



KNOWLEDGE ORGANISER
YEAR 10 ENGLISH, MATHS & SCIENCE
2024 - 2025



KNOWLEDGE ORGANISER
YEAR 10 - CORE SUBJECTS
2024 - 2025

Year 10: How to use your Knowledge Organiser book

This book contains **knowledge organisers** for all of your subjects.

Each knowledge organiser has the key information which needs to be memorised to help you master your core subjects and be successful in lessons.

Self- quizzing this key information promotes **retrieval strength**. This is your ability to **quickly recall key facts** related to your subject or topic from your **long term memory**.

There are lots of different ways to learn the information in your knowledge organiser. You will be using your **class books** to complete homework and write down and learn the information. You **must** bring your **class books** to school **on each day you have the lesson timetabled** and so packing your school bag the evening before is important.

If you lose your knowledge organiser book you will need to talk to your Head of Year and order a new one at a cost of £1.

Year 10 Subject	Page
Introduction	2 - 5
English	6-14
Mathematics	16-27
Science - Biology	28-59
Science - Chemistry	60-96
Science - Physics	97-128

CURRICULUM COMMAND WORDS

Knowing how to respond to a question, in any subject, is absolutely critical to successfully demonstrate your knowledge! Listed below, are the equally important but less frequent command words that you are likely to face from across your subjects. It is important to know that quite often, a single question can have multiple commands embedded—which will all need your attention in your work.

Command	How do I respond in my writing ?	Command	How do I respond in my writing ?	Command	How do I respond in my writing ?
Acknowledge	Music: To give credit for, recognise, and highlight something, such as a selected source or the work of others.	Explore	Music: To investigate, examine and look into with an open mind about what might be found and developed.	Produce	D&T: Draw or design an isometric or orthographic drawing
Apply	Music: To use knowledge, skills and understanding and to employ appropriate techniques when developing and progressing ideas.	Express	Maths: Re-write in another form, some working may be needed.	Prove	Maths: More formal than 'show', all steps must be present. In the case of a geometrical proof, reasons must be given.
Arrange	History: Put the factors in an order and then justify your choices	Factorise	Maths: Insert brackets by taking out common factors.	Prove algebraically	Maths: Use algebra in the proof.
Change	Maths: Usually convert from one unit to another, either using known metric unit conversions or the use of a conversion graph.	Factorise fully	Maths: Insert brackets by taking out all the common factors.	Realise	Music: To achieve, attain and/or accomplish your intentions.
Collate	Gather and organise your ideas logically	Find	Maths: Some working will be needed to get to the final answer.	Recommend	Put forward or suggest an answer that is suitable for the question
Comment	Write an informed opinion	Give	Typically a very short, undeveloped answer Synonyms: state, name and identify.	Record	Music: To document ideas, thoughts, insights and responses to starting points in visual and written annotated form.
Consider	To think through, review, reflect on, and respond to given information	Give a reason	Maths: Must be clear and accurate reasons. If the reasons are geometrical then make sure you: provide a reason for each stage of working (if required), use correct geometric terminology	Refine	Music: To improve, enhance and change elements of your work for the better.
Convert	Computing: change the form, character or function of something	How far do you agree...	History: Examine the evidence and form a detailed opinion	Research	Music: To study in detail, discover and find information about.
Demonstrate	Music: To show, exhibit, prove or express such things as subject specific knowledge, understanding and skills.	How important was...	History: Judge the importance of the factor and then compare relative to others	Respond	Music: To produce personal work generated by a subject, theme, starting point, or design brief.
Design	Computing: produce a plan, simulation or model	Identify	Provide an answer from a number of possibilities	Review	Review is to explain/evaluate e.g. write about and assess the importance, quality or value of the topic
Determine	Science: Use given data or information to obtain an answer	Interpret	Dance: Translate information into recognisable form. Other subjects: examine information for patterns and causation	Show	Show structured steps or evidence or all workings needed to get to a given answer
Develop	Music: To take forward, change, improve or build on an idea, theme or starting point.	List	Provide the information in a list rather than continuous writing	Simplify	Maths: Simplify the given expression
Draw	Produce a diagram or picture. Note: this command is often linked with 'label' or 'annotate'.	Match	Link or pair-up a definition to the a key term	Simplify fully	Maths: Simplify the given expression. Answer must be given in its simplest form
Estimate	Science: Assign an approximate value	Plan	Science: Write a method used extended bullet point method—unique to writing in Science!	Solve	Maths: Find the solution of an equation or inequality. Computing: Obtain the answer(s) using algebraic/numeric/graphical methods.
Evidence	To show, prove, support and make clear or verify something.	Predict	Science: Suggest the most likely outcome	State	Music: to express clearly and briefly your intentions.
Expand	Maths: Remove brackets	Present	Music: To give a response to an idea, theme or starting point that shows a personal, meaningful and organised fulfilment of intentions.	Tick	Put a mark to indicate that something is correct
Expand and simplify	Maths: Remove brackets and the collect like terms.	Produce	D&T: Draw or design an isometric or orthographic drawing	Use	Answer must be based on or include the information given within the question
				What	Suggest a suitable idea

COMMON CURRICULUM COMMAND WORDS

TOP 20

QUESTION DECONSTRUCTION SKILLS

Knowing how to respond to a question, in any subject, is absolutely critical to successfully demonstrate your knowledge. Responding in the correct way to a command word within a question makes the difference between accessing all the marks, or getting none at all! You must be secure in knowing how you should write according to these 'Top 20' highest frequency command words from across the curriculum. Almost all subjects have additional command words you must know too, so check the subject specific command word KOs for further advice on how to master responding to the full range of commands.

Command	How do I respond in my writing ?
Analyse	Systematically break down the theme of the question into parts and examine each in turn. You should include description, explanations and evidence to reach conclusions.
Annotate	Annotations are extended labels. When annotating, you should write brief descriptive or explanatory sentences linked to features referenced in the question.
Assess	Like analyse, assess means to break the theme of the question down into parts but offer your opinion on the successes and failures to reach an informed judgement.
Calculate	You need to use the data (numbers) within the question, or resource that the question is based on, and apply a mathematical function to get your answer.
Compare	An effective comparison will make clear references to both similarities and differences between the items within the questions.
Complete	You are directed to use information available to you (a resource with the question or your knowledge) to finish a task. This is most commonly linked to cloze paragraphs (a.k.a. gap-fill) style questions.
Contrast	Writing to show contrast will make clear references to just differences between the items within the questions.
Define	Give a definition (precise meaning) of the feature or item referenced in the question, such as a word, phrase, concept or physical quantity.
Describe	Write details of what the feature/item or theme are like within the question. Do not explain as a description requires no explanation.
Discuss	Describe and explain a balance of the similarities and differences, or positives and negatives of whatever the question is about. Evidence is important to include—as is your opinion. Always add a conclusion to summarise your discussion.

Command	How do I respond in my writing ?
Evaluate	Systematically break down the theme of the question to make an informed judgement supported by evidence for the strengths, weaknesses (or limitations), opportunities to improve a way of working or concept, to reach conclusions.
Explain	Give reasons for how or why something is like it is. Write in a way that shows cause and effect. The words 'because', '...as a result', '...this is due to', 'consequently' should be in your writing.
Justify	Write a convincing argument to reach a conclusion supported by evidence.
Label	Labelling is simply naming features or parts of something; these are not sentences
Outline	Give a brief overview of the whole theme of the question. You can describe or explain just the main points in limited detail. The amount you write depends on the amount of content within the question.
Plot	Add data (results or values) onto a graph. Read the axis labels carefully to understand the units. If present, your plotted data should 'look' like the other data already present on the graph.
State	Give the name of a feature or item referenced in the question. Synonyms are: give/name or identify.
Study	This command will often be linked to a resource within a question such as a map, photo or diagram; you are being encouraged to look at and understanding this resource for inclusion in an answer.
Suggest	Explain a possible reason for theme of the question. 'Suggest' questions are asking you to put forward an idea you have.
To what extent	The question is asking how far you agree with something—from fully agree to totally disagree—often a statement or a quote for example. Give your opinion immediately and examine arguments that support and discount your opinion. Support with evidence to reach a conclusion.



BUGS
Box around the command word
Underline the key words
Go over the question again
Spare a line/time for planning

Example of using BUGS:

Explain a valid reason
Q: Suggest why using BUGS is a good technique for writing successful answers to exam-style questions (6)
This means a method of working
I only earn marks for writing in the appropriate way in exam questions
Writing that demonstrates what I know suitable to the question

THE 'TRIPLE C' TECHNIQUE

The 'Triple C' technique for question deconstruction stands for 'Colour Code Complex' questions. This technique is a more in-depth take on using BUGS, which is more effective for longer answer essay questions, or with more complex command words such as: evaluate, discuss, analyse and assess for example. Get your highlighters out and use a different colour for the different clauses and keyword phrases within the question. This will ensure you respond to all parts of the question and paragraph effectively to demonstrate your writing stamina.

Example of using 'TRIPLE C':

Two commands: Must use real examples, and must evaluate (judge something).
Judge the effectiveness by evaluating strengths, weaknesses and opportunities to change something.
Q: Using examples you have studied, evaluate the effectiveness of using question deconstruction techniques to write successful answers (9)
A detailed, evaluative paragraph on each technique: 'BUGS' and 'Triple C'
Conclude on the effectiveness of whether the technique makes for successful written answers

THS Tier 2 Vocabulary - 100 Word List

Tier 2 words are words that you wouldn't normally use in your everyday speech and aren't subject specific terminology. You are likely to find them when you are reading, or you might use them in your writing. Our THS 100 Word List is made up of 100 words that are often used in exam questions and texts. They are divided into sublists: **sublist 1** has the **most common words** and **sublist 10** has **rarer words**.

Recognising these words will help you to understand the texts that you might be given in your different lessons and exams.

Sublist 1

1. process
2. individual
3. specific
4. source
5. identified
6. create
7. derived
8. factors
9. definition
10. interpretation
11. consistent
12. structure
13. analysis
14. indicate
15. response
16. context
17. significant

Sublist 2

1. community
2. relevant
3. impact
4. consequences
5. participation
6. cultural
7. affect
8. effect
9. complex

Sublist 4

1. overall
2. emerged
3. approximate
4. implications
5. commitment
6. promote
7. access
8. contrast
9. resolution
10. adequate

Sublist 6

1. presumption
2. enhanced
3. capable
4. revealed
5. explicit
6. underlying
7. exceed

Sublist 8

1. eventually
2. exploitation
3. virtually
4. predominantly
5. implicit
6. ambiguous
7. conformity
8. contemporary
9. deviation
10. minimises
11. radical
12. inevitably
13. complement
14. manipulation

Sublist 9

1. commenced
2. anticipated
3. incompatible
4. integral
5. conversely
6. temporary
7. assurance
8. inherent
9. duration

Sublist 3

1. convention
2. implies
3. dominant
4. constant
5. justification
6. alternative
7. initial
8. validity
9. sequence
10. corresponding
11. circumstances

Sublist 5

1. energy
2. symbolic
3. decline
4. facilitate
5. logic
6. sustainable
7. equivalent
8. generated
9. conflict

Sublist 7

1. intervention
2. definite
3. ultimately
4. converted
5. hierarchical
6. comprehensive
7. eliminate
8. contrary
9. successive
10. prohibited

Sublist 10

1. convinced
2. persistent
3. integrity
4. conceived



Most common

Least common

English Language GCSE: Reading Papers (Reading an extract and answering questions)			Component 1 Reading: read an extract from a story. Answer 5 questions, including quotations and showing you can analyse language	Component 2 Reading: read two non-fiction texts, linked by theme, and answer 6 questions.
Component 1 (1hr 45mins)		Component 2 (2 hours)		Useful vocabulary when answering the fiction and non-fiction reading papers In a sentence
A: Unseen 20 th Century Literature Reading (40 marks worth 20%) B: Creative Prose Writing (40 marks worth 20%)	A: Unseen 19 th and 21 st Century Non-Fiction Reading (40 marks worth 30%) B: Transactional writing (40 marks worth 30%)			
English Language: Assessment Objectives				
AO1	Identify and interpret explicit and implicit information and ideas			
	Select and synthesise evidence from different texts			
AO2	Explain comment on and analyse how writers use language and structure to achieve effects and influence readers, using relevant subject terminology to support their views			
AO3	Compare writers' ideas and perspectives, as well as how these are conveyed, across two or more texts			
AO4	Evaluate texts critically and support this with appropriate textual references			
AO5	Communicate clearly, effectively and imaginatively, selecting and adapting tone, style and register for different forms, purposes and audiences			
	Organise information and ideas, using structural and grammatical features to support coherences and cohesion of texts			
AO6	Use a range of vocabulary and sentence structures for clarity, purpose and effect, with accurate spelling and punctuation.			

Component 1 Reading: read an extract from a story. Answer 5 questions, including quotations and showing you can analyse language	Component 2 Reading: read two non-fiction texts, linked by theme, and answer 6 questions.
Useful vocabulary when answering the fiction and non-fiction reading papers	
Use	It means...
1 Highlights	Makes something stand out
2 Reinforces	Strengthens or supports
3 Contributes to	Adds to
4 Develops	Grows/unfolds
5 Reveals	Shows something new
6 Demonstrates	Gives an example
7 Ensures	Makes sure
8 Portrays	Describes
9 Initially	At first
10 Surprisingly	Unexpected
11 Contrasts	Shows a strong difference
12 Ultimately	In the end, to sum up
13 Ironic	Saying the opposite of what you mean, often to create humour.
14 Humorous	Funny
15 Sarcastic	Saying the opposite of what you mean to mock or show you disagree.
16 Cautious	Careful
17 Courteous	Polite
18 Nostalgic	Thinking about the past in a positive way
19 Detached	No emotion – separate from the event
20 Flattering	Praise and complement

1	Highlights	Makes something stand out	The writer highlights the character’s happiness by describing his beaming smile.
2	Reinforces	Strengthens or supports	The writer uses repetition to reinforce the importance of hand washing.
3	Contributes to	Adds to	The use of short sentences contributes to the rising tension.
4	Develops	Grows/unfolds	The writer develops a strong sense of fear as the character approaches the door.
5	Reveals	Shows something new	The writer reveals the secret of the hero’s true identity at the very end of the story.
6	Demonstrates	Gives an example	The use of exclamation marks demonstrates the writer’s enthusiasm .
7	Ensures	Makes sure	The writer repeats the information to ensure that the reader is left in no doubt.
8	Portrays	Describes	At the start of the extract, the writer portrays this character as shy.
9	Initially	At first	Initially , we are shocked at the character’s behaviour until we understand why they did this.
10	Surprisingly	Unexpected	Surprisingly , the author withholds this information until the end.
11	Contrasts	Shows a strong difference	The writer contrasts the behaviour of the two boys in this extract, revealing their differences.
12	Ultimately	In the end, to sum up	Ultimately , we are left satisfied with the outcome of the story.
13	Ironic	Saying the opposite of what you mean, often to create humour.	The writer creates an ironic tone by pretending that everyone is happy when they are really not.
14	Humorous	Funny	The writer includes a humorous anecdote to engage the reader.
15	Sarcastic	Saying the opposite of what you mean to mock or show you disagree.	The writer is clearly sarcastic when he says “everything is perfect” after describing the poor conditions.
16	Cautious	Careful	After being misled by the character, the reader is cautious about believing his later claims.
17	Courteous	Polite	The speaker is courteous as he ignores subjects which might offend the audience.
18	Nostalgic	Thinking about the past in a positive way	The writer evokes a nostalgic feeling when describing happy memories of a neglected playground.
19	Detached	No emotion – separate from the event	The detached tone confirms that the writer was not upset by the events.
20	Flattering	Praise and complement	The writer is clearly flattering the reader when he says he knows that they will understand what he is talking about.

Component 1 Reading: read an extract from a story. Answer 5 questions, including quotations and showing you can analyse language			Component 2 Reading: read two non-fiction texts, linked by theme, and answer 6 questions.
Useful vocabulary when answering the fiction and non-fiction reading papers In a sentence			
1	Highlights	Makes something stand out	The writer highlights the character's happiness by describing his beaming smile.
2	Reinforces	Strengthens or supports	The writer uses repetition to reinforce the importance of hand washing.
3	Contributes to	Adds to	The use of short sentences contributes to the rising tension.
4	Develops	Grows/unfolds	The writer develops a strong sense of fear as the character approaches the door.
5	Reveals	Shows something new	The writer reveals the secret of the hero's true identity at the very end of the story.
6	Demonstrates	Gives an example	The use of exclamation marks demonstrates the writer's enthusiasm .
7	Ensures	Makes sure	The writer repeats the information to ensure that the reader is left in no doubt.
8	Portrays	Describes	At the start of the extract, the writer portrays this character as shy.
9	Initially	At first	Initially , we are shocked at the character's behaviour until we understand why they did this.
10	Surprisingly	Unexpected	Surprisingly , the author withholds this information until the end.
11	Contrasts	Shows a strong difference	The writer contrasts the behaviour of the two boys in this extract, revealing their differences.
12	Ultimately	In the end, to sum up	Ultimately , we are left satisfied with the outcome of the story.
13	Ironic	Saying the opposite of what you mean, often to create humour.	The writer creates an ironic tone by pretending that everyone is happy when they are really not.
14	Humorous	Funny	The writer includes a humorous anecdote to engage the reader.
15	Sarcastic	Saying the opposite of what you mean to mock or show you disagree.	The writer is clearly sarcastic when he says "everything is perfect" after describing the poor conditions.
16	Cautious	Careful	After being misled by the character, the reader is cautious about believing his later claims.
17	Courteous	Polite	The speaker is courteous as he ignores subjects which might offend the audience.
18	Nostalgic	Thinking about the past in a positive way	The writer evokes a nostalgic feeling when describing happy memories of a neglected playground.
19	Detached	No emotion – separate from the event	The detached tone confirms that the writer was not upset by the events.
20	Flattering	Praise and complement	The writer is clearly flattering the reader when he says he knows that they will understand what he is talking about.

