will also reverse the direction in which the forces are acting. As a result, the coil will continue to **rotate**



45. Generator Effect

Generator effect: When a potential difference is induced across a conductor which is experiencing a change in an external magnetic field

Motion is being used to create electricity

Occurs two ways:

Method 1: When a wire cuts through the magnetic fields lines

This induces a potential difference in the wire.

Method 2: When a magnet moved through the coil, the field lines cut through the turns on the coil. This induces a potential difference in the coil

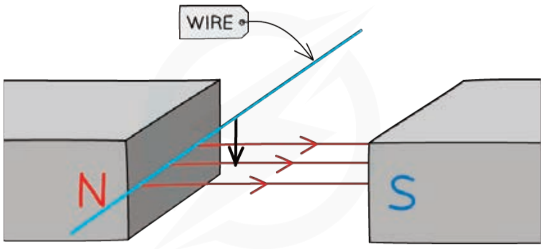
If the magnet is stationary

There is no relative movement between the coil and the magnetic field, so there are no magnetic field lines being cut.

If the magnetic field lines are not being cut then there will not be a potential difference induced

Factors Affecting the Induced Potential Difference

1. The **speed** at which the wire, coil or magnet is moved. Increasing the speed will increase the rate at which the magnetic field lines are cut.
2. The **number of turns** on the coils of wire. This is because each coil will cut through the magnetic field lines and the total potential difference induced will be the result of all of the coils cutting the magnetic field lines.
3. The **size** of the coils. This is because there will be more wire to cut through the magnetic field lines.
4. The **strength** of the magnetic field.



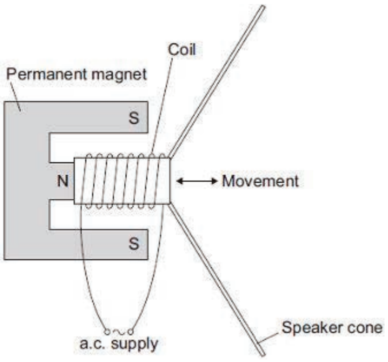
46. How a loudspeaker works

Headphones work because they contain small loudspeakers inside them.

A loudspeaker makes use of the motor effect to produce sound.

Variations in the AC electric current supplied to the device causes variations in the magnetic field produced.

These variations cause the cone in the loudspeaker to move and the vibrations are transferred to the air particles and generate a sound wave.



1. An alternating current is supplied through a coil of wire in the loudspeaker. creating an electromagnetic field around the wire.
2. The electromagnetic field interacts with the permanent magnetic field and a force is produced (the motor effect).
3. The force produced pushes the cone in the loudspeakers outwards.
4. The current is reversed and the force changes direction, pulling the cone back inwards.
5. The vibrations of the cone moving in and out creates vibrations in the air particles, which are transferred as sound waves.
6. The sound waves produced match the electrical signals supplied

47. Uses of the generator effect

AC Generator (Alternator)

•As the coil rotates, it cuts through the field lines

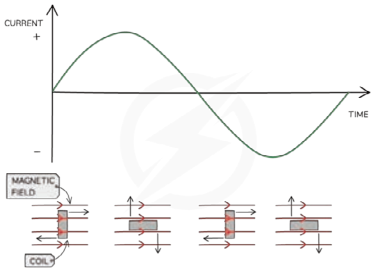
•This induces a potential difference between the end of the coil

Slip rings, attached to the ends of the coil, transfer the current to metal brushes whilst allowing the coil to rotate freely

The A.C. generator creates an alternating current, varying in size and direction as the coil rotates

EMF is greatest when the coil is horizontal, as in this position it cuts through the field at the fastest rate

EMF is smallest when the coil is vertical, as in this position it will not be cutting through field lines



DC generator (dynamo)

•A simple dynamo is the same as an AC generator (alternator) except that the dynamo has a split-ring commutator instead of two separate slip rings

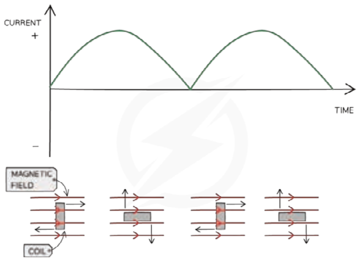
•The split ring commutator changes the connections between the coil and the brushes every half turn in order to keep the current leaving the dynamo in the same direction

•This happens each time the coil is perpendicular to the magnetic field lines

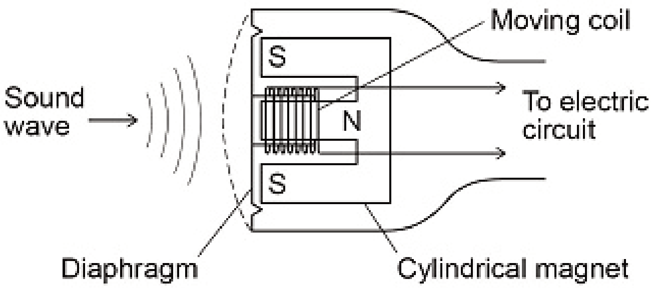
•Therefore, the induced potential difference does not reverse its direction as it does in the alternator

•Instead, it varies from zero to a maximum value twice each cycle of rotation, and never changes polarity (positive to negative)

•This means the current is always positive (or always negative)



48. How a microphone works



How a microphone works

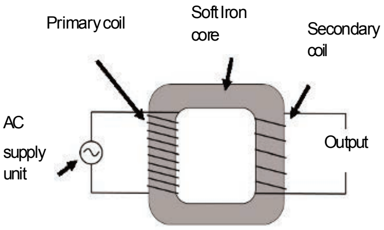
- sound (waves) cause the diaphragm to vibrate
- the diaphragm causes the coil / wire to vibrate
- the coil wire moves through the magnetic field
- a potential difference is induced across the ends of the coil

Function of a microphone: to convert the pressure variations in sound waves into variations in current

49. Transformers

A basic transformer consists of a primary coil and a secondary coil wound on a soft iron core. Iron is used as it is easily magnetised.

Fewer coils → lower potential difference → higher current



How a transformer works:

An alternating current through the primary coil causes an alternating magnetic field around the iron core

This induces an alternating potential difference across the secondary coil

Advantages of a transformer:

The transformer can be adjusted to have different numbers of turns on the secondary coil.

To vary the output potential difference

So that you don’t need a different generator for each type of device

Calculating Potential Difference

The ratio of potential differences on the transformer coils matches the ratio of the numbers of turns on the coils.

$$\frac{\textbf{Voltage in secondary coil } (V_s)}{\textbf{Voltage in primary coil } (V_p)} = \frac{\textbf{Number of turns on secondary coil } (n_s)}{\textbf{Number of turns on primary coil } (n_p)}$$

Assuming that a transformer is 100 per cent efficient, the following equation can be used to calculate the power output from the transformer:

input power = output power

$$V_p \times I_p = V_s \times I_s$$

V_P is input (primary) voltage

I_p is input (primary) current

V_s is output (secondary) voltage

I_s is output (secondary) curren

From Paper 1: Electricity module:

Power (W) = potential difference (V) × current (A)

50. Wave properties

Mechanical Waves travel through a medium (substance).

The particles oscillate (vibrate) and transfer energy.

The particles do not travel along in the wave.

Frequency (f) - the number of complete waves that pass a point every second.

1 wave per second has a frequency of 1Hz (hertz).

Time period (T) - the time for a complete cycle of a single wave.

Frequency (Hz) = 1 ÷ time period (s)

F = 1 ÷ T

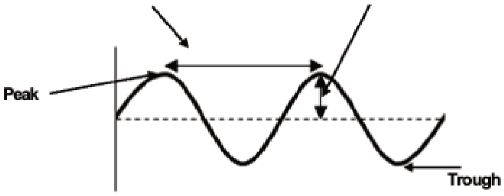
Example: What is the frequency for a wave with a time period of 0.2s

E	f = 1 ÷ T
V	T = 0.2 s
E	f = 1 ÷ 0.2
R	5
Y	Hz

f = 5Hz

Wavelength - the distance between adjacent waves (i.e. from peak to peak or trough to trough)

Amplitude - the maximum displacement from the horizontal mid-line.