1. Key Terms		English Language GCSE: Creative Writing (Writing a short story)		5. Building detail		8. Descriptive vocabulary			
1. Rising action: the part of the story where the plot becomes increasingly complicated. 2. Climax: the most dramatic, exciting part of a story. 3. Falling action: diminishing tension, leading towards a resolution. 4. Foreshadowing: hints at events to come. 5. Allusion: brief, indirect reference to a person, place, thing or idea of historical/cultural, literary/political significance. It does not describe in detail the person/thing. 6. Juxtaposition: two contrasting ideas put next to each to make the difference clear.		1. Adverbials: E.g. Forcefully, the... 1. -ed words: E.g. Focused, challenged 2. -ing verbs: E.g. Vaulting, sprinting... 3. Simile starts: e.g. Like an uncoiled spring, the ... 4. Prepositions: e.g. Above the door... 5. List of adjectives: e.g. Strong, powerful, majestic... 6. Comparisons: e.g. Unlike the armoured opponent, the... 7. A noun to start: e.g. Quests are often... 8. When... 9. After... 10. Abstract noun: Eg Fear coiled inside her stomach like...		1. Sensory description What would you be able to hear? See? Feel? Smell? Taste? 2. SHOW don't tell He wasbeet slumped in his chair, endlessly tapping his pencil. 3. Vary your sentences for pace Short sentences slow the pace; long sentences increase the pace. 4. Try figurative language Metaphor, simile, personification 5. Use words with precise meaning Beet Ugly Confusing Evil Uninspiring Went Ran Slunk Ambled Crept		1. Circular structure – link back to the start of your story. • A reveal – make sure there are hints along the way! • 'Almost' cliff hanger – hint at what happens...leave the reader to fill in the detail. • A moral message – what has your character learnt?		Radiant Happy/beautiful Gaudy Unpleasantly bright Nauseating Makes you feel sick Agonised Couldn't decide – painfully undecided. Acrid Strong, bitter – causes a burning feeling. Rancid Tastes or smells unpleasant as it's not fresh – rotting. Uncontrollable Can't stop – cannot control Hurtled Threw with forced Aromatic A pleasant smell Deviously Cunning Console Comfort someone Engulfed Covered Jabber Chat annoyingly Indecisively Cannot decide Avoid Don't do something on purpose. Loomed Tower over threateningly. Infinitely Much more Indifferently Don't care Unpologetically Not sorry Haughtily Stuck up – looks down on people.	
2. Typical titles It is important that your story idea matches the title you choose. Example: Write about a time when... (eg you were scared/ surprised/ at a birthday party...) Write a story that starts/ends... (I had to change my mind/ she wasn't there...) A statement (eg The Storm, The Stranger, The Test)		3. Varying your sentence starts		4. Structuring the narrative • Hook: a way in to the story. A way to grab the reader's interest – it can be one line. • Development: something changes – maybe a problem - that complicates the story and builds towards the climax. • Climax: a dramatic or eventful moment. • Resolution: the tidying-up of loose ends, pulling the threads of the story together. Remember to have a strong final sentence.		6. Hook your reader • Use ambiguous pronouns or articles: it, she, the, I, he, she, they, it etc. • Begin in the middle of the action • Open with dialogue • Mention an unusual event • Address the reader • Make a claim or state a moral • Set the scene in an intriguing way			
Story Structure Build-Up Wind-down									

English Language GCSE: Transactional Writing (Writing a piece of non-fiction writing)		7. Key vocabulary	
1. Text types	You will be asked to write two of the following, adapting your writing according to the PALL: - Formal letter - Informal letter - Report - Review - Article - Speech - Guide	6. Varying your sentence starts	
		1. Not only, but also E.g. Not only are holidays too infrequent, but they are also too short. 2. So, so E.g. Holidays are so infrequent, so short, that they feel as if they are over before they begin 3. Brackets although E.g. School holidays are too infrequent (although some killjoys will love to tell you otherwise) and the impact of this has been seen on students in the high anxiety rates among teenagers. 4. Triple abstract noun colon E.g. Fury, anger, dismay: the feelings felt by both staff and students at the end of the holidays are intense. 5. Simile start E.g. Like a child's first steps, holidays are something to be treasured. 6. Verb beginnings E.g. Considering the amount of time families spend apart, holidays are clearly too infrequent. 7. More more E.g. The more time children have to relax, the more energised and engaged they will be in their studies, and ultimately the more they will achieve. 8. Less less E.g. The less time spent with the family means the less time that is spent establishing family values, which means the less time a child is able to connect with their parents 9. Fortunately/unfortunately E.g. Fortunately, the holiday companies are aware of the holiday dates and can adjust the capacity for those dates; unfortunately, this comes at a significant financial premium. 10. Adverb beginnings E.g. Typically, no one consults children on how they feel about holiday dates and the frequency of their breaks.	
		8. Planning your writing	
		1. BUG the question 2. Work out the PALL : Purpose, Audience, Language, Layout. 3. Brainstorm your ideas. 4. Choose your strongest 5 ideas , including an introduction and conclusion.	

English Language GCSE: Reading Papers (Reading an extract and answering questions)				Component 1 Reading: <i>read an extract from a story. Answer 5 questions, including quotations and showing you can analyse language</i>		Component 2 Reading: <i>read two non-fiction texts, linked by theme, and answer 6 questions.</i>	
Component 1 (1hr 45mins)		Component 2 (2 hours)		Useful vocabulary when answering the fiction and non-fiction reading papers			
A: Unseen 20 th Century Literature Reading (40 marks worth 20%) B: Creative Prose Writing (40 marks worth 20%)		A: Unseen 19th and 21 st Century Non-Fiction Reading (40 marks worth 30%) B: Transactional writing (40 marks worth 30%)					
English Language: Assessment Objectives							
AO1	Identify and interpret explicit and implicit information and ideas						
	Select and synthesise evidence from different texts						
	Explain comment on and analyse how writers use language and structure to achieve effects and influence readers, using relevant subject terminology to support their views						
AO2							
AO3	Compare writers' ideas and perspectives, as well as how these are conveyed, across two or more texts						
AO4	Evaluate texts critically and support this with appropriate textual references						
AO5	Communicate clearly, effectively and imaginatively, selecting and adapting tone, style and register for different forms, purposes and audiences						
AO6	Organise information and ideas, using structural and grammatical features to support coherences and cohesion of texts						

Useful vocabulary when answering the fiction and non-fiction reading papers		Component 1 Reading: <i>read an extract from a story. Answer 5 questions, including quotations and showing you can analyse language</i>		Component 2 Reading: <i>read two non-fiction texts, linked by theme, and answer 6 questions.</i>	
Use		It means...		In a sentence	
1	Highlights	Makes something stand out	The writer highlights the character's happiness by describing his beaming smile.		
2	Reinforces	Strengthens or supports	The writer uses repetition to reinforce the importance of hand washing.		
3	Contributes to	Adds to	The use of short sentences contributes to the rising tension.		
4	Develops	Grows/unfolds	The writer develops a strong sense of fear as the character approaches the door.		
5	Reveals	Shows something new	The writer reveals the secret of the hero's true identity at the very end of the story.		
6	Demonstrates	Gives an example	The use of exclamation marks demonstrates the writer's enthusiasm.		
7	Ensures	Makes sure	The writer repeats the information to ensure that the reader is left in no doubt.		
8	Portrays	Describes	At the start of the extract, the writer portrays this character as shy.		
9	Initially	At first	Initially , we are shocked at the character's behaviour until we understand why they did this.		
10	Surprisingly	Unexpected	Surprisingly , the author withholds this information until the end.		
11	Contrasts	Shows a strong difference	The writer contrasts the behaviour of the two boys in this extract, revealing their differences.		
12	Ultimately	In the end, to sum up	Ultimately , we are left satisfied with the outcome of the story.		
13	Ironic	Saying the opposite of what you mean, often to create humour.	The writer creates an ironic tone by pretending that everyone is happy when they are really not.		
14	Humorous	Funny	The writer includes a humorous anecdote to engage the reader.		
15	Sarcastic	Saying the opposite of what you mean to mock or show you disagree.	The writer is clearly sarcastic when he says "everything is perfect" after describing the poor conditions.		
16	Cautious	Careful	After being misled by the character, the reader is cautious about believing his later claims.		
17	Courteous	Polite	The speaker is courteous as he ignores subjects which might offend the audience.		
18	Nostalgic	Thinking about the past in a positive way	The writer evokes a nostalgic feeling when describing happy memories of a neglected playground.		
19	Detached	No emotion – separate from the event	The detached tone confirms that the writer was not upset by the events.		
20	Flattering	Praise and complement	The writer is clearly flattering the reader when he says he knows that they will understand what he is talking about.		

	Macbeth	A Christmas Carol	An Inspector Calls
Language	Symbolism: Blood - symbol of guilt, especially blood on hands as guilt for murder. Milk is a symbol of innocence. Pathetic fallacy: natural events foreshadow future bad events, "thunder and lightning" associated with witches. Persuasive devices: LMB persuades MB to kill Duncan, using rhetorical questions, emotive language, imperative verbs, inclusive pronouns. Metaphor: Animal imagery often represents emotions, e.g. "O, full of scorpions is my mind, dear wife!" Euphemisms: a mild word as a substitute, e.g. "deed," "it," "the business," "assassination: to show their inability to admit to their terrible crimes. Motifs: a symbol that is repeated throughout the play, e.g. blood, crown, hands, sleep, animals.	Symbolism: Marley's chains represent what he valued in life, and his regrets in death – "cash boxes, ledgers" etc. Pathetic Fallacy: Cold weather, "cold and frost" represents Scrooge's cold heart. Conversational Narrative Voice: Used for opinions on characters. Creates relationship with reader. Similes: "Solitary as an oyster" (stave 1), "as light as a feather" (stave 5). Personification: "Innocence and Want," neglected children, represent problems of Victorian society. Description: highly descriptive language creating vivid images of character, place and setting.	Symbolism: The Inspector's photograph represents revelation and judgement. Inspector Goole is a moralistic figure, representing Priestley's own views. Anaphora: Emphatic repetition at the beginning of sentences, "We don't live alone. We are members of one body. We are responsible for each other." Makes the message memorable and persuasive. Slang: Younger generation use informal language like "squiffy" (Sheila/Eric), "chump" (Sheila), "tart" (Eric) which signals their youth. Realistic dialogue: plain language with less imagery adds to the realism: "But you're partly to blame. Just as your father is."
Structure	Acts/Scenes: Enables a variety of settings. The number and length of scenes affects the pace of the play. Cyclical structure: Play begins with death of a traitor, and ends with Macbeth, now a traitor, being killed. Verse: (witches = trochaic tetrameter and riddles), blank verse (unrhyming), iambic pentameter (five feet in each line creating _ / rhythm), prose (Porter) Foreshadowing: bloody battle-murders/hearing voice-insomnia/Macduff's suspicions-his opposition	Staves: each stave ('chapter') describes a new stage in Scrooge's journey of redemption. A musical term, adding to the idea of the story as a festive carol. Foreshadowing: Tension builds in Stave 4 as the reader realises first that the unfortunate dead man is Scrooge.	Acts: Each act begins as the previous ended, creating a sense of realism. Cliffhangers: Each act ends with a character under suspicion and facing interrogation, raising the audience's tension. Climax: Eric is revealed as the father of Eva's baby. Twist: After questioning the Inspector's identity, the phone call at the end comes as a surprise.
Form	Morality play: The audience is taught a lesson to learn from in life. E.g. MB allows himself to be influenced by the witches/his wife, ultimately leading to his downfall. Tragedy: A serious play where someone of high rank experiences a reversal of fortune (good to bad), resulting in the audience's pity/fear.	Allegory: ACC is a story used to deliver a moral message about real-world issues. The narration "Once upon a time..." suggests a morality tale. Ghost Story: Traditional, popular in festive season. Novella: A longer text than a short story but shorter than a traditional novel.	Morality play: AIC teaches the audience lessons based on 7 deadly sins. The audience is led to question their own behaviour. Crime thriller: Action centres around the suicide of Eva Smith. It turns out that every character is a potential suspect, even the audience.
Dramatic devices	Asides: The audience accesses a character's mental thoughts and observations through brief asides. "I fear thou play'st most foully for't." Soliloquies: A more extended aside. Characters often justify important decisions and expose internal conflict, e.g. A1Sc7, MB justifies his decision not to kill Duncan. Dramatic irony: E.g. the gentlewoman/Dr work out LMB's involvement with dark deeds through her sleepwalking. Foili: a character who contrasts with another character; typically, a character who contrasts with the protagonist to highlight difference, e.g. Banquo and Macbeth.	Foili: a character who contrasts with another character; typically, a character who contrasts with the protagonist to highlight difference, e.g. Cratchit and Scrooge, Fezziwig and Scrooge.	Stage directions: Priestley's instructions on lighting, setting or how characters should behave/deliver lines. These have a huge impact on our perception of characters. Setting: Constant setting in real time. Dramatic irony: E.g. we realise Eric is the father of Eva's child before Mrs B. Interruptions: Deliberately placed to raise tension, e.g. the "sharp ring of the front doorbell." Dramatic pauses: We anticipate characters' responses. Tension builds.

1. The Exam (1 hour)

The anthology paper is 1 hour long, and you have to write about two poems from the anthology. One is given to you, and you compare it to one from memory.

Answer both part (a) and part (b) ^{SEP} You are advised to spend about 20 minutes on part (a) and about 40 minutes on part (b).

Read the poem below, (*Poem title*) by (*poet*). **Write about the ways in which (the poet) presents (key theme) in this poem.** [15]

Choose one other poem from the anthology in which the poet also writes about (key theme). **Compare the presentation of (key theme) in your chosen poem to the presentation of (key theme) in (poem given in part a).** [25]

2. Form

* **Sonnet** (Sonnet 43; Ozymandias; The Soldier): Written in iambic pentameter with a strong and specific rhyme scheme. 14-line poems, usually structured with an octave (8 lines) which poses a problem and a sestet (6 lines) which answer the problem.

* **Dramatic monologue** (London; Hawk Roosting): First person, speaking passionately about a topic.

* **Ode** (To Autumn; Cozy Apologia- To Fred): A poem in praise of something.

* **Narrative poem** (Death of a Naturalist; The Prelude): Poems that tell a story.

* **Elegy** (Mametz Wood; As Imperceptibly as Grief): a poem of serious reflection, typically a lament for the dead.

3. Vocabulary to describe tone

admiring
appreciative
assertive
candid
earnest
enthusiastic
impassioned
imploping
intimate
nostalgic
pensive
reverent
sincere
solemn

angry
arrogant
bitter
callous
cautionary
condescending
critical
defensive
disapproving
egotistical
narcissistic
regretful
uneasy

English Literature GCSE: Poetry Anthology

Romantic poems (1800-1850)		Victorian (1837-1901)		WW1 (1914-18)		Modern poems (1950 onwards)	
Poem		Overview					
London by William Blake (1794)		Blake describes the terrible conditions of 18 th century London, including child labour, the 'corrupt' Church and prostitution.					
She Walks in Beauty by Lord Byron (1814)		Byron describes the physical beauty and moral goodness of a woman, using the imagery of night and darkness to suggest mystery and exoticism.					
Ozymandias by Percy Bysshe Shelley (1818)		Shelley describes a broken and abandoned statue of a once-powerful Egyptian king, reflecting how all his arrogance and pride came to nothing.					
To Autumn by John Keats (1819)		Keats writes a lyrical description, personifying autumn as a romanticised country labourer. He emphasises the beauty of the season and harvest-time.					
Excerpt from The Prelude by William Wordsworth (1850)		Wordsworth nostalgically describes ice skating on a winter's evening in his youth, emphasising the rural setting with sensual imagery.					
Sonnet 43 by Elizabeth Barrett Browning (1850)		Browning writes a passionate description of her love, using religious imagery to convey the strength of her emotion.					
As Imperceptibly as Grief by Emily Dickinson (1865)		The poet writes an apparently simple elegy on time passing, which is in fact very complex in its reflection on depression and human experience, using summertime as a metaphor for grief.					
A Wife in London by Thomas Hardy (1899)		This is a bleak and ironic comment on the tragedy of war: a woman learns of her husband's death, then gets a letter from him full of happy future plans.					
The Soldier by Rupert Brooke (1914)		Brooke writes about how glorious it is to die abroad fighting for England, using happy, patriotic imagery which ignores the horrors of war.					
Dulce et Decorum Est by Wilfred Owen (1917)		Owen describes death by gas in WW1 in vivid horrifying detail, comparing this ironically to the Latin title which says it is sweet to die for your country.					
Afternoons by Philip Larkin (1959)		Larkin's negative view of human relationships is shown as he describes the emptiness of young mothers' lives as they take their children to the park.					
Hawk Roosting by Ted Hughes (1960)		Hughes writes in the voice of a hawk resting between killing its prey, showing that it is arrogant, controlling and brutal.					
Death of a Naturalist by Seamus Heaney (1966)		Heaney vividly describes enjoying collecting frogspawn as a young boy and later being disgusted by the frogs to illustrate his loss of innocence.					
Valentine by Carol Ann Duffy (1993)		Duffy's poem is rejection of romantic clichés, using the extended metaphor of an onion to show love can bring pain and suggest passion can be sinister.					
Cozy Apologia by Rita Dove (2003)		Dove describes working at her desk while a hurricane approaches, thinking about her husband and celebrating their ordinary, comfortable love.					
Mametz Wood by Owen Sheers (2007)		Sheers describes farmers finding the skeletons of soldiers who died in WW1 which emphasises the horrors of war and the vulnerability of human beings.					
The Manhunt by Simon Armitage (2007)		Armitage writes in the voice of a woman dealing with the physical and mental damage caused to her husband by being seriously injured in war.					
Living Space by Imtiaz Dharker (2009)		Dharker describes a slum in India, contrasting the disapproving attitude of an outside observer with the optimistic efforts of those trying to make a life there					

English Literature – A Christmas Carol (45 minutes: 1 exploding extract)

	Social Injustice	Redemption	Christmas
1 Stave	“Are there no prisons?...and the Union workhouses?” Scrooge to the charity collector. “it’s not fair. If I was to stop half a crown for it, you’d think yourself ill used” Scrooge about paying Bob for Christmas.	“I wear the chain I forged in life” Marley’s ghost. “Hard and sharp as flint...solitary as an oyster” description of Scrooge.	“A merry Christmas, uncle!” Fred, spreading Christmas cheer. “every idiot who goes about with ‘Merry Christmas’ on his lips, should be boiled with his own pudding” Scrooge to Fred.
	“You... weigh everything by Gain” Belle when she “releases” Scrooge from their engagement. “This is the even-handed dealing of the world” Scrooge’s reasoning to Belle for pursuing wealth.	“A solitary child, neglected by his friends, is left there still” Ghost of CP’s description of Scrooge as a child. “I should like to say a word or two to my clerk just now” Scrooge.	“Yo ho my boys... no more work to-night!” Fezziwig to his employees. “In they all came... anyhow and anyhow.” guests to Fezziwig’s party – all welcome.
	“This boy is Ignorance. This girl is Want. Beware of them both” Ghost of CP about the ugly, dirty children under his robes. “His wealth is of no use to him. He don’t do any good with it.” Fred’s description of Scrooge.	“such an odious, stingy, hard, unfeeling man as Mr. Scrooge” Mrs Cratchit’s description of Scrooge as he watches. “Oh no kind spirit! Say he will be spared” Scrooge pleads for Tiny Tim.	“Such a bustle ensued that you might have thought a goose the rarest of all birds.” The Cratchits are excited and grateful for their little feast. “he begged like a boy to stay” Scrooge watching Fred’s Christmas merriment.
	“my little, little child” cried Bob.” Bob Cratchit about Tiny Tim. “He frightened every one away from him when he was alive, to profit us when he was dead! Ha, ha, ha!” a thief as they examine their haul..	“This is a fearful place. In leaving it, I shall not leave its lesson, trust me” Scrooge is ready to learn. “Assure me that I yet may change these shadows you have shown me, by an altered life!” Scrooge wants to change things.	“the room above, which was lighted cheerfully and hung with Christmas” the Cratchits’ house, even after Tiny Tim’s death. “I will honour Christmas in my heart and try to keep it all the year.” Scrooge to the Ghost of CYTC.
	“A merrier Christmas, Bob.. Than I have given you for many a year!” on raising BC’s salary. “A great many back payments are included in it, I assure you” Scrooge to the charity collector.	“to Tiny Tim, who did not die, he was a second father” Scrooge showing love and compassion. “Uncle Scrooge had... become so gay and light of heart” Scrooge’s character transformation.	“It’s I. Your uncle Scrooge. I have come to dinner.” Finally attending Christmas dinner – to their amazement. “I’ll send it to Bob Cratchit’s!” Scrooge sending the Turkey.

Scrooge makes Cratchit work in the cold

Scrooge refuses to give to charity

Scrooge is haunted by Marley

Visit from Ghost of Christmas Past

Visit from Ghost of Christmas Present

Visit from Ghost of Christmas Yet to Come

Scrooge mends his ways

Scrooge is redeemed

25 DEC

Published in 1843 in Victorian England

Scrooge

Adjectives: miserly, cold-hearted, repentant, redeemed.

Writer’s intention: Dickens uses Scrooge to show what was wrong with wealthy Victorians. On his tour with the ghosts, he learns to take social responsibility and redeems himself. Dickens wanted his readers to do the same.

Fred is Scrooge’s nephew.

Adjectives: warm, cheerful, patient and family-orientated.

Writer’s intention: Dickens uses Fred to model Christmas spirit when inviting Scrooge to dinner. Contrast with Scrooge, shows Scrooge’s cold heartedness and need for redemption.

Marley’s Ghost was Scrooge’s late business partner,

Adjectives: remorseful, troubled and grave.

Writer’s intention: Dickens uses Marley’s Ghost to warn wealthy Victorians of the consequences of living a selfish and greedy existence: regret and eternal misery.

Fezziwig was Scrooge’s first employer, who throws a party on Christmas Eve for employees and locals.

Adjectives: jolly, altruistic, inclusive.

Writer’s intention: Dickens uses Fezziwig, to show what wealthy Victorians could and should be like, in contrast with Scrooge.

Belle was Scrooge’s fiancée who broke off their engagement due to his obsession with money.

Adjectives: beautiful, gentle, unmaterialistic.

Writer’s intention: Dickens uses Belle to remind readers that greed and selfishness can cost us love and happiness, which money can’t buy.

Published in 1843 in Victorian England

English Literature – An Inspector Calls (45 mins: 1 exploding extract)

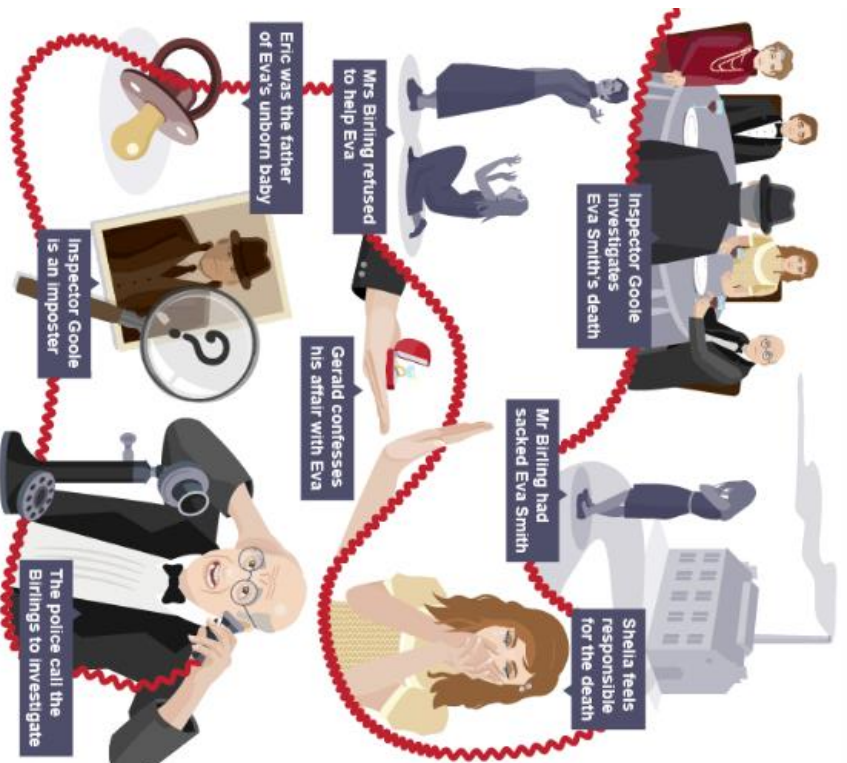
Key Quotations

Mr Birling	Mrs Birling	Sheila	Eric	Gerald	Inspector
"community and all that nonsense" Mr B to Eric and Gerald. [1] "the Germans don't want war" to Gerald and Eric [1] "She had a lot to say – far too much – she had to go" Mr B to the Inspector. [1] "Now Sheila... you must understand that a lot of young men..." to Sheila, defending Gerald. [2] "There'll be a public scandal." to Eric, furious. [3] "[excitedly] By jingo! A faker" to Gerald [3] "the famous younger generation who know it all" about Eric and Sheila [3]	"Men with important work to do sometimes have to spend nearly all their time and energy on their business." to Sheila [1] "I did nothing I'm ashamed of" to Inspector [2] "I used my influence to have it refused" To Inspector about Eva's request for help. [2] "As if a girl of that sort would ever refuse money!" to Inspector [2] "You're behaving like a hysterical child" to Sheila [2]	"Look – mummy – isn't it a beauty?" to Mrs B [1] "Except for last summer when you never came near me" Sheila to Gerald [1] "But these girls aren't cheap labour – they're people!" Sheila to Mr B [1] "I know I'm to blame – and I'm desperately sorry" to Inspector [2] "We all started like that – so confident, so pleased with ourselves" to Mrs B [2] "You don't seem to have learnt anything" to Mr B [3]	"Why shouldn't they try for higher wages?" to Mr B. [1] "I was in that state when a chap easily turns nasty" to the Inspector about his first night with Eva. [3] "You're not the kind of father a chap could go to when he's in trouble" to Mr B [3] "[nearly at breaking point] Then – you killed her." to Mrs B when he finds out she refused Eva help. [3] "We all helped to kill her – and that's what matters." [3]	"[very much the well-bred young man-about-town]" Description [1] "I didn't feel about her as she felt about me" to Sheila, about Daisy. [2] "I'm rather more – upset – by this business than I probably appear to be" to the Inspector [2] "Everything's all right now, Sheila [holds up the ring]" [3]	"[a sharp ring of the front door bell]" interrupting Mr B's speech [1] "she died in misery and agony – mating life" to Gerald and Sheila [2] "[massively] Public men, Mr Birling, have responsibilities as well as privileges." to Mr B [2] "used her... as if she was an animal, a thing, not a person" to Eric [3] "We are members of one body." to the Birlings [3] "fire and blood and anguish" to the Birlings. [3]

Written in 1945 (Post the wars) – Set in 1912 (Pre the wars)

THEMES: SOCIAL RESPONSIBILITY – YOUTH V AGE – SOCIAL STATUS – GENDER INEQUALITY

Mr Birling Adjectives: pompous, stubborn, social-climber Writer's intention: Used to highlight the danger of selfish capitalists who exploit workers for profits. His flawed views on WW1 and the Titanic warn against having the same irresponsible arrogance post WW2.	Mrs Birling Adjectives: Cold, prejudiced, supercilious, callous. Writer's intention: Mrs B ignores any signs of trouble in the family for the sake of appearances. Her charity work sounds impressive, but allows her to enjoy power. She feels above social responsibility.	Sheila Adjectives: Spoilt, insecure, candid, ashamed. Writer's intention: Sheila accepts the Inspector's message and responsibility for her actions with remorse, creating hope for the younger generation. Her socialist views contrast with her parents'.	Eric Adjectives: Irresponsible, devastated, repentant, frustrated. Writer's intention: Priestley shows the danger of privileged, irresponsible young men. Like Sheila, he is genuinely appalled the consequences of his actions, as well as his parents' attitudes, which partially redeems him.	Gerald Adjectives: "attractive", "well-bred", Writer's intention: While Gerald's actions showed care for Eva, he did take advantage of her and left her broken-hearted without hope of life improving. His social status and charm seem to mitigate his behaviour.	Eva Smith (Daisy Renton) Adjectives: principled, destitute, helpless. Writer's intention: Eva highlights the plight of the working class, especially women and how they are often victims of circumstance and prejudice from their social superiors.	The Inspector Adjectives: Brusque, assured, enigmatic, righteous. Writer's intention: Priestley's mouthpiece for his socialist message, warning his audience not to repeat the mistakes of past generations and to look after each other.
--	--	---	--	--	--	---

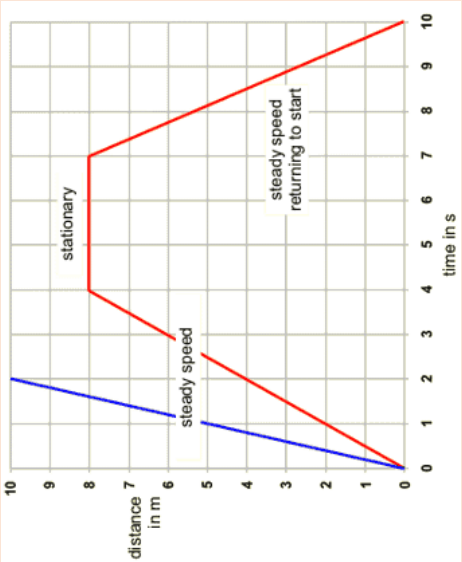
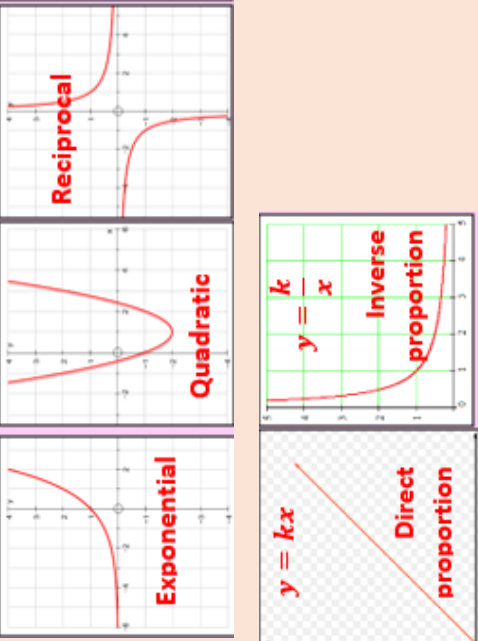
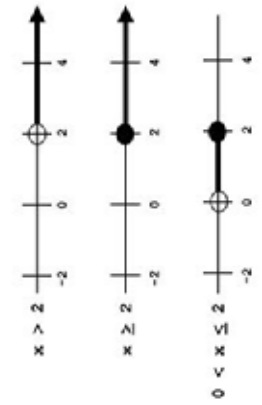


English Literature – Macbeth (1 hour exam: 20 mins extract, 40 minutes essay)

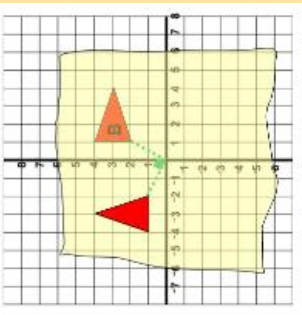
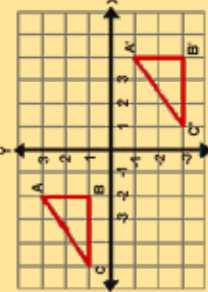
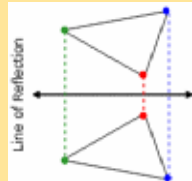
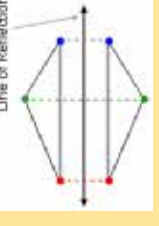
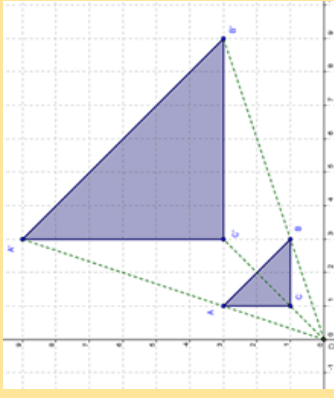
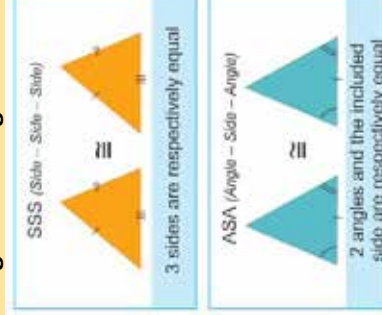
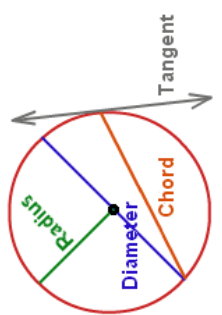
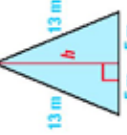
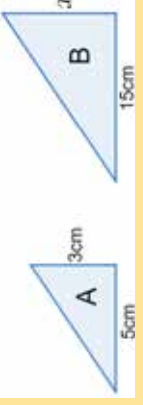
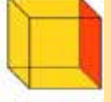
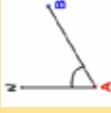
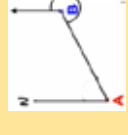
Key Quotations