Wave speed (m/s) = frequency (Hz) x wavelength (m)

V = f λ

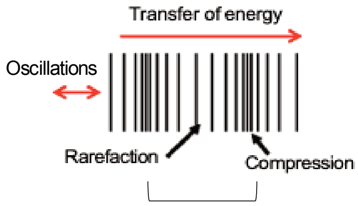
Example: How fast is a wave travelling which has a 3m wavelength and a frequency of 20Hz?

E	V = f x λ
V	f = 20 Hz; λ = 3 m
E	V = 20 x 3
R	V = 60
Y	m/s

51. Transverse and Longitudinal waves

Longitudinal Waves

The **oscillations** (vibrations causing the wave are **parallel** to the direction of **energy transfer**.



One wavelength

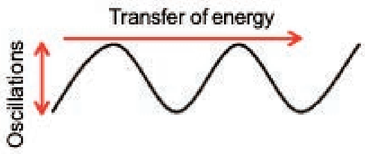
Compression: particles bunch up

Rarefaction: particles spread out

Example: Sound waves

Transverse Waves

The **oscillations** (vibrations causing the wave) are **perpendicular** (90°) to the direction of **energy transfer**.



Example: Light waves, X-rays and water waves (ripples)

All electromagnetic waves

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52. Sound Waves and Speed of Sound experiment

Sound waves are **mechanical longitudinal waves**.
They need a medium to travel through.

The speed of sound can be calculated using:

Speed (m/s) = distance (m) ÷ time (s)

Unit conversions:

km to m:	x 1000
cm to m:	÷ 100
minutes to seconds:	x 60
hours to seconds:	x 3600

Speed of sound experiment

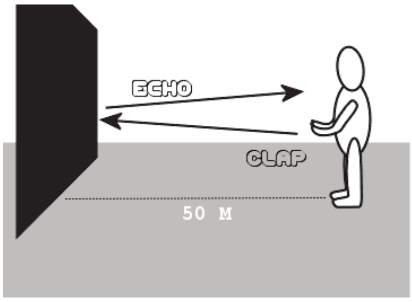
1. Measure the distance between the person and the wall using a metre ruler.
2. Double this distance.
3. Using a stop clock, measure the time taken from the clap being made to hearings it's echo.
4. Use the equation,

   speed = distance ÷ time.

Sound waves

Bigger the amplitude – taller the wave – louder the sound

Higher the frequency – more waves per second – higher pitch



53. Sound and Seismic waves

Human hearing can detect sound in the frequency range of 20Hz to 20,000Hz.

Ultrasound > 20kHz
Infrasound < 20Hz

Ultrasound is used to detect the depth of the sea bed, where inclusions or other defects are found in solid metal and to image soft tissue in humans.

When ultrasound is used to measure the depth of an object, or the distance below a surface to a defect, the signal travels from the transducer to the object and is bounced back to the transducer. The total distance travelled by the sound is twice the depth of the object.

Depth of object (m) = 0.5 x speed of ultrasound (m/s) x time (s)

Seismic Wave type	Description
Primary (P-waves)	• Causes the initial Earth tremor • Longitudinal waves which push or pull on material. • Bend as they travel through the earth's mantle • Refract at boundary between mantle and core • Travels through solids and liquids
Secondary (S-waves)	• Transverse waves that travel more slowly than P-waves • Shake material from side-to-side. • Bend as they travel through the Earth's mantle • Cannot travel through liquid outer core • Travels through solids only
Long (L-waves)	• Arrive last and and cause violent movements on the surface • Only happen in the Earth's crust.

54. Reflection, transmission and absorption of waves

Reflection

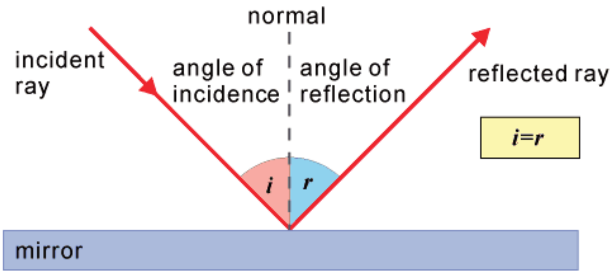
Angles are measured between the wave direction (ray) and a line at 90º to the mirror (boundary)

Normal = an imaginary line drawn at 90º to the surface

The angle of the wave approaching the boundary is called the angle of incidence (i)

The angle of the wave leaving the boundary is called the angle of reflection (r)

Angle of incidence (i) = Angle of reflection (r)



Absorption

Occurs when energy is transferred from the wave into the particles of a substance

Sound waves are absorbed by brick or concrete in houses

Light will be absorbed if the frequency of light matches the energy levels of the electrons

If an object appears red, only red light has been reflected. All the other frequencies of visible light have been absorbed

Transmission

Transmission occurs when a wave passes through a substance

The more transparent the material, the more light will pass through

For the process to count as transmission, the wave must pass through the material and emerge from the other side

When passing through a material, waves are usually partially absorbed

The transmitted wave may have a lower amplitude because of some absorption

For example, sound waves are quieter after they pass through a wall

55. Refraction of waves

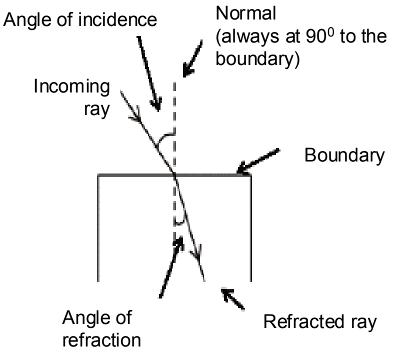
Refraction

Waves change speed when they cross a **boundary** between two materials of different density or a boundary of different depths.

If the wave enters a medium of higher **density** at an **angle** the ray bends towards the normal (see diagram).

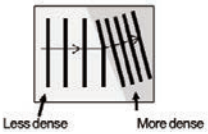
If it enters a medium **along the normal** then the wave does not change direction but the **wavelength** and **speed decrease**.
(waves closer together on diagram below but have not changed direction)

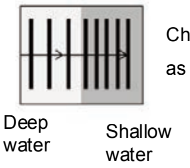
Refraction of Light ray



Wave Front Diagrams

The part of the wave front that enters the more dense medium first, slows down as the rest of the wave front continues at the same speed but has to travel further. The difference in distance and speed causes the wave to refract. A wave travelling from deep to shallow water also refracts.

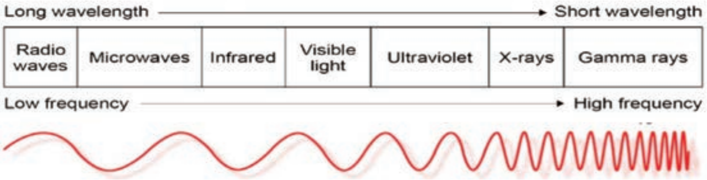




Change in speed but no change in direction as wave entered **along the normal**

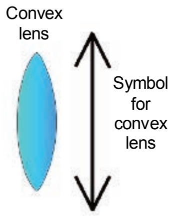
56. Electromagnetic Spectrum

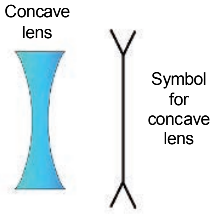
All parts of the EM spectrum travel at the same speed.
They all travel at 300,000,000 m/s.
They are all transverse waves
All parts of the EM spectrum can travel through a vacuum (e.g. space)