Act 1	Act 2	Act 3	Act 4	Act 5
"Fair is foul and foul is fair" The Witches, chanting (A1, S1). "Unseamed him from the nave to the chaps" Captain describing Macbeth's brutal combat. (A1, S2) "He seems rapt withal" Banquo noticing Macbeth's reaction to the prophecies. (A1, S3) "He was a gentleman on whom I built an absolute trust" Duncan about the traitor Thane of Cawdor (A1, S4) "O worthiest cousin" Duncan to Macbeth after his promotion (A1, S4) "I do fear thy nature—it is too full o' th' milk of human kindness" Lady Macbeth (A1, S5) "Come you spirits...unsex me here" Lady Macbeth (A1, S5) "When you durst do it, then you were a man" Lady Macbeth manipulating her husband into killing Duncan. (A1, S7)	"My bosom franchised and allegiance clear" Banquo hints to Macbeth he will always act morally. (A2, S1) "Is this a dagger I see before me?" Macbeth's vision before killing Duncan. (A2, S1) "Will all great Neptune's ocean wash this blood clean from my hand?" Macbeth's guilt having just killed Duncan (A2, S3) "A little water clears us of this deed" LM dismisses the impact of guilt. (A2, S3) "O horror horror horror" Macduff discovers Duncan's body. (A2, S4)	"I fear thou played'st most foully for't." Banquo's suspicions about Macbeth (A3, S1) "Nought's had, all's spent, where our desire is got without content" LM is unhappy as queen (A3, S2) "We have scotch'd the snake, not kill'd it!" Macbeth feels the threat to the throne is alive in Banquo/his son (A3, S2) "O, full of scorpions is my mind, dear wife!" Macbeth's torment at the idea of losing the crown (A3, S2) "Thou canst not say I did it, never shake thy gory locks at me!" Macbeth's fear and outrage at being haunted by Banquo's ghost (A3, S4) "Are you a man?" LM uses her previous tactic to try to calm Macbeth. (A3, S4) "Blood will have blood" Macbeth fears the consequences of his actions. (A3, S4)	"Beware Macduff" the witches' apparition warns Macbeth. (A4, S1) "None of women born shall harm Macbeth" another apparition from the witches gives Macbeth confidence (A4, S1) "Give to th' edge o'th; sword his wife, his babes" Macbeth orders the murders of Macduff's family. (A4, S1) "all my pretty chickens and their dam at one fell swoop?" Macduff is devastated and in disbelief that his family are gone (A4, S3) "Let's make us medicines of our great revenge!" Malcolm encourages Macduff to use his devastation to destroy Macbeth. (A4, S3)	"Out damned spot!" LM has visions of blood on her hands as she sleepwalks. (A5, S1) "who would have thought the old man to have so much blood in him?" LM is disturbed by all the killings triggered by Duncan's death. (A5, S1) "Our castle's strength will laugh a siege to scorn!" Macbeth is over-confident about the battle. (A5, S5) "Out, out, brief candle!" Macbeth mourns the loss of LM (A5, S5) "Life's but a walking shadow" Macbeth remarks on the futility of life. "Macduff was from his mother's womb untimely ripped!" Macduff before beheading Macbeth (A5, S10)
Macbeth kills the king. Macbeth becomes king. Macbeth gets more prophecies from the witches. Lady Macbeth goes mad and dies.	Macbeth has his friend Banquo murdered. Macduff joins up with Malcolm, son of the dead king. Macduff kills the family of Macduff, Thane of Fife. Macduff and Malcolm dress up like trees and attack Macbeth.	Macbeth kills Macbeth.	Macbeth kills Macbeth.	Macbeth kills Macbeth.
Macbeth Adjectives: violent, easily-influenced, guilty, paranoid, tyrannical, arrogant Writer's intention: Shakespeare uses Macbeth to show how loyal men can be corrupted by ambition and supernatural evils. His death warns of the inevitable fate of those who challenge the king's authority. Lady Macbeth Adjectives: Ambitious, manipulative, discontent, disturbed. Writer's intentions: Lady Macbeth could show the dangers of strong women with ambition, especially those who call upon supernatural help. She also shows the maddening effect of guilt.	The Witches Adjectives: Ominous, meddlesome, evil. Writer's intention: They represent the danger of being influenced by the supernatural.	King Duncan Adjectives: Warm, appreciative, naive. Writer's Intention: Duncan's weakness is putting his trust in valiant yet corruptible men like Macbeth and the previous Thane of Cawdor.	Macduff Adjectives: suspicious, loyal, patriotic, devastated, motivated, heroic. Writer's Intentions: Macduff passionately fights for Scotland and to avenge his family. He follows his morals rather than fearing the wrath of Macbeth. Although he's a hero, he pays a heavy price.	Banquo Adjectives: wary, loyal, suspicious. Writer's Intention: Banquo distrusts the witches and doesn't act on their prophecies like Macbeth, displaying better judgement. Banquo's death shows Macbeth's total corruption when he arranges the murder of his best friend and innocent child to protect himself. Banquo's ghost distresses Macbeth, displaying his guilt.

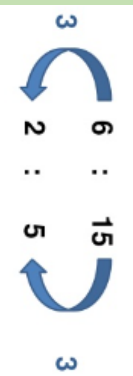
THEMES: AMBITION – SUPERNATURAL – GUILT – LOYALTY – POWERFUL WOMEN – APPEARANCE V REALITY

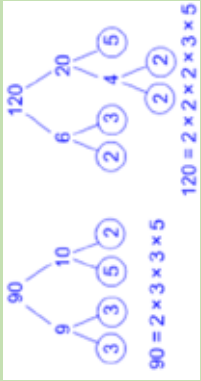
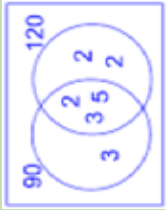
Notation $ab = a \times b$ $a^2 = a \times a$ $(2a)^3 = 2a \times 2a \times 2a$ $(a + b)^2 = (a + b)(a + b)$	Factorising and expanding 	Straight line graphs $y = mx + c$ $m = \text{gradient}$ $c = y - \text{intercept}$ positive gradient negative gradient $m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\text{change in } y}{\text{change in } x}$ Parallel lines – have equal gradients
Definitions Expression – no equal signs e.g. $2x + 3$, $2y$, $(3x - 2)^2$ Equations – equal signs, can be solved, e.g. $y + 4 = 10$ Identities – identical/equivalent to e.g. $2(y + 4) \equiv 2y + 8$ Formulae – equal signs, more than one unknown e.g. $A = \frac{1}{2}bh$	Distance / Time Graphs 	Graphs that need to be recognised 
Simplifying expressions by collecting like terms Always circle the sign IN FRONT of the term to avoid errors. $3x(-7b - x) + 9b \equiv 2x + 2b$ Typical Exam Q: Create an expression for the perimeter of the shape by adding and collecting like terms. If the perimeter is given as 20cm, for example, you can create an equation: $4 + 3a + 4 + 6 + 2a = 20$ $5a + 14 = 20$	Turning point and roots of a quadratic equation 	Finding the nth term of a linear sequence 5, 7, 9, 11, 13, ... - Find the common difference: 2 - This is the coefficient of n: $2n$ - Find the difference between the coefficient of n and the first term $5 - 2 = 3$ - Add this to the amount of n $2n + 3$
Simplifying expressions multiplication and division $2ma^2 \times 7ma = 14m^2a^3$ $\frac{18b^6}{3ab^2} = \frac{6b^4}{a}$		
Inequalities  Open circle: $< / >$ Closed circle: $\leq / \geq$		

Trigonometry Example – finding a side: $\sin 37^\circ = \frac{x}{5}$$x = 5 \times \sin 37^\circ$ Example – finding a side: $\tan \gamma = \frac{3.2}{7.1}$$\gamma = \tan^{-1}\left(\frac{3.2}{7.1}\right).$ 5cm 37° x 7.1cm γ° 3.2cm		Angle Facts m b a n a 70° b 120° Vertically opposite angles are equal: a=b and m=n Angles in a triangle sum to 180°. Angles on a straight line sum to 180°. E.G: b=60° so a = 50°		Simple vector notation $\begin{pmatrix} a \\ b \end{pmatrix}$ a: movement along the x-axis (left or right) b: movement along the y-axis (up or down) –a: movement left –b: movement down Operations with vectors $\begin{pmatrix} 2 \\ 6 \end{pmatrix} + \begin{pmatrix} 7 \\ -3 \end{pmatrix} = \begin{pmatrix} 9 \\ 3 \end{pmatrix}$ If $b = \begin{pmatrix} 4 \\ -2 \end{pmatrix}$, then $3b = \begin{pmatrix} 12 \\ -6 \end{pmatrix}$ Area of key shapes Triangle : $A = \frac{b \times h}{2}$ (h = perpendicular height) Parallelogram: $A = b \times h$ (h = perpendicular height) Trapezium: $A = \left(\frac{a+b}{2}\right) \times h$ (add together the parallel sides, divide the total by 2, and then multiply by the perpendicular height between the parallel sides)		Angles in parallel lines 110° 110° Corresponding Angles 110° 65° Alternate Angles 110° 70° Interior Angles Corresponding angles are equal Alternate angles are equal Co-interior angles add to 180.		Volume & surface area Volume = area of cross section x length Surface area = area of all the faces of a 3D shape Learn the cylinder $V = \pi r^2 h$$SA = 2\pi r^2 + \pi dl$ Angles in regular polygons $n = \text{number of sides}$ Interior angle + exterior angle = 180° Exterior angle = $\frac{360}{n}$ $n = \frac{360}{\text{Exterior angle}}$ Interior angle Exterior angle	
--	--	--	--	--	--	---	--	--	--

Transformations – rotation Always use tracing paper. Describe: 1. It's a rotation 2. Size of rotation in degrees 3. Orientations: clockwise or anticlockwise 4. Centre of rotation given as a coordinate (x,y) 	Transformations – translations and reflections  Translate triangle ABC to A'B'C' with the vector $\begin{pmatrix} -6 \\ 4 \end{pmatrix}$  Reflection in the line $x=a$  Reflection in the line $y=a$	Transformations - enlargement  Describe: 1. It's an enlargement 2. The scale factor (if the image is smaller than the object the scale factor is fractional e.g. $\frac{1}{2}$) 3. The centre of enlargement given as a coordinate
Congruent triangles 	Circles  Area = πr^2 Circumference = πd Sector Area = $\frac{\theta}{360} \pi r^2$ Arc length = $\frac{\theta}{360} \pi d$	Pythagoras' Theorem $a^2 + b^2 = c^2$ Only applies to right angled triangles. Can be used to find the height of an isosceles triangle  Can be used to find the length distance between two coordinates
Similar shapes Same shape, different sizes The ratio of the lengths of corresponding sides are equal  Length scale factor = $15 \div 5 = 3$ $x = 3\text{cm} \times 3$	3D notation Cube: Faces: 6 Edges: 12 Vertices: 8    Square based pyramid:  $F = 5, E = 8, V = 5$	Bearings Measure from the North Measured in a clockwise direction Written using 3 digits Bearing of B from A (start at A)  Bearing of A from B (start at B) 

Number Ratio and Proportion - Foundation

Estimate Round each value to one significant figure	Simplifying Ratio Divide both sides by the highest common factor 	Percentages Finding percentages of an amount 1% ÷100 5% ÷20 20% ÷5 25% ÷4 50% ÷2 Multipliers: To find the multiplier for a percentage, divide by 100 Use multipliers on a calculator paper e.g. 35% of 370 = 0.35 x 370 Increasing and decreasing a given amount Calculator: <i>Original Amount x multiplier = new amount</i> Non-calculator: find the increase or decrease and add to the original amount Finding percentage increase or decrease (profit/loss) $\frac{\text{value of increase/decrease}}{\text{Original}} \times 100$ Writing an amount as a percentage of the original $\frac{\text{Amount}}{\text{Original}} \times 100$ Reverse Percentage – finding the original amount $\text{Original Amount} = \frac{\text{New Amount}}{\text{multiplier}}$
Standard form $a \times 10^n$, where $1 \leq a < 10$		
Reciprocal Reciprocal of 7 is $\frac{1}{7}$, reciprocal of $\frac{2}{3}$ is $\frac{3}{2}$ etc		
Sequences Fibonacci sequence: 1, 1, 2, 3, 5, 8, 13, 21 Geometric Sequence: each term is multiplied but he same constant to get the next number. E.g. 3, 12, 48, 191, (x by 4 each time)		
Squares and Cubes Square numbers: 1, 4, 9, 16, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 etc Cube numbers: 1, 8, 27, 64, 125, 216, 343, 512, etc	Fractions Add and Subtract – ensure the fractions have the same denominator before adding numerators $\frac{4}{5} - \frac{1}{3} = \frac{12}{15} - \frac{5}{15} = \frac{7}{15}$ Multiply – multiply numerators and denominators $\frac{4}{5} \times \frac{1}{3} = \frac{4}{15}$	
Sharing in a given Ratio A Add the ratio parts D Divide the amount by the total parts A and M Multiply the ratio by the value of one part e.g. share £420 in the ratio 2:5 $2 + 5 = 7$ $420 \div 7 = \text{£}60$ 2: 5 (x60) (x60) £120 : £300	Divide – take reciprocal of the second fraction and then multiply the new numerators and denominators $\frac{4}{5} \div \frac{1}{3} = \frac{4}{5} \times \frac{3}{1} = \frac{12}{5} = 2\frac{2}{5}$	

Growth & Decay / Compound interest <i>original amount</i> $\times$ <i>multiplier^{time}</i> Where the multiplier is the percentage, increase or decrease from 100%, converted to a decimal. e.g. 30% decrease is $70\% = 0.7$ 30% increase is $130\% = 1.3$	Dividing by decimals: 1. Write the calculation as a fraction 2. Form an equivalent fraction to makes integers (multiply by powers of 10) 3. Use short division (bus stop) to calculate e.g. $460 \div 0.4 = \frac{460}{0.4} = \frac{4600}{4} = 1150$	Conversions 10 millimetres = 1 centimetre 15 minutes = 0.25 hours 100 centimetres = 1 metre 30 minutes = 0.5 hours 1000 metres = 1 kilometre 45 minutes = 0.75 hours 1000cm³ = 1 litre 1000g = 1 kilogram 1000ml = 1 litre 1000kg = 1 tonne
Compound Units (rearrange as necessary) $Speed = \frac{Distance}{Time}$ $Area = \frac{Force}{Pressure}$ $Density = \frac{Mass}{Volume}$	Error Intervals least possible value $\leq x <$ greatest possible value e.g. A fence is 30 m long to the nearest 10 m. $25 \text{ m} \leq l < 35 \text{ m}$ Truncation Truncation is a method of approximating a decimal number by dropping all decimal places past a certain point without rounding. e.g. Truncate 3.14159265 to 4 decimal places. = 3.1415	Negative numbers Adding and subtracting: (vertical number lines help) -3 - 5 = -8 -3 + 5 = 2 -3 - 5 = -3 + 5 = 2 -3 - 5 = -3 - 5 = -8 -3 + 5 = -3 - 5 = -8 Multiplying and dividing: Different signs – answer will be negative + x - = -, - x + = - Same signs – answer will be positive - x - = +
Ordering fractions Calc: use division to write each fraction as a decimal Non-calc: write fractions with common denominators	Order of operations Bracket Indices Division and Multiplication Addition and Subtraction	Rounding to significant figures Start from the first non-zero number and round as normal, but ensure the place value is correct e.g. 345,635 to 2SF = 350,000 0.0060821 to 3SF = 0.0608
Index Laws $a^n \times a^m = a^{n+m}$ $a^n \div a^m = a^{n-m}$ $(a^n)^m = a^{nm}$ $a^0 = 1$ $a^{-n} = \frac{1}{a^n}$ $\frac{n}{a^m} = \sqrt[n]{a^m}$	Prime Factorisation  90 = 2 x 3 x 3 x 5 120 = 2 x 2 x 2 x 3 x 5	HCF and LCM of 90 and 120 (Factor Tree & Venn Diagram) HCF is the product of common factors LCM is the product of common factors and remaining factors. HCF: 2x3x5 LCM: 2³x3²x5 

Probability and Statistics - Foundation

Averages

Mode: most common piece of data

Mean: Sum of the data $\div$ total frequency

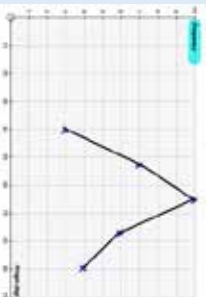
Median: order the data and find the middle value

Range: Highest value – lowest value

Frequency Polygons

1. Plot frequency at the mid-point
2. Join with straight lines

Weight w (kg)	Frequency
$30 \leq w < 50$	3
$50 \leq w < 55$	7
$55 \leq w < 75$	10
$75 \leq w < 80$	6
$80 \leq w < 100$	4



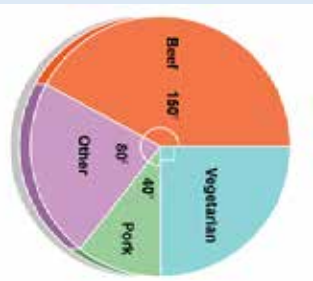
Reading and Drawing Pie Charts

Find the fraction of the total

1000 people were surveyed

$$\text{Beef: } \frac{150}{360} \times 1000$$

$$\text{Vegetarian: } \frac{90}{360} \times 1000$$



Hair colour	People
Blonde	8
Brown	12
Red	3
Grey	2
Black	6

Find the fraction of the full circle.

$$\text{Size of Blonde sector: } \frac{8}{31} \times 360^\circ$$

Expected outcomes

Expected outcome = probability $\times$ number of trials

E.g. A biased spinner is spun 800 times. The probabilities it lands on each colour is below. The probability of it landing on red is the same as the probability of it landing on green. How many times would you expect yellow to come up.