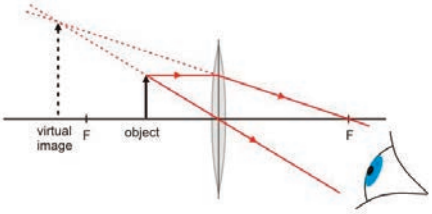


Radio Waves	Used for communication. Used for television and radios. Radio waves can be produced by oscillations in electrical circuits. When radio waves are absorbed they may create an alternating current with the same frequency as the radio wave itself, so radio waves can themselves induce oscillations in an electrical circuit.
Microwaves	Used to communicate with satellites (T.V, mobile Phone) Cooking food.
Infra-red Radiation (IR)	Used for electrical heaters, cooking food, infrared cameras
Visible Light	Optical fibres transmit data using light over long distances
Ultra Violet Radiation (UV)	energy efficient lamps, sun tanning UV can damage surface cells, causing sunburn and increasing the risk of skin cancer.
X-Rays	X-Rays pass through flesh but are absorbed by the more dense bone. Ionising, so can cause mutations in DNA, destroy cells and cause cancer
Gamma Rays	Gamma rays can be used as a tracer. A gamma source is injected and its path through the body can be detected. Both are used to treat cancer as they kill cells. Ionising, so can cause mutations in DNA, destroy cells and cause cancer

57. Lenses and Virtual Image Ray Diagrams

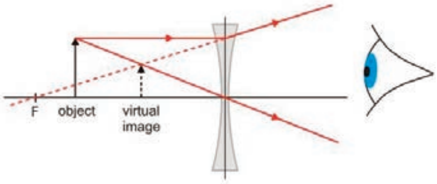






With a convex lens when object is placed at a distance less than the focal length away from the lens the image appears **upright**, **magnified** and is **virtual. Virtual images** cannot be projected on to a screen.

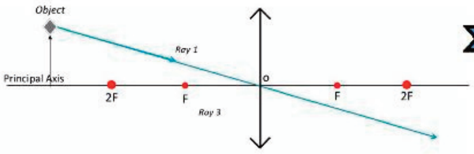
Magnification = $\frac{\text{Image size}}{\text{Actual size}}$



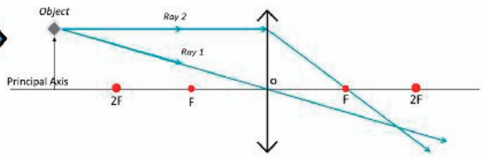
Concave lenses always produce virtual images. The image is **upright, diminished** and **virtual**

58. Ray Diagrams for Convex lens: Real Image

Drawing Ray Diagram for convex lens



Ray 1 - Draw a ray from the object, passing through the optical centre of the lens ‘O’



Ray 2 - Draw a ray parallel to the principal axis, which refracts through the lens, passing through the principal focus

Ray Diagram Key Terms

F = focal point of the lens.

Focal length = Distance from F to the centre of the lens

2F = Twice the focal length.

Depending on how far away from the lens the object is (measured in focal lengths) the image can appear either **magnified** or **diminished** (smaller than the object).

The image produced can be **upright** or **inverted** (upside down compared to the object).

An image is **real** if it can be projected , it will appear on the opposite side of the lens to the object.

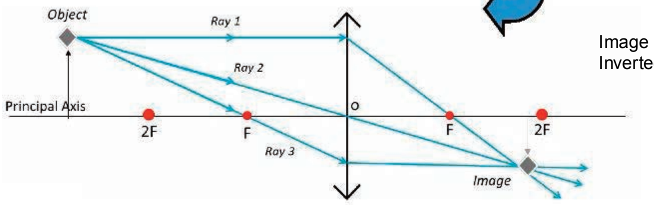


Image is real
Inverted and diminished

Ray 3 - Draw a ray passing through the principal focus (on the same side as the object) and being refracted through the lens, emerging parallel to the principal axis

59. Light

Transparent (window)	Transmits all the incident light through the object enabling a clear image to be seen.
Translucent (obscured glass)	Allows light to pass through but scatters it due to internal boundaries that repeatedly changes the direction of light meaning no clear image is seen through it.
Opaque (wooden block)	Absorbs, reflects or surface scatters all of the light that hits it. No light is transmitted through it

Surfaces and Colour

The colour of an opaque object is determined by which wavelengths of light are more strongly reflected. Wavelengths that are not reflected are absorbed.

- If all wavelengths are reflected equally the object appears white.
- If all wavelengths are absorbed the objects appears black.

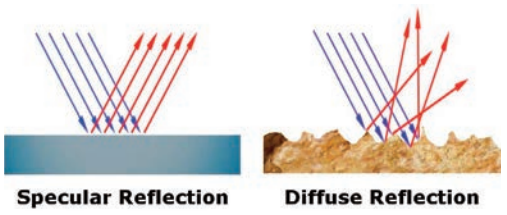
Specular Reflection

Reflection from a smooth, flat surface is called **specular reflection**. This is the type of reflection that happens with a flat mirror. The image in a mirror is **upright** and **virtual**.

In a **virtual image**, the rays appear to diverge from behind the mirror, so the image appears to come from behind the mirror.

Diffuse Reflection

If a surface is rough, **diffuse reflection** happens. Instead of forming an image, the reflected light is scattered in all directions. This may cause a distorted image of the object, as occurs with rippling water, or no image at all. Each individual reflection still obeys the law of reflection, but the different parts of the rough surface are at different angles.



Specular Reflection **Diffuse Reflection**

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60. Black body radiation

All bodies (objects) emit and absorb infrared radiation.
The hotter the body:
•the more infrared radiation it gives out in a given time
•the greater the proportion of emitted radiation is visible light

A perfect black body is a theoretical object.

Properties of a black body:

- It would absorb all the radiation that falls on it
- It would not reflect or transmit any radiation
- An object that is good at absorbing radiation is also a good emitter, so a perfect black body would be the best possible emitter of radiation.

Different temperatures emit different intensities of infrared which are represented on the infrared camera as different shades

All bodies (objects) emit a spectrum of thermal radiation in the form of electromagnetic waves

The intensity and wavelength distribution of any emitted waves depends on the temperature of the body

This is represented on a black body radiation curve

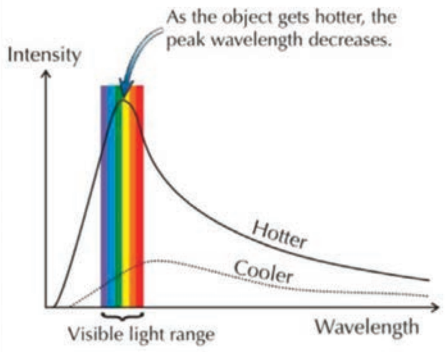
As the temperature increases, the peak of the curve moves

This moves to a lower wavelength and a higher intensity

From the electromagnetic spectrum, waves with a smaller wavelength have higher energy (e.g. UV rays, X-rays)

When an object gets hotter, the amount of thermal radiation it emits increases

This increases the thermal energy emitted and therefore the wavelength of the emitted radiation decreases



61. Forces

Scalar	A quantity which has only magnitude	Speed, distance, time, mass…
Vector	A quantity which has both magnitude and direction	Force, velocity, momentum, acceleration..

Mass: Amount of matter in an object
Measured using a balance
Measured in kg
Weight: A force depending on the object's mass and force of gravity
Measured using a Newton meter
Measured in N

Centre of mass: The point through which the weight of an object acts.
- The **wider** base an object has, the **lower** its centre of mass and it is more **stable**
- The **narrower** base an object has, the **higher** its centre of mass and the object is more likely to topple over if pushed

Contact Force	Involves 2 or more objects that must touch to act on each other	Friction, air resistance
Non contact force	Involves 2 or more objects that do not need to be touching for forces to act on each other	Gravitational force, electrostatic force, magnetic force

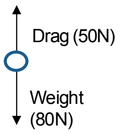
Weight (N) = mass (kg) x gravitational field strength (N/kg)

W = mg
e.g. What is the weight of a 2kg mass on earth

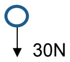
E	W=m x g
V	m = 2kg and g = 9.8N/kg
E	W = 2 x 9.8
R	W = 19.6
Y	N

62. Resultant Forces

Found by adding together any forces acting along the same line (direction) and subtracting any that act in the opposite direction:



The resultant force is 30N (80-50) downwards.