Result	Red	Green	Brown	Yellow
Probability		0.48	0.2	

$$P(Y) = (1 - 0.48 - 0.2) \div 2 = 0.32 \div 2 = 0.16$$

$$\text{Expected yellow} = 0.16 \times 800 = 128$$

Averages from a frequency table

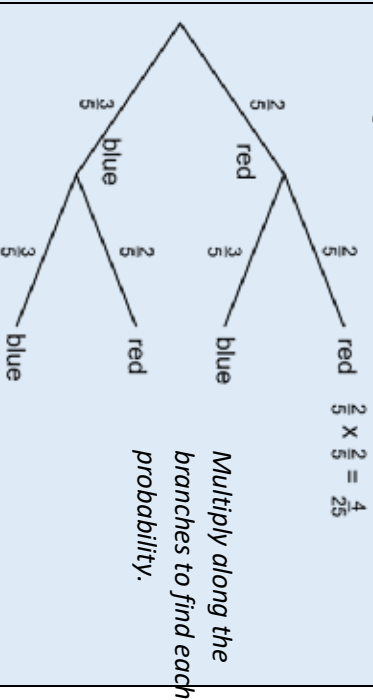
Mean: $\frac{\sum fw}{\sum f}$; where, w is the midpoint of the group.

Median group: find which group the $\frac{n+1}{2}$ th value lies. Where, n is the total frequency.

E.G. in this table 51.5th value which lies in group $8 < w \leq 12$ (using the cumulative frequency

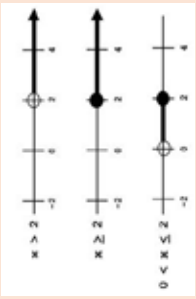
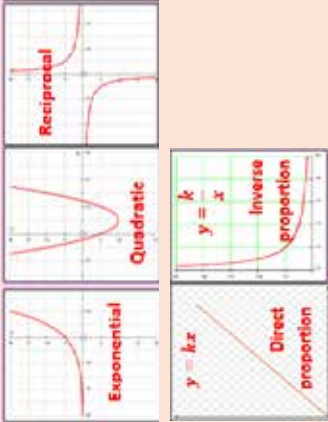
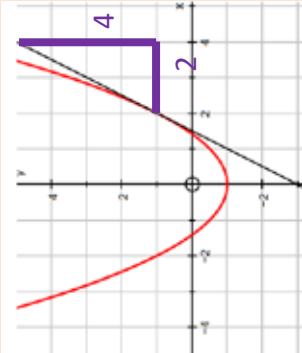
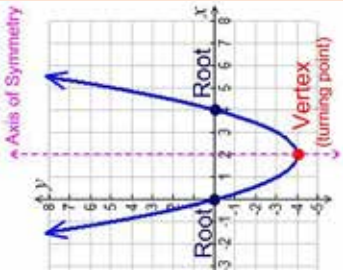
Weight of box (w kg)	Frequency
$0 < w \leq 4$	11
$4 < w \leq 8$	16
$8 < w \leq 12$	29
$12 < w \leq 16$	26
$16 < w \leq 20$	20

Tree diagrams



1. Probability that a red counter is picked both times $P(RR) = \frac{2}{5} \times \frac{2}{4} = \frac{1}{5}$

2. Probability that the counters are different colours $= P(RB) + P(BR) = \frac{2}{5} \times \frac{3}{4} + \frac{3}{5} \times \frac{2}{4} = \frac{12}{25}$

Quadratic Formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	Algebraic proof – toolkit Even numbers: $2n, 2n+2, 2n+4, \dots$ Odd numbers: $2n+1, 2n+3, 2n+5, \dots$ Sum: add Product: multiply Difference: subtract Show it's a multiple: factorise Show it's even: show it's a multiple of 2 Show it's odd: show it's a multiple of 2, plus 1	Straight line graphs $y = mx + c$ $m = \text{gradient}$ $c = y - \text{intercept}$ positive gradient negative gradient $m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\text{change in } y}{\text{change in } x}$ Parallel lines – have equal gradients Perpendicular lines – If L_1 and L_2 are perpendicular then $m_2 = -\frac{1}{m_1}$
Linear Inequalities Open circle: $< / >$ Closed circle: $\leq / \geq$ 	Completing the square Quadratic expression factorised by completing the square: $(x + a)^2 + b$ Turning point of graph occurs at $(-a, b)$ Solve quadratic inequalities e.g solve $x^2 + 5x - 24 \geq 0$ 1. Factorise: $(x + 8)(x - 3) \geq 0$ 2. Solve: $x = -8, x = 3$ 3. Sketch the graph 4. Values that satisfy the inequality $x \leq -8, x \geq 3$ 	Graphs that need to be recognised:  Equation of a circle centre $(0, 0)$ $x^2 + y^2 = r^2$
Gradients of curves Gradient of a curve at a point = gradient of the tangent at the point 	Turning point and roots of a quadratic equation 	Functions $f(4)$: Substitute 4 into the function $f(g(x))$: Substitute $g(x)$ into $f(x)$ i.e. replace all values of x in $f(x)$ with the entire function $g(x)$ e.g. $f(x) = 2x + 3, g(x) = x - 3, fg(x) = 2(x-3) + 3$

Trigonometry

$$\frac{O}{H} = \frac{A}{H} = \frac{T}{A}$$

Example – finding a side:

$$\sin 37^\circ = \frac{x}{5}$$

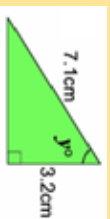
$$x = 5 \times \sin 37^\circ$$



Example – finding a side:

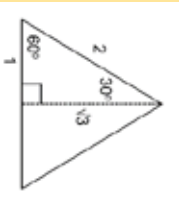
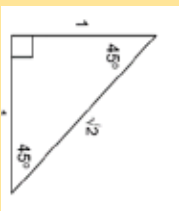
$$\tan y = \frac{3.2}{7.1}$$

$$y = \tan^{-1}\left(\frac{3.2}{7.1}\right)$$

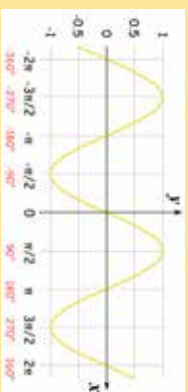


Exact Trig values

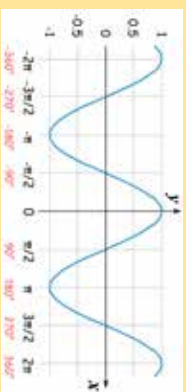
Angle (θ)	$\sin(\theta)$	$\cos(\theta)$	$\tan(\theta)$
0°	0	1	0
30°	$\frac{1}{2}$	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{3}}$
45°	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}$	1
60°	$\frac{\sqrt{3}}{2}$	$\frac{1}{2}$	$\sqrt{3}$
90°	1	0	undefined



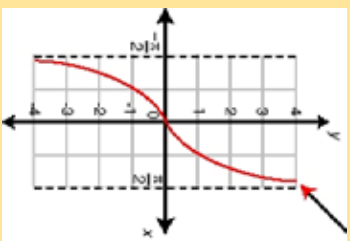
Sine Curve



Cosine Curve



Tangent Curve



Simple vector notation

$$\begin{pmatrix} a \\ b \end{pmatrix}$$

a : movement along the x-axis (left or right)
 b : movement along the y-axis (up or down)

$-a$: movement left

$-b$: movement down

Operations with vectors

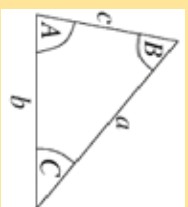
$$\begin{pmatrix} 2 \\ 6 \end{pmatrix} + \begin{pmatrix} 7 \\ -3 \end{pmatrix} = \begin{pmatrix} 9 \\ 3 \end{pmatrix}$$

If $b = \begin{pmatrix} 4 \\ -2 \end{pmatrix}$, then $3b = \begin{pmatrix} 12 \\ -6 \end{pmatrix}$

Sine rule

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$\text{sides: } \frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$



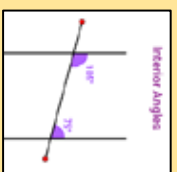
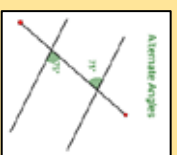
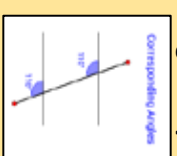
Cosine rule

$$a^2 = b^2 + c^2 - 2bc \cos A$$

Area of a triangle

$$\frac{1}{2}ab \sin C$$

Angles in parallel lines



Corresponding angles are equal

Alternate angles are equal

Co-interior angles add to 180.

Volume & surface area

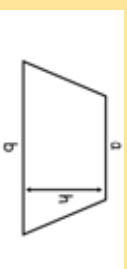
Learn the cylinder

$$V = \pi r^2 h$$

$$SA = 2\pi r^2 + \pi d l$$

Area of a trapezium

$$A = \frac{1}{2}(a + b)h$$



Angles in regular polygons

n = number of sides

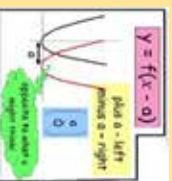
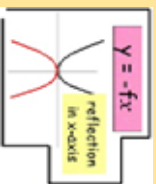
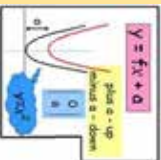
Interior angle + exterior angle = 180°

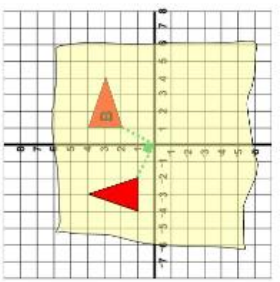
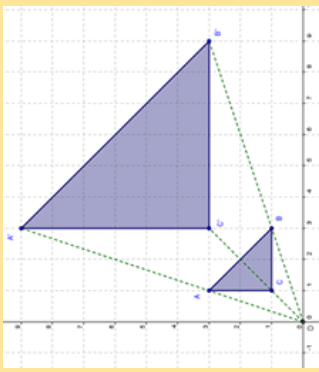
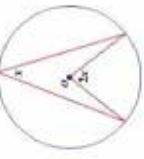
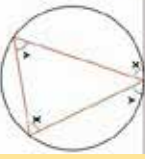
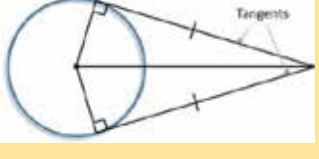
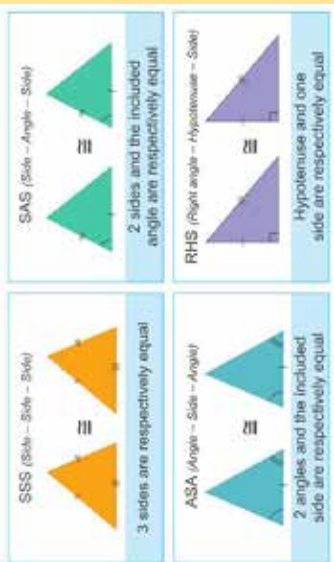
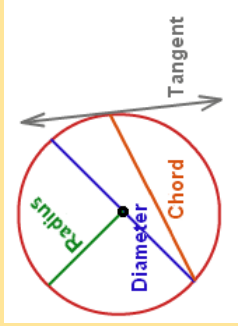
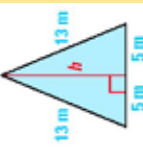
$$\text{Exterior angle} = \frac{360}{n}$$

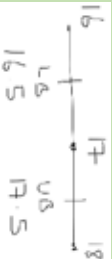
$$n = \frac{360}{\text{Exterior angle}}$$

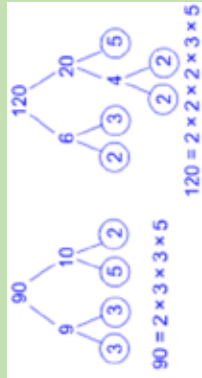
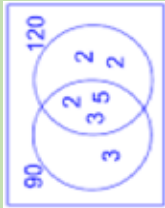


Transformation of a graph



Transformations – rotation – describing: Always use tracing paper. Describe: 1. It's a rotation 2. Size of rotation in degrees 3. Orientations: clockwise or anticlockwise 4. Centre of rotation given as a coordinate (x,y)  Transformation – translation Vector $\begin{pmatrix} 6 \\ -4 \end{pmatrix}$ 6 right, 4 down	Transformations – enlargement - describing: 1. It's an enlargement 2. The scale factor (if the image is smaller than the object the scale factor is fractional e.g. $\frac{1}{2}$) 3. The centre of enlargement given as a coordinate 	Circle Theorems  Angle at the centre is twice the angle at the circumference  Angles in a semicircle are 90°.  Angles in the same segment are equal.  Opposite angles of a cyclic quadrilateral add up to 180.  Alternate segment theorem.  Tangents from an external point are equal in length. The tangent to a circle is perpendicular (90°) to the radius
Congruent triangles 	Circles  $Area = \pi r^2$ $Circumference = \pi d$ Sector Area = $\frac{\theta}{360} \pi r^2$ Arc length = $\frac{\theta}{360} \pi d$	Pythagoras' Theorem $a^2 + b^2 = c^2$ Only applies to right angled triangles. Can be used to find the height of an isosceles triangle  Can be used to find the length distance between two coordinates
Similar shapes Same shape, different sizes The ratio of the lengths of corresponding sides are equal Length scale factor = x Area scale factor = x^2 Volume scale factor = x^3		

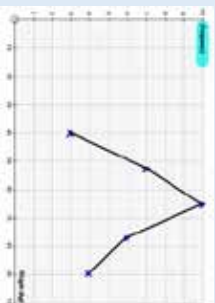
Number Ratio and Proportion - Higher		
Estimate Round each value to one significant figure	Recurring Decimals Form two equations where the digits following the decimal point are the same, and therefore can be cancelled	Percentages Finding percentages of an amount 1% ÷100 5% ÷20 20% ÷5 25% ÷4 50% ÷2 Multipliers: To find the multiplier for a percentage, divide by 100 Use multipliers on a calculator paper e.g. 35% of 370 = 0.35 x 370
Standard form $a \times 10^n$, where $1 \leq a < 10$	Upper and lower bounds Look at the value above and below for the same place value. LB and UB will be half way between these points	Increasing and decreasing a given amount Calculator: <i>Original Amount x multiplier = new amount</i> Non-calculator: find the increase or decrease and add to the original amount
Reciprocal Reciprocal of 7 is $\frac{1}{7}$, reciprocal of $\frac{2}{3}$ is $\frac{3}{2}$ etc	e.g. 17 rounded to the nearest integer  e.g. 24.6 rounded to one decimal place. LB = 24.55, UB = 24.65	Finding percentage increase or decrease (profit/loss) $\frac{\text{value of increase/decrease}}{\text{Original}} \times 100$
Sequences Fibonacci sequence: 1, 1, 2, 3, 5, 8, 13, 21 Geometric Sequence: each term is multiplied but the same constant to get the next number. E.g. 3, 12, 48, 192, ... (x by 4 each time)	Fractions Add and Subtract – ensure the fractions have the same denominator before adding numerators $\frac{4}{5} - \frac{1}{3} = \frac{12}{15} - \frac{5}{15} = \frac{7}{15}$ Multiply – multiply numerators and denominators $\frac{4}{5} \times \frac{1}{3} = \frac{4}{15}$	Writing an amount as a percentage of the original $\frac{\text{Amount}}{\text{Original}} \times 100$ Reverse Percentage – finding the original amount $\text{Original Amount} = \frac{\text{New Amount}}{\text{multiplier}}$
Simplifying Surds Find a factor that is a square number $\sqrt{96} = \sqrt{16 \times 6} = 4\sqrt{6}$		
Manipulating surds $\sqrt{ab} = \sqrt{a} \times \sqrt{b}$ $\sqrt{\frac{a}{b}} = \frac{\sqrt{a}}{\sqrt{b}}$		
Rationalising Surds Rationalise by removing any surds from the denominator E.g with surd. $\frac{2\sqrt{3}}{\sqrt{5}} = \frac{2\sqrt{3} \times \sqrt{5}}{\sqrt{5} \times \sqrt{5}} = \frac{2\sqrt{15}}{\sqrt{25}} = \frac{2\sqrt{15}}{5}$ E.G with surd expressions multiply by top and bottom by the denominator with the opposite sign. $\frac{5}{3 + \sqrt{2}} = \frac{5 \times (3 - \sqrt{2})}{(3 + \sqrt{2}) \times (3 - \sqrt{2})} = \frac{5(3 - \sqrt{2})}{9 - \sqrt{4}} = \frac{5(3 - \sqrt{2})}{7}$	Divide – take reciprocal of the second fraction and then multiply the new numerators and denominators $\frac{4}{5} \div \frac{1}{3} = \frac{4}{5} \times \frac{3}{1} = \frac{12}{5} = 2 \frac{2}{5}$	

Growth & Decay / Compound interest <i>original amount</i> $\times$ <i>multiplier^{time}</i> Where the multiplier is the percentage, increase or decrease from 100%, converted to a decimal. e.g. 30% decrease is $70\% = 0.7$ 30% increase is $130\% = 1.3$	Dividing by decimals: 1. Write the calculation as a fraction 2. Form an equivalent fraction to makes integers (multiply by powers of 10) 3. Use short division (bus stop) to calculate e.g. $460 \div 0.4 = \frac{460}{0.4} = \frac{4600}{4} = 1150$	Conversions 10 millimetres = 1 centimetre 15 minutes = 0.25 hours 100 centimetres = 1 metre 30 minutes = 0.5 hours 1000 metres = 1 kilometre 45 minutes = 0.75 hours 1000cm³ = 1 litre 1000g = 1 kilogram 1000ml = 1 litre 1000kg = 1 tonne
Compound Units (rearrange as necessary) $Speed = \frac{Distance}{Time}$ $Area = \frac{Force}{Pressure}$ $Density = \frac{Mass}{Volume}$	Error Intervals least possible value $\leq x <$ greatest possible value e.g. A fence is 30 m long to the nearest 10 m. $25 \text{ m} \leq l < 35 \text{ m}$ Truncation Truncation is a method of approximating a decimal number by dropping all decimal places past a certain point without rounding. e.g. Truncate 3.14159265 to 4 decimal places. = 3.1415	Negative numbers Adding and subtracting: (vertical number lines help) $-3 - 5 = -8$ $-3 + 5 = 2$ $-3 - -5 = -3 + 5 = 2$ $-3 + -5 = -3 - 5 = -8$ $-3 + -5 = -3 - 5 = -8$ Multiplying and dividing: Different signs – answer will be negative $+ \times - = -$, $- \times + = -$ Same signs – answer will be positive $- \times - = +$
Product rule If there are m ways to do one thing and n ways to do another, then there are m $\times$ n ways to do both	Order of operations Bracket Indices Division and Multiplication Addition and Subtraction	Rounding to significant figures Start from the first non-zero number and round as normal, but ensure the place value is correct e.g. 345,635 to 2SF = 350,000 0.0060821 to 3SF = 0.006
Index Laws $a^n \times a^m = a^{n+m}$ $a^n \div a^m = a^{n-m}$ $(a^n)^m = a^{nm}$ $a^0 = 1$ $a^{-n} = \frac{1}{a^n}$ $\sqrt[n]{a^m} = a^{\frac{m}{n}}$	Prime Factorisation  $90 = 2 \times 3 \times 3 \times 5$ $120 = 2 \times 2 \times 2 \times 3 \times 5$	HCF and LCM of 90 and 120 (Factor Tree & Venn Diagram) HCF is the product of common factors LCM is the product of common factors and remaining factors. HCF: $2 \times 3 \times 5$ LCM: $2^3 \times 3^2 \times 5$ 

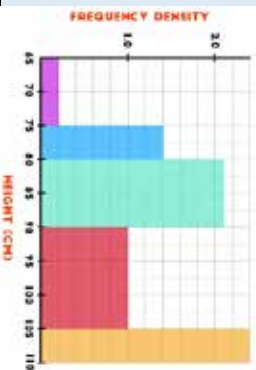
Frequency Polygons

1. Plot frequency at the mid-point
2. Join with straight lines

Weight w (kg)	Frequency
$30 \leq w < 50$	3
$50 \leq w < 55$	7
$55 \leq w < 75$	10
$75 \leq w < 80$	6
$80 \leq w < 100$	4



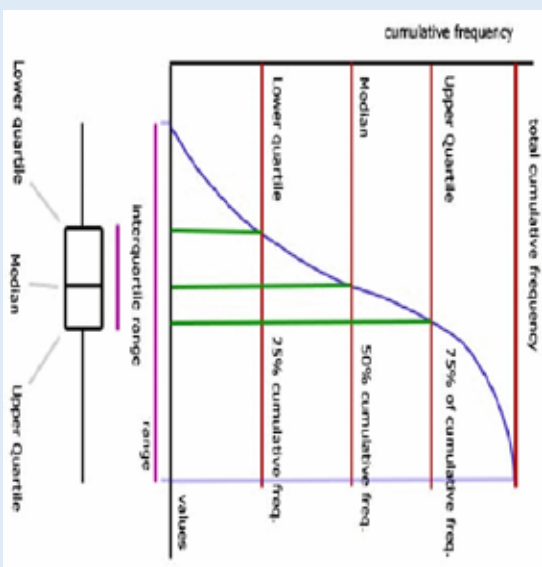
Histograms



FD = Frequency density

$$FD = \frac{\text{Frequency}}{\text{Class Width}}$$

Cumulative Frequency Diagrams and Box Plots



Expected outcomes

Relative frequency: $\text{frequency} \div \text{total trials}$

Expected outcome = probability x number of trials

E.g. A biased spinner is spun 800 times. The probabilities it lands on each colour is below. The probability of it landing on red is the same as the probability of it landing on green. How many times would you expect yellow to come up.

Result	Red	Green	Brown	Yellow
Probability		0.48	0.2	

$$P(Y) = (1 - 0.48 - 0.2) \div 2 = 0.32 \div 2 = 0.16$$

$$\text{Expected yellow} = 0.16 \times 800 = 128$$

Averages from a frequency table

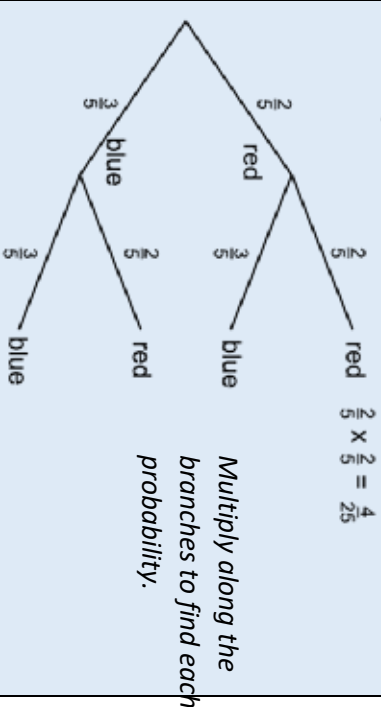
Mean: $\frac{\sum fw}{\sum f}$; where, w is the midpoint of the group.

Median group: find which group the $\frac{n+1}{2}$ th, value lies. Where, n is the total frequency.

E.G. in this table 51.5th value which lies in group $8 < w \leq 12$ (using the cumulative frequency

Weight of box (w kg)	Frequency
$0 < w \leq 4$	11
$4 < w \leq 8$	16
$8 < w \leq 12$	29
$12 < w \leq 16$	26
$16 < w \leq 20$	20

Tree diagrams



1. Probability that a red counter is picked both times $P(RR) = \frac{2}{5} \times \frac{2}{5} = \frac{4}{25}$

2. Probability that the counters are different colours $= P(RB) + P(BR) = \frac{2}{5} \times \frac{3}{5} + \frac{3}{5} \times \frac{2}{5} = \frac{12}{25}$

Knowledge Organiser – 4.1.1 Cell Biology

4.1.1 Cell Structure

4.1.1.1. Eukaryotes & Prokaryotes:

Eukaryotic (plant, animal & fungal cells).

- Cell membrane
- Cytoplasm
- Genetic material enclosed in membrane

Prokaryotic (bacteria and archaea)

- smaller with no true nucleus.
- No mitochondria or chloroplasts.
- DNA loops called plasmids
- Bacteria are prokaryotes.

4.1.1.2 Definitions

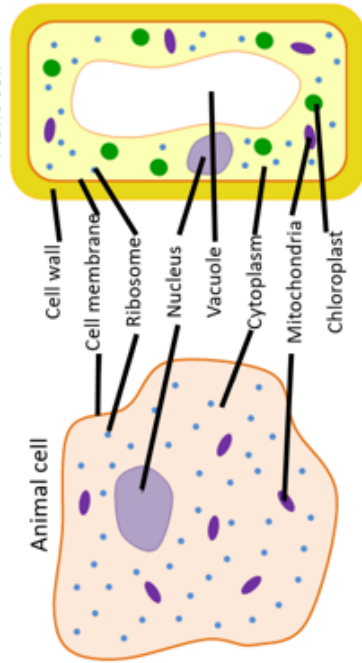
eukaryotic	A type of cell that has a nucleus.
prokaryotic cell	A simple cell that does not have a nucleus – the DNA is free in the cytoplasm.
mitochondria	Structures in the cytoplasm of all cells where aerobic respiration takes place
ribosome	The site of protein synthesis.
sub-cellular	Structures smaller than a cell that are found within it.
tissue	A group of similar cells that carry out the same function, <u>eg</u> muscle tissue.
Nucleus	Contains the cell's genetic materials
Cell membrane	Controls the movement of substances in and out of the cell
Cytoplasm	where many chemical reactions take place
Chloroplasts	where photosynthesis occurs
Vacuole	Filled with cell sap to help support the plant
Cell wall	made of cellulose to strengthen the cell.

4.1.1.4 Cell differentiation

As an organism develops, cells differentiate to form different types of cells.

- Most types of animal cell differentiate at an early stage.
- Many types of plant cells retain the ability to differentiate throughout life.

4.1.1.2 Animal & plant cells



You must be able to label the animal and plant cells

Sub-cellular structures:

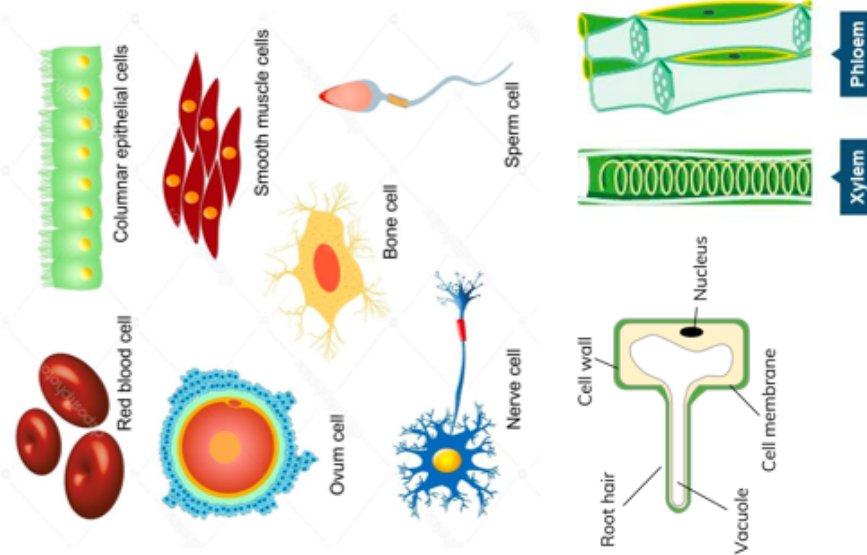
Most animal cells have the following

- **nucleus**
- **cytoplasm**
- **a cell membrane**
- **mitochondria**
- **ribosomes.**

In addition to the parts found in animal cells, plant cells often have:

- **chloroplasts**
- a permanent **vacuole** filled with cell sap.
- Plant and algal cells also have a **cell wall made of cellulose**, which strengthens the cell

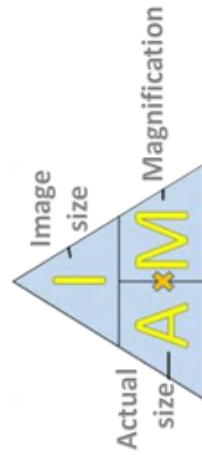
4.1.1.3. Cell specialisation:



4.1.1.5 Microscopy

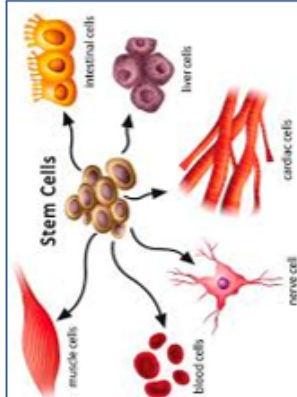
Electron microscope

- has much **higher magnification** and **resolving power** than a light microscope.
- Can be used to **study cells in much finer detail.**
- Enabled biologists to see and **understand many more sub-cellular structures.**



$$\text{Actual size} = \frac{\text{Image size}}{\text{Magnification}}$$

$$\text{Magnification} = \frac{\text{Image size}}{\text{Actual size}}$$



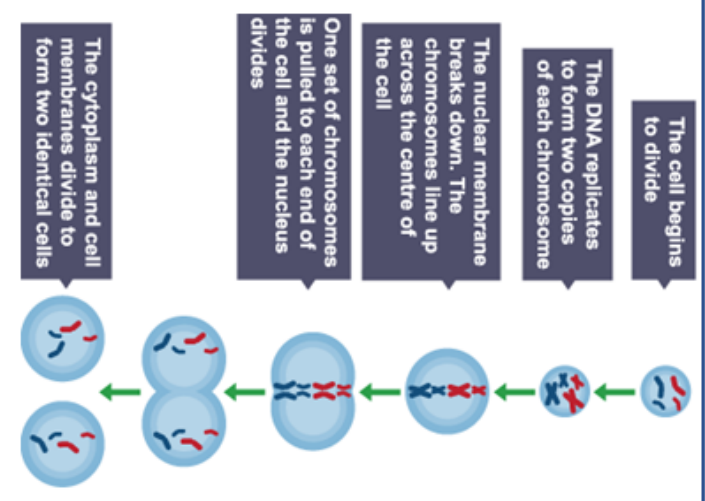
Knowledge Organiser – 4.1.2 Cell Biology

4.1.2 Cell Division : MITOSIS

- The nucleus of a cell contains **chromosomes** made of **DNA** molecules.
- Each chromosome carries a large number of **genes**.
- In body cells the chromosomes are **normally found in pairs**.
- Mitosis is cell division for growth & repair**.
- 2 genetically identical daughter cells are formed.

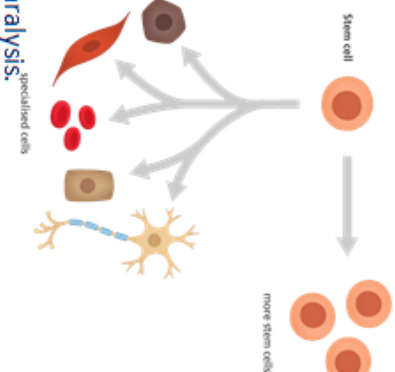
4.1.2.3 Stem cells - Plants

- Meristem tissue** in plants can **differentiate** into any **type of plant cell**, throughout the life of the plant.
- can be used to **produce clones** of plants quickly and economically and to prevent extinction.
- Crop plants** with special features such as disease resistance can be cloned to produce large numbers of identical plants for farmers.



4.1.2.3 Stem cells - animals

- A **stem cell** is an **undifferentiated cell of an organism** which is capable of giving rise to cells of any type.
- Stem cells from human embryos can be cloned** and made to **differentiate** into most types of human cells.
- Stem cells from adult bone marrow** can form many types of cells including **blood cells**.



Treatment with stem cells

- may be able to help conditions such as diabetes and paralysis.
- In **therapeutic cloning** an embryo is produced with the same genes as the patient. Stem cells from the embryo are not rejected by the patient's body so they may be used for medical treatment.
- The use of stem cells has potential risks such as transfer of viral infection and some people have ethical or religious objections.

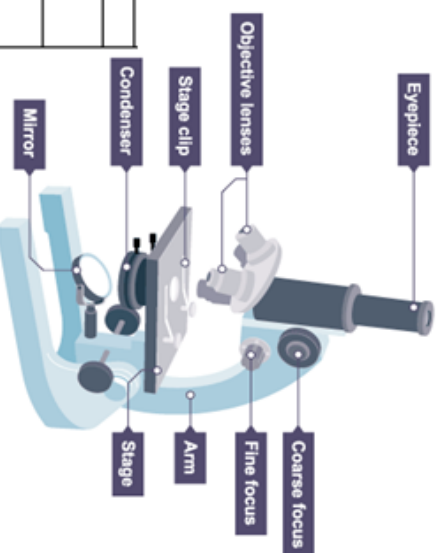
RPA: Microscopy Definitions

calibrate	To set an instrument or scale against a standard.
field of view	The area seen when looking through a microscope.
graticule	The graticule has a scale ruled on it and is used to estimate the size of a specimen when viewed with a microscope.
magnification	The amount that an image of something is scaled up when viewed through a microscope.
order of magnitude	For each order of magnitude, a number is ten times the previous one.
resolution	The fineness of detail that can be seen in an image - the higher the resolution of an image, the more detail it holds.
significant figure	Giving a number to a specified number of significant figures is a method of rounding. E.g., in the number 7483, the most significant, or important, figure is 7, as its value is 7000. To give 7483 correct to one significant figure (1 sf), would be 7000. To 2 sf, it would be 7500.
stage micrometer	A glass slide with a scale etched on it. It is used to calibrate the eyepiece graticule of a microscope.
standard form	A system in which numbers are written as a number greater than 1 and less than 10 multiplied by a power of 10 (either positive or negative.)

Required practical activity:

use a light microscope to observe, draw and label a selection of plant and animal cells. A magnification scale must be included

Millimetre (mm)	0.001m
Micrometre (µm)	0.000001m
Nanometre (nm)	0.000000001m
	10 ⁻³ m
	10 ⁻⁶ m
	10 ⁻⁹ m



Knowledge Organiser – 4.1.3 Transport in Cells

4.1.3.1 Diffusion

Substances may move into and out of cells across the cell membranes via diffusion.