The resultant force is a single force which is equivalent to the 2 forces acting together

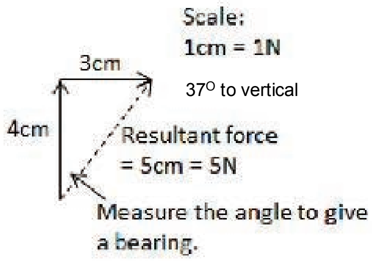
When a **force** moves an object through a **distance**, **energy is transferred** and **work is done**.

To make something move a force must be applied, which requires energy.

The force does work to move the object and energy is transferred between stores.

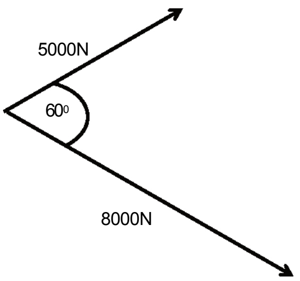
Calculating Resultant Forces using a diagram
A scooter is pushed with 4N north and is blown 3N east by the wind. Find the magnitude and direction of the resultant force.

1. Draw a scale diagram.
2. Join the ends of the two forces (dotted arrow)
3. Measure the length of this line and use the scale to work out the size (magnitude) of the force.
4. Measure the bearing (angle) with a protractor.

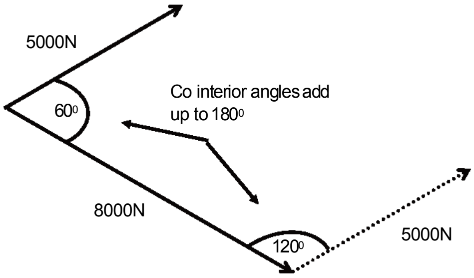


63. Resolving Forces—Parallelogram of forces 1

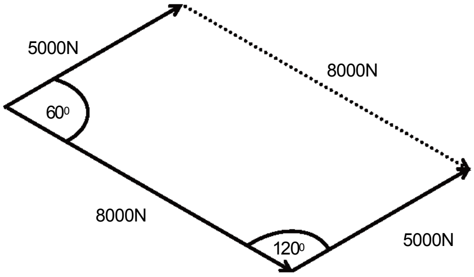
You will be given this vector diagram



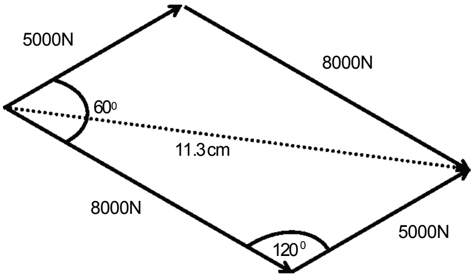
1. Draw the missing side of the parallelogram from the highlighted force



2. Draw in the last side of the parallelogram

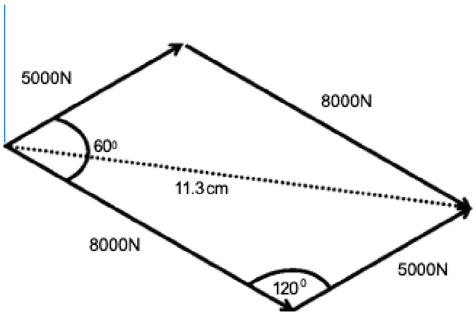


3. Draw the resultant force and measure with a ruler

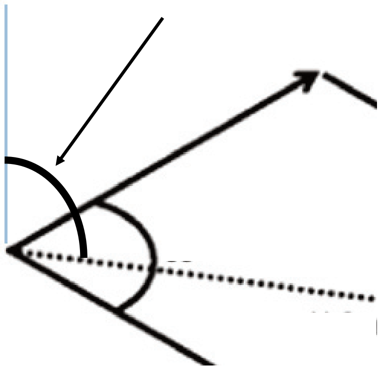


64. Resolving Forces—Parallelogram of forces 2

4. Use your scale to calculate the size of the resultant force



Measure angle to give vector angle e.g 110^0 from vertical



Resultant force length = 11.3 cm

Scale = 1 cm = 1000 N

11.3 x 1000 = 11300N Resultant force = 11300 N

Measure angle resultant force acts at from vertical because vector requires magnitude and direction.

Resultant force = 11.3 kN at 110^0 to vertical

65. Elasticity

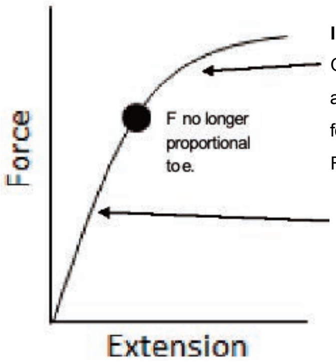
Extension happens when an object increases in length, and Compression happens when it decreases in length.

The extension of an elastic object, such as a spring, is described by **Hooke's law**:

Extension is directly proportional to force:

Force (N) = spring constant (N/m) x extension (m)

F = ke



Inelastically deformed

Object cannot return to its original shape and extension is not directly proportional to force.

F no longer proportional to e. (curved line)

Elastically deformed

Object can return to its original shape and

Extension ∝ force. (Straight Line)

Elastic Potential Energy

A force acting on an object may cause the shape of an object to change.

Elastic objects can store elastic potential energy if they are stretched or squashed. For example, this happens when a catapult is used or a spring is stretched.

Objects can also store elastic potential energy when they are squashed.

Elastic potential energy (J) = 0.5 x spring constant (N/m) x extension^2 (m)

Unit conversions:
kJ to J: x 1000
cm to m: ÷ 100

66. Newton’s laws of motion

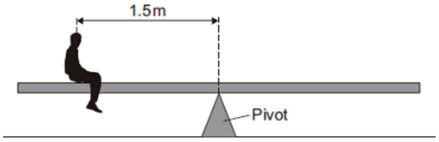
First Law	A body at rest will remain at rest, and a body in motion will remain in motion, unless it is acted upon by an unbalanced force. Inertia is the tendency of a body to remain in the same state of motion	
Second Law	The amount a body accelerates is directly proportional to the force applied to it and inversely proportional to the mass of the body. F = ma e.g. An aeroplane accelerates from a low speed to a high speed with the engines at maximum power At maximum power the forward force of the engines is constant as it accelerates the air resistance increases resultant force = force from engines – air resistance Therefore resultant force decreases acceleration is directly proportional to resultant force	**Inertial mass** is the property of an object which describes how difficult it is to change its velocity Inertial mass = force ÷ acceleration Inertial mass is defined as the ratio of force to acceleration Inertial mass is inversely proportional to acceleration (mass = 1 ÷ acceleration) Larger inertial masses will experience small accelerations Smaller inertial masses will experience large accelerations
Third Law	When two objects interact, the forces they exert on each other are **equal** and **opposite**. This is an **equilibrium** situation - neither object moves because the forces are balanced.	

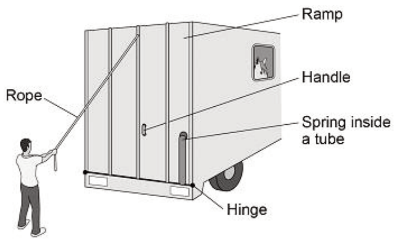
67. Moments and gears

Moments

Moment: The turning effect of a force.
Moments act about a point in a clockwise or anticlockwise direction.
The point chosen could be any point on the object, but the **pivot,** also known as the fulcrum, is usually chosen for calculation purposes.

Moment (Nm) = force (N) x perpendicular distance (m)





Use of moments
Easier to pull down ramp with rope than the handle because
The perpendicular distance from the pivot / hinge to the line of action of the force is greater.
So a smaller force is required

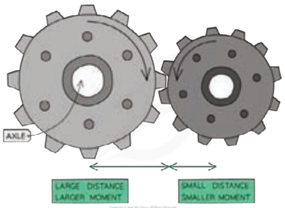
Levers **increase** the size of a **force** acting on an object to make the object turn more easily. The force applied to a lever must act **further** from the pivot than the force has to overcome.

Gears

Gears, like levers, can transmit turning forces. They can transfer turning effects whilst increasing or decreasing the required force.
As one gear turns, the other gear must also turn. Where the gears meet, the teeth must both move in the same direction.