- Diffusion is the spreading out of the particles of any substance in solution, or particles of a gas, resulting in a **net movement from an area of higher concentration to an area of lower concentration**.

Some of the substances transported in and out of cells by diffusion are:

- oxygen** and **carbon dioxide** in gas exchange,
- waste product **urea** from cells into the blood plasma for excretion in the kidney.

Factors which affect the rate of diffusion are:

- the difference in concentrations (**concentration gradient**)
- the **temperature**
- the **surface area** of the membrane.

The effectiveness of an exchange surface is increased by:

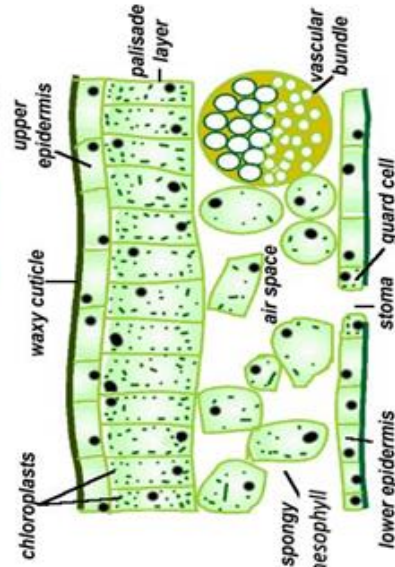
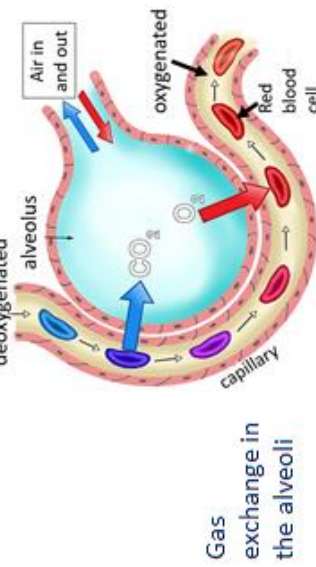
- having a **large surface area**
- a membrane that is **thin** to provide a short diffusion path
- (in animals) having an **efficient blood supply**
- (in animals, for gaseous exchange) being **ventilated**.

4.1.3.1 Diffusion - examples

Single-celled organisms have a **large surface area to volume ratio**, allowing sufficient transport of molecules in and out of the cell.

Multicellular organisms have a **relatively small surface area to volume ratio** so they **need specialised exchange surfaces** and a transport system:

- Large surface area
- Thin membranes for a short diffusion path
- Efficient blood supply (animals)
- Being ventilated (animals)



CO₂ diffuses from high concentration in the air space to a low concentration inside the mesophyll cells

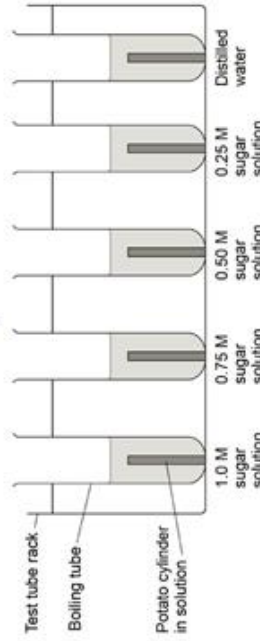
4.1.3.2 Osmosis

Osmosis is the **diffusion of water from a dilute solution to a concentrated solution** through a partially permeable membrane.

Effects of Osmosis on Plant Cells



RPA: investigate the effect of a range of concentrations of salt or sugar solutions on the mass of plant tissue



4.1.3.3 Active Transport

Is the movement of substances from a more dilute to a more concentrated solution (**against** the concentration gradient).

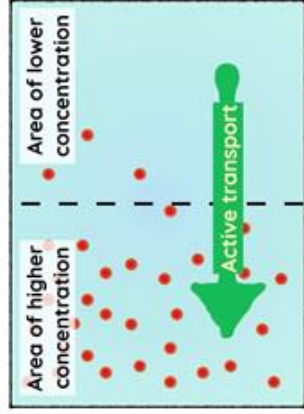
It needs ENERGY from respiration for respiration.

Eg 1 - Mineral ions

absorbed **into root hair cells** from very dilute solutions in the soil.

Eg 2 - Sugar molecules

absorbed **from the gut** (lower concentration) into the blood for respiration.

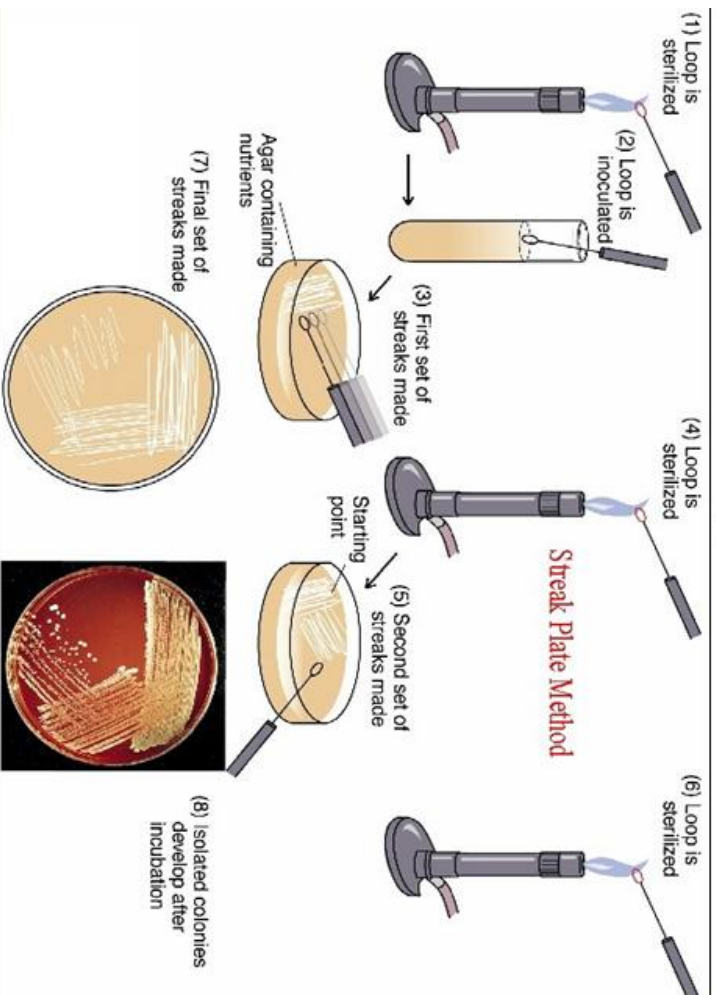


Knowledge Organiser – 4.1.1.6 Culturing Microorganisms (Separate Biology RPA)

4.1.1.6 Culturing microorganisms

The loop is sterilised by the Bunsen flame as the microbes are killed by the heat

The base of the petri dish should be labelled with date, sample etc just in case the lid comes off.



Do not blow on the loop as it cools – this might transfer microbes from you to the loop

Replace the lid quickly after inoculation to avoid contamination.

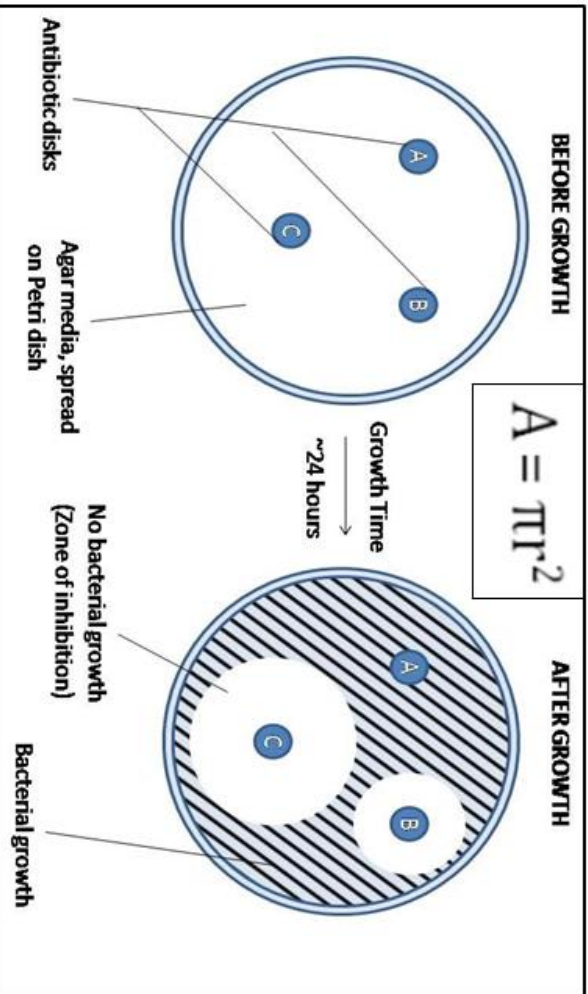
The lid must be taped on in a cross shape so air flow is not stopped – this will prevent harmful anaerobic bacteria from growing.

The petri dish must be stored upside down to prevent condensation dripping on the surface of the agar.

Bacterial Growth

Bacteria multiply by simple cell division if they have enough nutrients and a suitable temperature

You can investigate the effects of disinfectants and antibiotics on bacterial growth using agar plates and calculating the cross-sectional area of colonies grown or of clear areas of agar

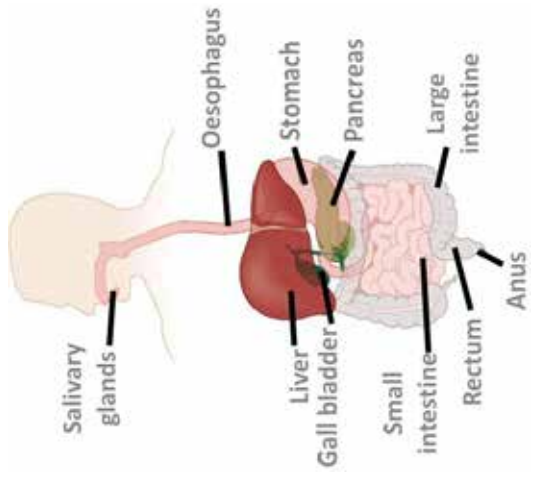


Knowledge Organiser – 4.2 Organisation

4.2.1 Principles of organisation

4.2.1	Definitions
Cells	The basic building blocks of all living organisms. Eg. Muscle, skin, nerve, root hair and palisade leaf cells
Tissue	A group of cells with a similar structure and function (job). Eg. Muscle, heart, xylem and epidermal tissue
Organs	A group of tissues performing a specific function. Eg. Heart, liver, brain, roots, stem, leaf & flower
Organ systems	Groups of organs working together to form an organism. Eg. circulatory, nervous & transpiration systems
Digestive system	Organ system in which several organs work together to digest & absorb food.

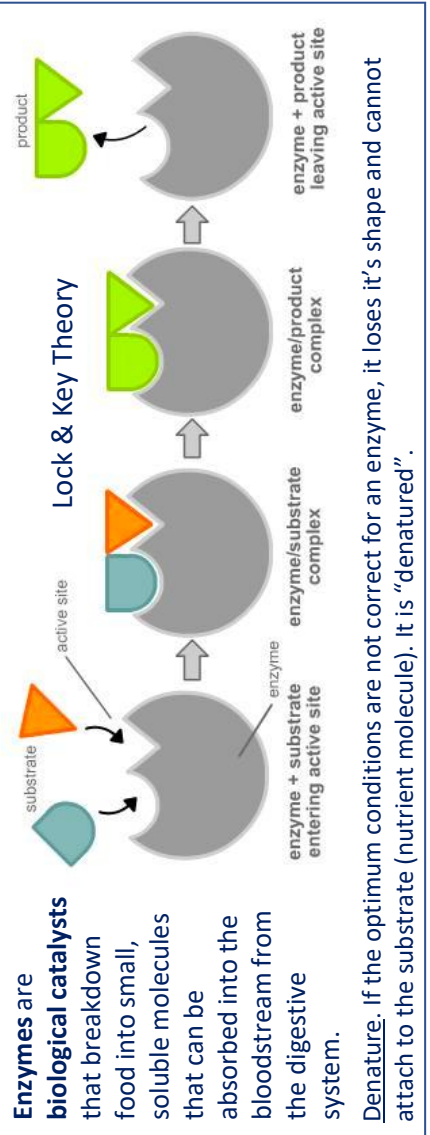
4.2.2.1 The human digestive system



4.2.2 Animal tissues, organs and organ systems

bile	Made in the liver, stored in gall bladder. Emulsifies fats to for digestion and neutralises stomach acid.
carbohydrate	Food consisting of sugars, starch and cellulose. Carbohydrates are vital for energy in humans and are stored as fat if eaten in excess.
digestion	The breakdown of large insoluble food molecules to smaller soluble ones.
digestive system	Organ system involved in breaking food down so that it can be absorbed into the bloodstream.
egestion	The process of passing out the remains of food that has not been digested, as faeces, through the anus.
emulsify	To mix water with lipids to produce a cloudy mixture called an emulsion.
fats	Naturally occurring compounds of carbon, hydrogen and oxygen. They are esters made from fatty acids and glycerol.
fatty acids	Carboxylic acids with a long chain of carbon atoms. Fatty acids react with glycerol to produce lipids (fats and oils).
gall bladder	Stores bile before releasing it into the duodenum.
glucose	A simple sugar used by cells for respiration.
glycogen	Animals store glucose as glycogen in their liver and muscle tissues.
gut	The digestive system.
lipid	Fat or oils, composed of fatty acids and glycerol.
liver	The large organ, beside the stomach, which has many functions, including processing substances absorbed by the digestive system and a role in the storage of the body's carbohydrate.
metabolism	All the chemical reactions in the cells of an organism, including respiration.
microvilli	Projections from the surface of an epithelial cell of the small intestine wall.
pancreas	Large gland located in the abdomen near the stomach which produces digestive enzymes and the hormone insulin.
protein	Organic compound made up of amino acid molecules. Proteins are needed by the body for cell growth and repair.
starch	A type of carbohydrate. Plants can turn the glucose produced in photosynthesis into starch for storage
sugar	A simple carbohydrate that is sweet to the taste.
villi	Finger-like projections in the small intestine that provide a large surface area for the absorption of food.

Enzyme	Produced	Nutrients acted upon	Products (smaller molecules)	Optimum pH & temperature
Carbohydrase Eg. Amylase	Salivary glands	Carbohydrate Eg. starch	Simple sugars Eg. glucose	pH7 37°C
Protease	Stomach, pancreas	Protein	Amino acids	pH2 37°C
Lipase	Pancreas, small intestine	Lipid (fats & oils)	Glycerol & fatty acids	pH8 37°C



Knowledge Organiser – 4.2 Organisation

RPA: investigate the effect of pH on the rate of reaction of amylase on starch

Amylase breaks down starch. Starch turns blue/black when iodine (an orange solution) is added.



- Starch solution (CV)
- Amylase solution (CV)
- Buffer solutions of different pH (**IV**)
- Spotting tiles
- Test tubes
- Water bath (temp CV)
- Iodine solution
- Stop clock

DV is the time at which the starch/ amylase solution no longer turns blue/black.

RPA: use qualitative reagents to test for carbohydrates (starch and glucose), proteins and lipids

Food group	Reagent	Positive result
Glucose	Benedict's solution (heated)	Bright blue to orange/brick red
Protein	Biuret's solution	Bright blue to lilac
Starch	Iodine solution	Orange to blue/ black
Lipid (Fat/oil)	Ethanol & water	Clear to milky/ cloudy

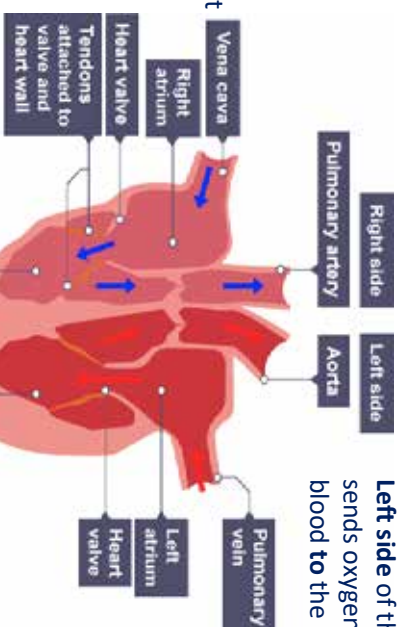
4.2.2.2 The heart and blood vessels

4.2.2.2 The heart and blood vessels

Right side of the heart receives deoxygenated blood **from** the body and pumps it to the lungs.

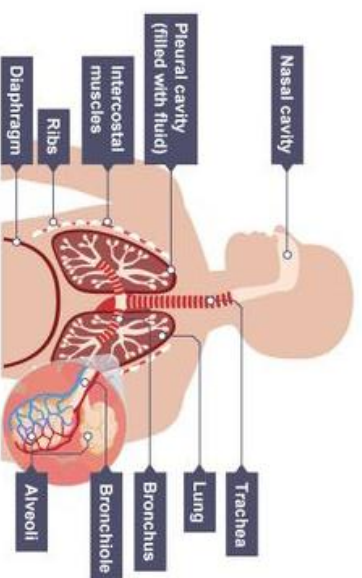
Pacemaker
Group of cells in the right atrium that control resting heart rate.