The forces acting on the teeth are identical for both gears (newtons 3rd law equal and opposite), but their moments can be different depending upon the radius from the centre of the gear to where the force is applied (where the gears touch).

If a larger gear is driven by a smaller gear, the large gear will rotate slower but will apply a greater moment for the same force. If a smaller gear is driven by a larger gear, the smaller gear will rotate quickly but will apply a smaller moment.



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68. Momentum

A vector quantity (has size and direction).

Momentum (kg m/s) = mass (kg) x velocity (m/s)

P = mv

Conserved momentum:
total momentum before = total momentum afterwards

e.g. A 2 kg object (A) moving at 3m/s crashes into a 4 kg stationary object (B) causing both objects to move away locked together.
What velocity do they move away at?

Total momentum before = $(m_A \times v_A) + (m_B \times v_B)$
= (2 x 3) + (4 x 0) = 6kgm/s

Total momentum after = 6kgm/s = $(m_A + m_B) \times v_{new}$
V_{new} = 6 / (2+4) = 1m/s

Momentum is a vector therefore the direction is the same because it is a positive answer. A negative sign would show the opposite direction.

$$\textbf{Force} = \frac{\underline{\textbf{change in momentum}}}{\textbf{change in time}}$$

Change in momentum safety features

Seat belts

Seat belts stop you tumbling around inside the car if there is a collision. However, they are designed to stretch a bit in a collision.
This increases the time taken for the body's momentum to reach zero, and so reduces the forces on it.

Air bags

Air bags increase the time taken for the head's momentum to reach zero, and so reduce the forces on it.
They also act a soft cushion and prevent cuts.

Crumple zones

Crumple zones are areas of a vehicle that are designed to crush in a controlled way in a collision.
They increase the time taken to change the momentum of the driver and passengers in a crash, which reduces the force involved.

69. Speed, velocity and acceleration

Typical Speed Walking	1.5 m/s
Running	3 m/s
Cycling	6 m/s
Car	25 m/s
Train	55 m/s
Plane	250 m/s

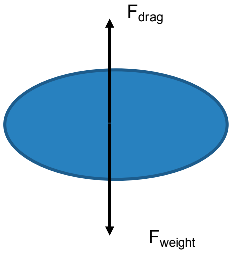
Speed	How fast something is going without reference to a direction. It is a scalar quantity.
Velocity	A speed in a given direction
Acceleration	How quickly something is speeding up, or its rate of change of velocity. Deceleration is how quickly something is slowing down or negative acceleration.

Terminal Velocity

The maximum speed an object will fall at through a fluid (liquid or gas).

As the speed of a falling object increases so does the frictional force (drag) opposing the objects weight (which doesn't change).

The resultant force is therefore reducing until the drag is equal to the weight. Acceleration is reduced to zero and the terminal velocity is reached.



Uniform Acceleration

This can happen due to gravity acting on an object in free fall.

$$v^2 - u^2 = 2\,a\,s$$

v = final velocity (m/s)
u = initial velocity (m/s)
a = acceleration (m/s^2)
s = distance (m)

Velocity and circular motion

When an object travels along a circular path, its velocity is always changing

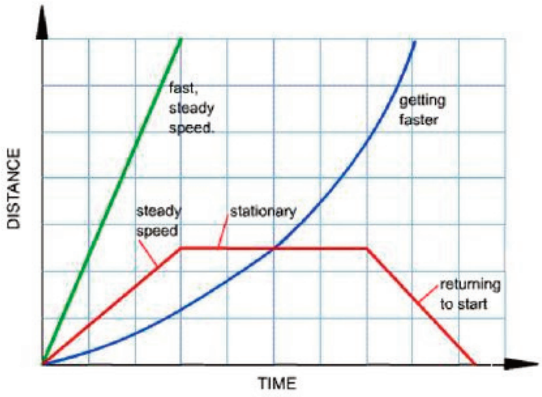
The **speed** of the object moving in a circle is constant (travelling the same distance every second)

The **direction** of travel is always changing as the object moves along the circular path

This means that an object moving in circular motion travels at a **constant speed** but has a **changing velocity**

70. Graphs of Motion

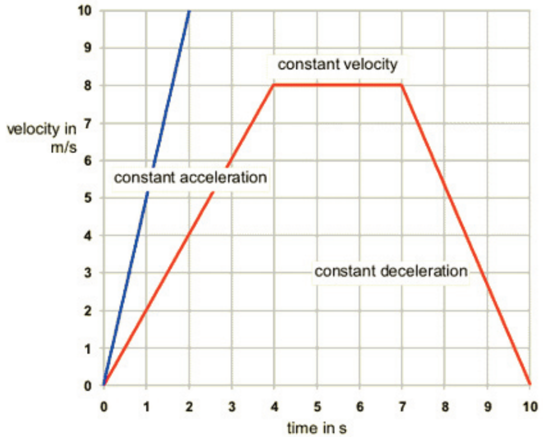
Distance – time graph



Gradient = speed of object

Gradient = $\frac{\text{change in y}}{\text{change in x}}$

Velocity – time graph



Gradient = acceleration of object

Distance travelled = area under the line

Average velocity = (v + u) / 2

71. Thinking, Braking and Stopping Distances

Typical **reaction time** for a person is 0.2-0.9s

Thinking distance – the distance travelled by the vehicle in the time it takes for the driver to react

Braking distance – the distance travelled by the vehicle during the time the braking force acts

Stopping distance= thinking distance + braking distance

Reaction time – the time taken for the driver to react to the stimulus

Thinking distance is affected by:

- Speed
- Your reaction time which is affected by:
  I. Alcohol
  II. Drugs
  III. Sleep deprivation
  IV. Distractions

Braking distance is affected by:

- Speed
- Weather and the road surface e.g. icy
- Condition of tyres e.g. bald tyres cannot get rid of the water in wet conditions leading to skidding
- Quality of brakes

Reaction time experiment:

Ruler drop test

Computer based experiments

When a force is applied to the brakes of a vehicle, **work done** by the friction force between the brakes and the wheel reduces the kinetic energy of the vehicle and the temperature of the brakes increases.

The greater the speed of a vehicle the greater the braking force needed to stop the vehicle in a certain distance.

The greater the braking force the greater the deceleration of the vehicle. Large decelerations may lead to brakes overheating and/or loss of control.

When the car has stopped, the decrease in energy from the kinetic energy store is equal to the work done by the brakes

Work done (J) = Force (N) x distance (m)

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72. Pressure and fluids

Pressure

The pressure in fluids causes a normal **force** (at right angles) to any surface.

The pressure at the surface of a fluid can be calculated using the equation:

Pressure (Pa) = force (N) ÷ area (m^3)

$p=F/A$

Pressure in a column of liquid

The pressure of liquid increases with depth (height). The deeper you are in a swimming pool the greater the pressure acting on you.

Pressure (Pa) = height of column above object (m) x density (kg/m^3) x gravitational field strength (N/kg)

$p=h\rho g$

e.g. What is the water pressure at the bottom of a diving pool which is 6m deep. g – 9.8N/kg, ρ_{water} – 1000kg/m^3

$p=h\rho g$ = 6 x 1000 x 9.8 = 58800Pa or 58.8 kPa

Atmospheric Pressure

The atmosphere is a thin layer of air around the Earth. The density of the atmosphere reduces with height. The weight acting upon a surface reduces, as the object is increased in height within the atmosphere, therefore reducing the pressure too. ($p=h\rho g$)

The atmospheric pressure at ground level is therefore higher than it is at the top of a mountain because the height of the column of air at the top of the mountain is smaller and the average density of the air would be lower.

Upthrust and flotation

A partially (or totally) submerged object experiences a greater pressure on the bottom surface than on the top surface. This creates a resultant force upwards. This force is called the upthrust.

73. Space

Keyword	Description
Asteroid	A lump of rock (may or may not be orbiting anything)
Comet	A ball of ice, dust and gas orbiting a star in an elliptical orbit
Galaxy	A group of billions of stars. Earth is in the Milky Way galaxy
Meteor	A small piece of rocky matter entering Earth's atmosphere from space
Moon	A sphere of rock orbiting a planet
Planet	A sphere of rock or gas orbiting a star
Red Shift	Objects which are moving away from us are said to be red shifted because the wavelengths of light from these objects is shifted towards the red end of the spectrum. Hubble determined that the most distant galaxies are those most red shifted, meaning they are accelerating away from us. This supports the big bang theory.
Satellite	An object which orbits another. Natural (moon) or man-made (space station). They travel at a constant speed. Their orbit is determined by their speed.
Star	A sphere of (mainly) hydrogen carrying out nuclear fusion, producing heat and light
Universe	Everything that exists. Contains billions of galaxies

74. Star formation

Process of star formation: nuclear fusion

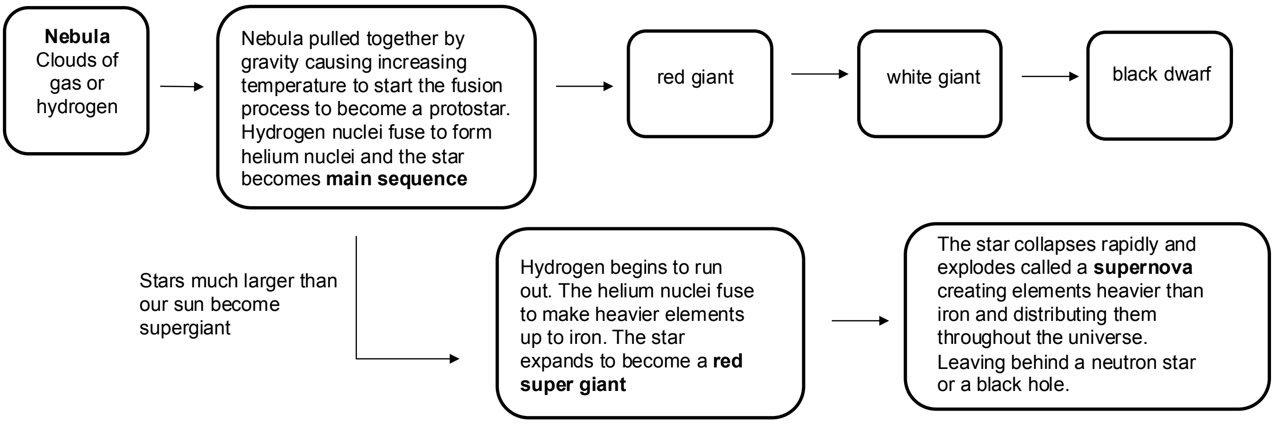
Main fuel source: Hydrogen

The Sun is a stable star. This is because the forces pulling inwards caused by gravity are in equilibrium with the forces pushing outwards caused by the energy released by nuclear fusion.

Range of wavelengths of a star depend on the temperature of the star.

A light year is the distance that light travels in a year

The life cycle of a star



Nebula Clouds of gas or hydrogen

Nebula pulled together by gravity causing increasing temperature to start the fusion process to become a protostar. Hydrogen nuclei fuse to form helium nuclei and the star becomes **main sequence**

red giant

white giant

black dwarf

Stars much larger than our sun become supergiant

Hydrogen begins to run out. The helium nuclei fuse to make heavier elements up to iron. The star expands to become a **red super giant**

The star collapses rapidly and explodes called a **supernova** creating elements heavier than iron and distributing them throughout the universe. Leaving behind a neutron star or a black hole.

75. Creation of the Universe

Much is still unknown about the universe and galaxies spin faster than they should based on the amount of mass in them. Scientist think that the missing mass is made up of something they have named **dark matter**.

The universe is not only expanding but accelerating in its expansion. Scientists think that **dark energy** is responsible for this acceleration but like **dark matter** they have no idea what **dark energy** is.

The universe could either end in a **big crunch** where the rapid expansion stops and a rapid contraction occurs or it could expand for ever in what is called the **big yawn**.

Mid 20th Century theories for the creation of the universe	**Key points**
Stay State Theory	Universe expands with a constant density, white holes leak matter into the universe to maintain the density as volume increases. Dropped after the discovery of cosmic microwave background radiation (CMBR)
Big Bang Theory	Universe expanded from an extremely small, hot, dense region creating space, time and matter

76. Required Practical 6: Force and extension

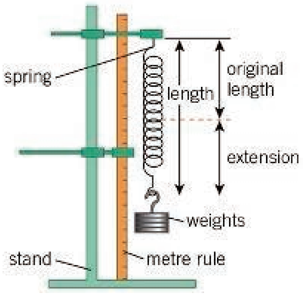
Force and Extension

The extension of a spring is directly proportional to the force applied, provided its limit of proportionality is not exceeded

Independent variable - Force applied (N)

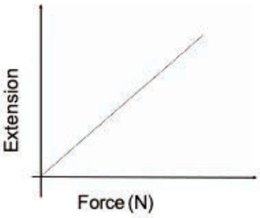
Dependent variable - Extension of spring (m)

Control variable - same spring, keep ruler in the same position.



Method

1. Hang the spring on the end of the clamp and gently clamp it to secure it.
2. Measure the original length of the spring and record this length.
3. Add a 100 g (1 Newton) mass holder to the end of the spring.
4. Measure the new length and calculate the extension.
5. Add 100 g masses, one at a time, measuring the length and calculating (and recording) the extension of the spring each time.
6. Stop when you have added a total of 500 g. Be careful not to overstretch the spring.



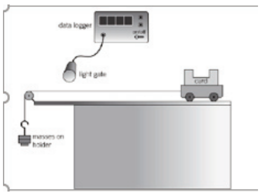
Spring constant (N/m) = Force (N) ÷ extension (m)
Spring constant = gradient of the line

77. Required Practical 7: The effect of force on acceleration

Independent variable – Force (N)   (weight due to mass W=mg)

Dependent variable – acceleration (m/s^2)

Control variables – mass of trolley, same trolley starts from same position each time



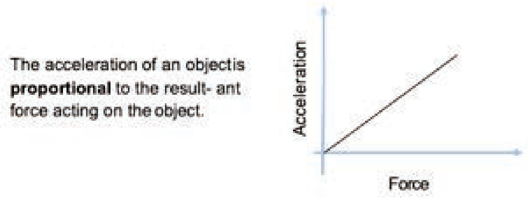
Method

1. Measure the length of each card segment and make a note of this.
2. Set up the apparatus as shown in the diagram below. When the trolley is as close to the pulley as it can get, the bottom of the mass holder should be between 0.5 cm and 1 cm above the floor.
3. During this experiment the trolley will travel towards the pulley.
4. Set up the data logger. You will use its measurements to find the trolley's acceleration.
5. Add mass to the mass holder so that the total mass, including the holder, is 250 g.
6. Pull back the trolley, set the data logger to record, and then let the trolley run to the pulley. Collect the necessary measurements from the data logger.
7. Take 50 g off the mass holder and place it onto the trolley. You may need to use a small amount of tape or sticky tack to hold the mass securely in place. Repeat step 6.
8. Repeat steps 6-7 until there is 200 g on the trolley - this will be the fifth and final run.

How to reduce random errors

Repeat the measurements/investigation

Ignore anomalies and calculate the mean



The acceleration of an object is **proportional** to the result- ant force acting on the object.

The acceleration of an object is proportional to the resultant force acting upon it. F = ma or a = F/m

m is the mass of the trolley and not the weight being attached to the string

78. Required Practical 8: The effect of mass on acceleration

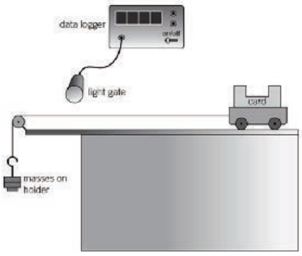
Independent variable – mass of the trolley (N)

Dependent variable – acceleration (m/s^2)

Control variables – Force being applied, trolley starts from same position each time

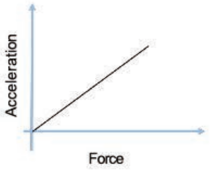
Method

1. Measure the length of each card segment and make a note of this.
2. Set up the apparatus as shown in the diagram below. When the trolley is as close to the pulley as it can get, the bottom of the mass holder should be between 0.5 cm and 1 cm above the floor.
3. During this experiment the trolley will travel towards the pulley. If you need to, place a lump of modelling clay or a block in front of the pulley to protect it from being hit by the trolley.
4. Set up the data logger. You will use its measurements to find the trolley's acceleration. There are different ways of doing this, depending on the data logger and the method your teacher asks you to use.
5. You will be changing the mass (by stacking extra trolleys under the first one) but keeping the applied force the same (by keeping the same number of masses on the mass holder). First, measure the mass of one trolley. (You can assume all trolleys have the same mass.)
6. Each time you change the number of stacked trolleys, measure the acceleration. You may need to change the height of the light gate so that the card still passes through it.



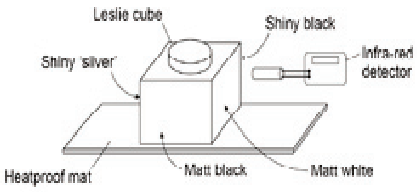
The acceleration of an object is **inversely proportional** to the mass of the object.

a = F/m



79. Required practical 9: Infra red radiation

Demonstration



Method:

1. Set up equipment as shown in diagram
2. Fill cube with hot water and put on lid
3. Use the detector to measure the amount of radiation from each surface

IV: surface
DV: Amount of IR absorbed or radiated
CV: Distance between surface and IR detector

Advantages of using this cube:

- All surfaces are at the same temperature
- More surfaces are tested
- Volume and temperature of the water does not need to be measured

All bodies (objects) emit and absorb **infrared radiation**.

An object that is good at absorbing radiation is also a good **emitter**, so a perfect black body would be the best possible emitter of radiation.

White and shiny silvery surfaces are the worst absorbers, as they reflect all visible light wavelengths. Poor absorbers are also poor emitters, and do not emit radiation as quickly as darker colours. Radiators in homes are usually painted white so that the infrared radiation is emitted gradually.

Class practical

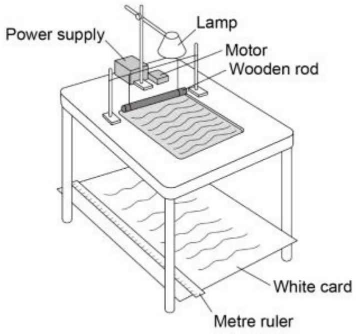
1. Fill a matt black boiling tube and a shiny boiling tube with equal volumes of hot water.
2. Record temperature of water inside boiling tubes every 30 seconds.
3. Plot results on a graph

IV: surface of boiling tube
DV: temperature of hot water
CV: volume of hot water, time intervals recording the temperature

Matt black boiling tube: Temperature drops the most and it is the best at it is the best at emitting heat.

80. Required practical 10: Speed of water waves

1. Set up the ripple tank as shown in the diagram.
2. Make sure that there is a large sheet of white card or paper on the floor under the tank.
3. Pour water to a depth of about 5 mm into the tank.
4. Adjust the height of the wooden rod so that it just touches the surface of the water.
5. Switch on the overhead lamp and the electric motor.
6. Adjust the speed of the motor to produce low frequency water waves.
7. Adjust the height of the lamp so that the pattern of the waves can be clearly seen on the white card.



How to find the frequency of a wave using a ripple tank: count the number of ripples that pass a point in 10 seconds. Divide the number of waves by 10.

How to measure the wavelength: measure the distance across 10 gaps between the shadow lines. Divide this distance by 10.

How to calculate the speed of the wave
Wave speed (m/s) = frequency (Hz) x wavelength (m)

How to improve the method of calculating the wavelength:
Take a photo of the shadows and the ruler.
Benefit is that the waves are not being disturbed.

Reasons for using a:
Lamp: create shadows of the ripples
Metre ruler: measure the distance between 10 waves.
Signal generator**:** The vibration generator can have a built in signal generator so that you can directly set the frequency of paddle oscillation i.e. frequency of the ripple waves.

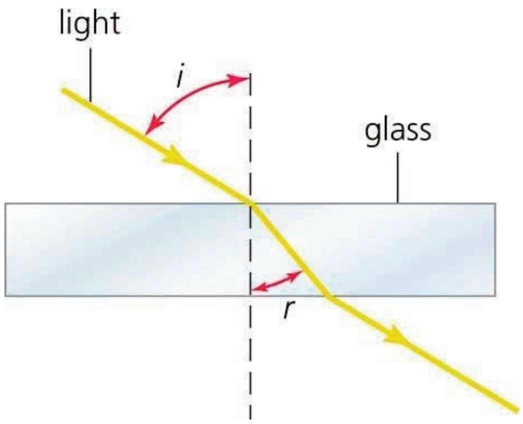
Deeper water means longer wavelength because velocity increases and frequency is constant

81. Required practical 11: Refraction of light

1. Place a glass block on a piece of paper
2. Draw around the glass block and then remove from the paper
3. Draw a line at 90° to one side of the block (the normal)
4. Use a protractor to measure and then draw a line at an angle of 20° to the normal
5. Replace the glass block
6. Using a ray box and slit point the ray of light down the drawn line
7. Mark the ray of light emerging from the block
8. Remove the block and draw in the refracted ray
9. Measure the angle of refraction with a protractor
10. Repeat the procedure for a range of values of the angle of incidence

Source of inaccuracy: The width of the light ray

Reason for inaccuracy: Makes it difficult to judge where the centre of the ray causes a large uncertainty



Normal (90º to the surface)

82. Maths in Science 1

Anomalous result	A number that does not fit the pattern
Mean	Adding up a list of numbers and dividing by how many numbers are in the list. Exclude the anomalous result.
Median	The middle value when a list of numbers is put in order from smallest to largest
Mode	The most common value in a list of numbers. If two values are tied then there are two modes. If more than two values are tied then there is no mode.
Range	The largest number take away the smallest value in a set of data or written as X-Y.
Uncertainty	range ÷ 2
Surface area of a cube	(area of 1 side) x 6 sides
Volume of a cube	Width x height x depth
Area of a circle	∏ x (radius)^2

Prefixes

1 kJ = 1 x 10^3 J = 1000 J

1 pm = 1 x 10^{-12} m

1 mm = 1 x 10^{-3} m= 0.001 m

tera	10^{12}	T
giga	10^{9}	G
mega	10^{6}	M
kilo	10^{3}	k
centi	10^{-2}	c
milli	10^{-3}	m
micro	10^{-6}	μ
nano	10^{-9}	n
pico	10^{-12}	p

5607.376

Standard form: 5.607 x 10^3

2 decimal places: 5607.38

3 significant figures: 5610

0.03581

Standard form: 3.581 x 10^{-2}

2 decimal places: 0.04

3 significant figures: 0.0358

83. Maths in Science 2

Calculating percentage: (part ÷ whole) x 100

e.g. Out of 90 insects, 40 of them were ladybirds. What is the % of ladybirds?

(40 ÷ 90) x 100 = 44 %

Calculating percentage change:

(difference ÷ starting value) x 100

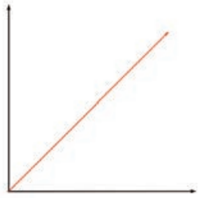
(0.59 ÷ 2.22) x 100 = 26.6 %

Conc of Sucrose (M)	Mass of potato at start (g)	Mass of potato at end (g)	Change in mass (g)
0	2.22	2.81	0.59

Graphs

Proportional (α)

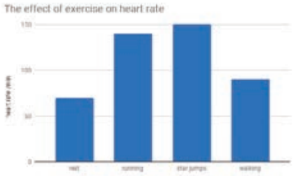
When the line passes through the origin



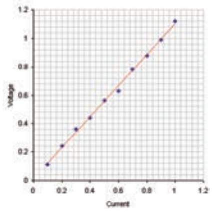
x axis = independent variable = left hand column of results table

y axis = dependent variable = right hand column of results table

Categoric data: data put into groups e.g. colour of eyes
Draw a bar chart

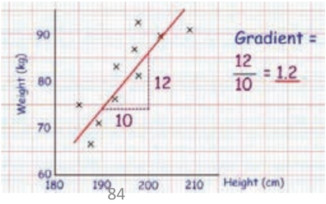


Continuous data: data that can take any value e.g. current
Draw a line graph



Gradient and Graphs

Gradient = $\frac{\text{Change in y}}{\text{Change in x}}$



kinetic energy = 0.5 × mass × (speed)²	$E_k = \frac{1}{2} m v^2$
elastic potential energy = 0.5 × spring constant × (extension)²	$E_e = \frac{1}{2} k e^2$
gravitational potential energy = mass × gravitational field strength × height	$E_p = m g h$
change in thermal energy = mass × specific heat capacity × temperature change	$\Delta E = m c \Delta\theta$
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 = $\frac{\text{useful power output}}{\text{total power input}}$	
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	$E = Q\,V$
	$\text{density} = \frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{V}$
	thermal energy for a change of state = mass × specific latent heat	$E = m\,L$
	For gases: pressure × volume = constant	$p\,V = \textit{constant}$
	weight = mass × gravitational field strength	$W = m\,g$
	work done = force × distance (along the line of action of the force)	$W = F\,s$
	force = spring constant × extension	$F = k\,e$
	moment of a force = force × distance (normal to direction of force)	$M = F\,d$
	$\text{pressure} = \frac{\text{force normal to a surface}}{\text{area of that surface}}$	$p = \frac{F}{A}$
HT	**pressure due to a column of liquid = height of column × density of liquid × gravitational field strength**	$\boldsymbol{p = h\,\rho\,g}$

	distance travelled = speed × time	$s = v\,t$
	$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$	$a = \frac{\Delta v}{t}$
	(final velocity)² – (initial velocity)² = 2 × acceleration × distance	$v^2 - u^2 = 2\,a\,s$
	resultant force = mass × acceleration	$F = m\,a$
HT	**momentum = mass × velocity**	$\boldsymbol{p = m\,v}$
HT	$\textbf{force} = \frac{\textbf{change in momentum}}{\textbf{time taken}}$	$\boldsymbol{F = \frac{m\,\Delta v}{\Delta t}}$
	$\text{period} = \frac{1}{\text{frequency}}$	$T = \frac{1}{f}$
	wave speed = frequency × wavelength	$v = f\,\lambda$
	$\text{magnification} = \frac{\text{image height}}{\text{object height}}$	
HT	**force on a conductor (at right angles to a magnetic field) carrying a current = magnetic flux density × current × length**	$\boldsymbol{F = B\,I\,l}$
HT	$\frac{\textbf{potential difference across primary coil}}{\textbf{potential difference across secondary coil}} = \frac{\textbf{number of turns in primary coil}}{\textbf{number of turns in secondary coil}}$	$\boldsymbol{\frac{V_p}{V_s} = \frac{n_p}{n_s}}$
HT	**potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil**	$\boldsymbol{V_p\,I_p = V_s\,I_s}$

INDEPENDENCE: DIAGNOSIS – THERAPY - TEST

NAME: CLASS:

TOPIC:

DIAGNOSIS: The thing I don't understand

THERAPY: Where am I going to learn about this?

Which of the templates will I use to transform the information?

TEST: 5 questions someone can ask me about my new understanding.

You can download this template from the school website: www.saintben.sch.uk/content/independence

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INDEPENDENCE: DIAGNOSE

NAME: CLASS:

SUBJECT:

Be clear about what you know and what you don't know before you begin.

First, use a contents page or a topic list for the subject you are going to revise.

Then, fill in the following table – the topics, and how well you know them.

Next, prioritise. Which topics will you revise first? Spend time studying the topics which will make the biggest difference to your results.

Topic	Knowledge	Priority
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	
	Know it/Sort of know it/Don't know it	

Finally, use the **diagnosis – therapy – test** worksheet to plan your independent study.

You can download this template from the school website: www.saintben.sch.uk/content/independence

INDEPENDENCE: PRIORITISE, REDUCE, CATEGORISE, EXTEND

NAME: CLASS:

TOPIC:

Take a section of text and do the following:

Prioritise: write out the three most important sentences. Rank 1-3 in terms of importance. Justify your decision.
Reduce: reduce the key information to 20 words.
Categorise: sort out the information into three categories. Give each category a title which sums up the information.
Extend: write down three questions you would like to ask an expert in this subject.

INDEPENDENCE: RANKING TRIANGLE

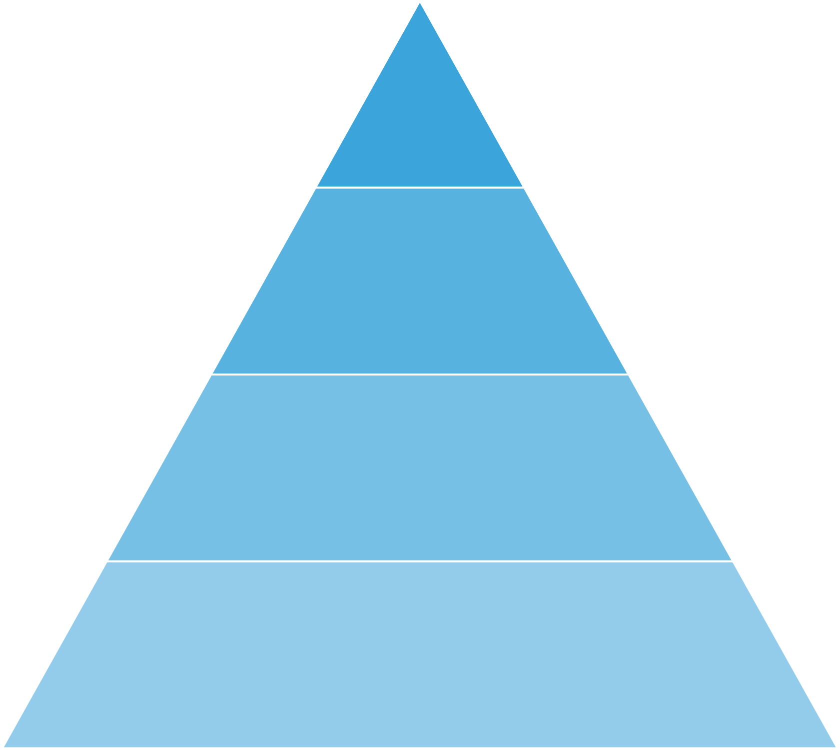
NAME: CLASS:

TOPIC:

The most important information goes at the top.

The least important information goes at the bottom.

Justify WHY. Why is it the most important? Why is it the least important?



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INDEPENDENCE: QUIZZING

NAME: CLASS:

TOPIC:

Read the text and transform it into 10 questions to ask someone.

	Question	Answer
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Question stems:

State... Explain... Suggest...

Describe... Evaluate... Compare...

INDEPENDENCE: BOXING UP

NAME: CLASS:

TOPIC:

Take a section of text. Read it and put your thoughts about the text into different boxes.

Needs a boost: 3 things I did not know:

Almost there: 3 things I understand better now:

I've got these: 3 things I already knew:

INDEPENDENCE: OTHER IDEAS

Steps → flow chart Transform a sequence of steps into a flow chart or a diagram.

Flow chart → steps Transform a flow chart or a diagram into a sequence of steps.

Look, cover, write, check Cover a list of key words. Write them down. Check which ones you have got right. Repeat until you get them all right.

Link key words Take three words from a topic. Link them together in a sentence or a diagram. Repeat until all the key words have been linked.

INDEPENDENCE: PICTIONARY

NAME: CLASS:

TOPIC:

Transform the material into 6 pictures – one per paragraph or one per key piece of information. The pictures should represent the information so that they can act as a reminder of what the text said. Underneath each picture, explain your thinking.

1.	2.	3.

4.	5.	6.