Vena cava
Right atrium
Heart valve
Tendons attached to valve and heart wall



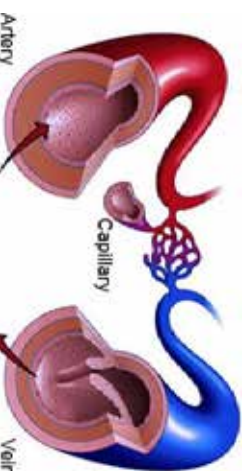
Left side of the heart sends oxygenated blood **to** the body.

Right ventricle
Left ventricle

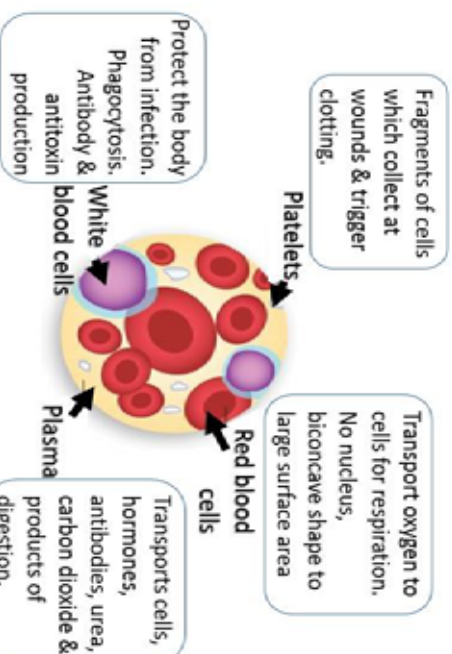


4.2.2.3 Blood

- Blood away from heart
- Thick muscular wall
- Small lumen
- Under high pressure

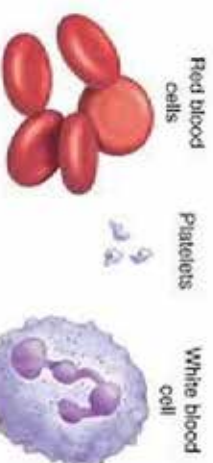


- Blood towards from heart
- Thinner wall
- Large lumen
- Under low pressure



4.2.2.3 Blood

Blood is a tissue consisting of plasma containing red blood cells, white blood cells and platelets



Knowledge Organiser – 4.2 Organisation

4.2.2.4 Coronary heart disease: a non-communicable disease

- **Coronary heart disease** layers of fatty material build up inside the coronary arteries, narrowing them.
- Reduces the flow of blood through the coronary arteries, resulting in a lack of oxygen for the heart muscle.
- Stents are used to keep the coronary arteries open.
- Statins are widely used to reduce blood cholesterol levels which slows down the rate of fatty material deposit.
- **Heart valves may become faulty**, preventing the valve from opening fully, or the heart valve might develop a leak.
- Faulty heart valves can be replaced using biological or mechanical valves.
- **Heart Transplants:** the case of heart failure a donor heart, or heart and lungs can be transplanted.
- Artificial hearts are occasionally used to keep patients alive whilst waiting for a heart transplant, or the heart to rest as an aid to recovery.



4.2.2.5 Health issues & types of disease

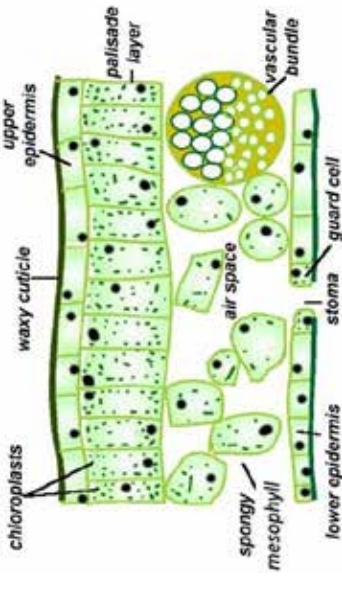
communicable, can be transferred from one organism to another, e.g. measles, food poisoning and malaria
non-communicable, which are not transferred between people or other organisms, e.g.

- **cancer**
- **diabetes**
- **genetic diseases** and conditions
- heart disease
- neurological disorders

Other factors that can effect physical and mental health include:

- **diet**
- **lifestyle factors** such as alcohol and other drugs
- **stress**
- situations that may occur in a person's life

4.2.3.1 Plant tissues



Epidermis	Covers outer leaf surface for protection
Palisade mesophyll	Main site for photosynthesis. Many chloroplasts
Spongy mesophyll	Air spaces between cells allow gases to diffuse

4.2.2.6 lifestyle on non-communicable disease

Risk factors are linked to increased rate of a disease. aspects of a person's lifestyle

- substances in the body or environment.
- The effects of diet, smoking and exercise on cardiovascular disease.
- Obesity as a risk factor for Type 2 diabetes.
- The effect of alcohol on liver & brain function.
- Effect of smoking on lung disease & lung cancer.
- Effects of smoking & alcohol on unborn babies.
- Carcinogens, including ionising radiation, as risk factors in cancer.

4.2.2.7 Cancer

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

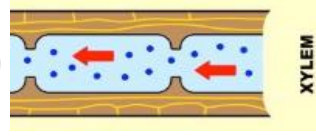
Malignant tumour cells are cancers. Invade neighbouring tissues and **spread to different parts of the body** where they form secondary tumours.

4.2.3.2 Plant organ system

Roots, stem, leaves form plant transport organ system.



- **Root hair cells** are adapted for the efficient uptake of water by osmosis, and mineral ions by active transport.

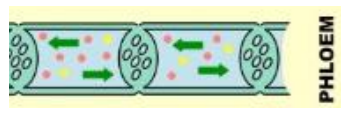


- **Xylem tissue** transports water and mineral ions from the roots to the stems and leaves.
- Made of hollow tubes strengthened by **lignin** adapted for the transport of water in the **transpiration** stream.

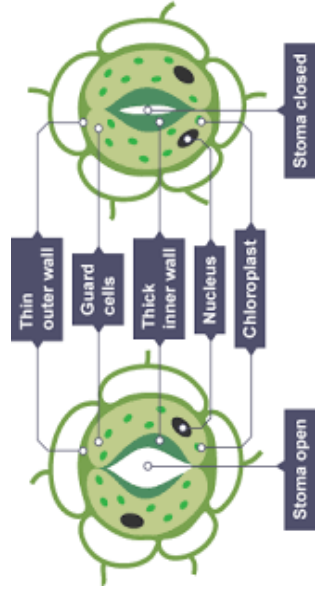
Phloem tissue transports

dissolved sugars from the leaves to the rest of the plant for immediate use or storage. This transport is called **translocation**.

- **Phloem** is composed of tubes of elongated cells. **Cell sap can move from one phloem cell to the next through pores in the end walls.**



- **Stomata and guard cells** control gas exchange and water loss.



Knowledge Organiser – 4.3 Infection and response

4.3.1.1 Communicable (infectious) diseases

Pathogens are microorganisms that cause infectious disease.

- Pathogens may be **viruses, bacteria, protists or fungi**.
- They may infect plants or animals and can be spread by direct contact, by water or by air.
- Bacteria and viruses may reproduce rapidly inside the body.
- Bacteria may produce poisons (toxins) that damage tissues and make us feel ill.
- Viruses live and reproduce inside cells, causing cell damage. Viruses are not considered to be living organisms.

Pathogen	Example in animals	Example in plants	Treatment
----------	--------------------	-------------------	-----------

Viruses	Measles, HIV potentially leading to AIDS	Tobacco mosaic virus	Vaccination
Bacteria	Salmonella Gonorrhoea	Agrobacterium	Antibiotics
Fungi	Athlete's foot	Rose black spot	Anti fungal medication & Fungicides.
Protists	Malaria (Spread by mosquitos)	Downy mildew	Anti malarial drugs, prevention from vector contact eg mosquito nets



Tobacco mosaic virus



Rose Black Spot



Downy mildew

4.3.1.2 Viral diseases

Measles is a viral disease

- Symptoms: fever and a red skin rash.
- Measles can be fatal if complications arise.
- Most young children are vaccinated against measles.
- The measles virus is spread by inhalation of droplets from sneezes and coughs.

HIV initially causes a flu-like illness.

- Unless successfully controlled with antiretroviral drugs the virus attacks the body's immune cells.
- Late stage HIV infection, or AIDS, occurs when the body's immune system becomes so badly damaged it can no longer deal with other infections or cancers.
- HIV is spread by sexual contact or exchange of body fluids such as blood which occurs when drug users share needles.

Tobacco mosaic virus (TMV) is a widespread plant

pathogen

- Affecting many species of plants including tomatoes.
- Symptoms: Gives a distinctive 'mosaic' pattern of discolouration on the leaves which affects the growth of the plant due to lack of photosynthesis.

4.3.1.3 Bacterial diseases

Salmonella food poisoning

- Spread by bacteria ingested in food, or on food prepared in unhygienic conditions.
- In the UK, poultry are vaccinated against salmonella to control the spread.
- Symptoms: Fever, abdominal cramps, vomiting and diarrhoea are caused by the bacteria and the toxins they secrete.

Gonorrhoea is a sexually transmitted disease (STD)

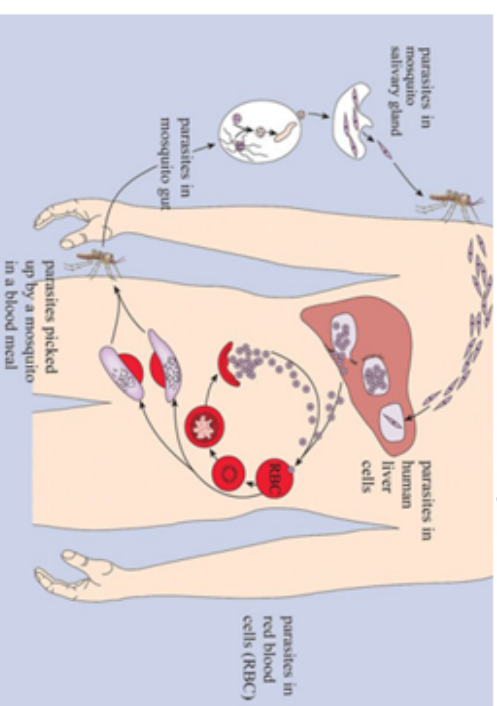
- Symptoms: thick yellow or green discharge from the vagina or penis and pain on urinating.
- Was easily treated with the antibiotic penicillin until many resistant strains appeared.
- Spread by sexual contact.
- The spread can be controlled by treatment with antibiotics or the use of a barrier method of contraception such as a condom.

4.3.1.4 Fungal diseases

Rose black spot is a fungal disease

- Symptoms: purple or black spots develop on leaves, which often turn yellow and drop early.
- It affects the growth of the plant as photosynthesis is reduced.
- It is spread in the environment by water or wind. Rose black spot can be treated by using fungicides and/or removing and destroying the affected leaves.

4.3.1.5 Protist diseases : Malaria Life Cycle



Knowledge Organiser – 4.3.1.6 Human defence systems

4.3.1.6 Human defence systems

Humans have a variety of **specific** and **non specific** Human defences against invading pathogens.

Non-specific:

Specific via white blood cells

Skin (physical barrier)

Nose (mucus)

Trachea and bronchi (cilia)

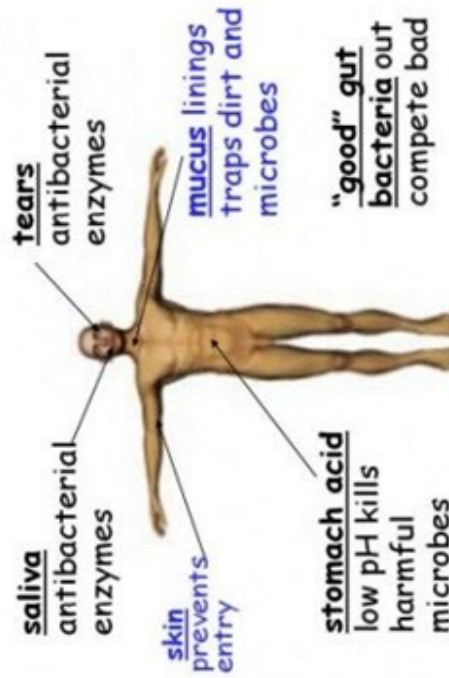
Stomach (acid)

Phagocytosis

Antibodies

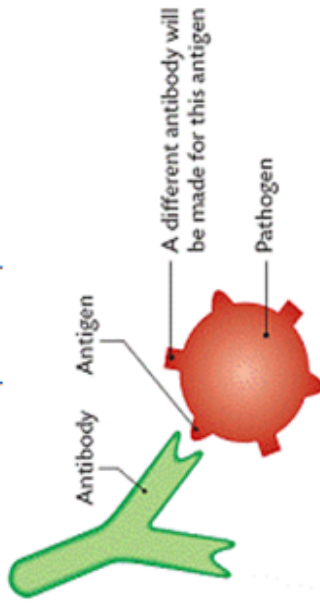
Antitoxins

First Lines of Defence



4.3.1.7 Vaccination

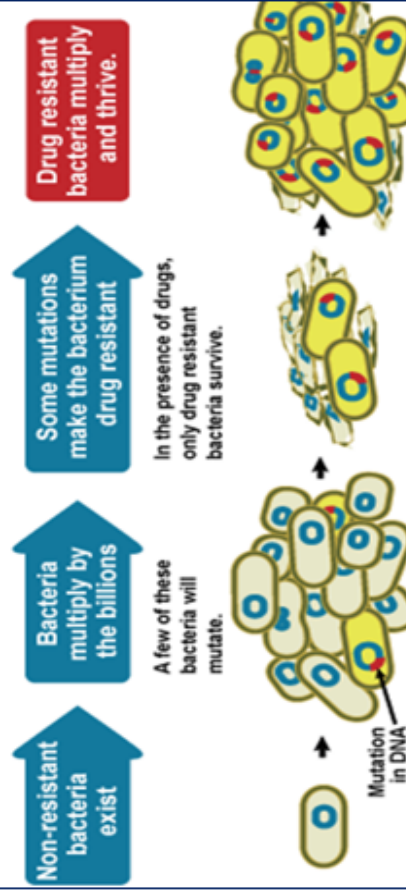
- Introducing small quantities of **dead or inactive pathogens** to **stimulate antibody production**.
- This leads to a quicker response in future infections.



4.3.1.8 Antibiotics and pain killers

- Antibiotics**, such as **penicillin**, are medicines that help to cure bacterial disease by killing infective bacteria inside the body.
- Specific bacteria should be treated by specific antibiotics
- Emergence of antibiotic resistant bacteria** is of great concern.
- Antibiotics CANNOT kill viral pathogens**
- Painkillers and other drugs are used to treat the symptoms of disease, but do not kill pathogens.

Genetic Mutation Causes Drug Resistance



4.3.1.9 Discovery and development of drugs

Have traditionally been extracted from

Plants and microorganisms.

Digitalis – Foxgloves

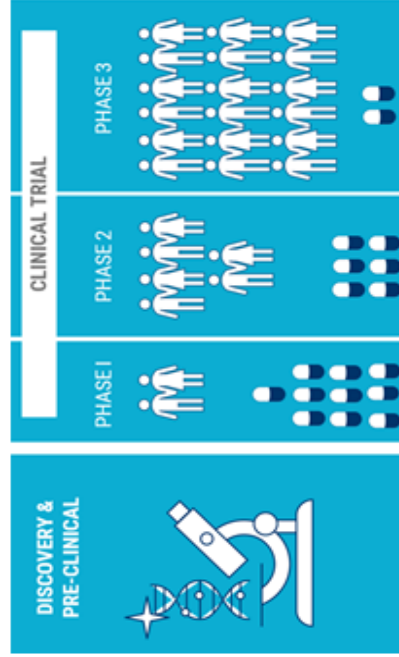
Aspirin – Willow

Penicillin – Penicillium mould

- Most new drugs are **synthesised** by chemists in pharmaceutical industry
- New drugs have to be **tested** and **trialled** before use to check they are **safe and effective**.
- New drugs tested for toxicity, efficacy and dose

Clinical trials use healthy volunteers and patients.

- Very low doses of the drug are given at the start of the clinical trial.
- If the drug is found to be safe, further clinical trials are carried out to find the optimum dose for the drug.
- In double blind trials, some patients are given a placebo



Knowledge Organiser – 4.3 Separate Biology

4.3.2.1 Producing monoclonal antibodies (HT) are identical copies of one **type of antibody** produced in a laboratory. How to produce monoclonal antibodies:

1. A **mouse** is injected with a **pathogen**
2. White blood cells called lymphocytes produce **antibodies**
3. **Lymphocytes** are removed from the mouse and fused with rapidly dividing mouse **tumour** cells. The new cells are called **hybridomas**.
4. The hybridomas divide **rapidly** & release lots of **antibodies** which are then **collected**

4.3.2.2 Uses of monoclonal antibodies: Used in treatment of diseases and monoclonal antibodies have been developed against the **antigens** on **cancer cells**. Monoclonal antibodies are bound to **radioactive** substances (or **toxic** drugs and chemicals) that **stop** cells growing and dividing. Monoclonal antibodies have **side effects** and are not as widely used in cancer treatment.

4.3.3.1 Detection and identification of plant diseases

- Plants can be infected by a range of **viral, bacterial and fungal** pathogens as well as insect **pests**. We can detect a plant is diseased by looking for **unusual growths, spots or discoloured leaves and malformed leaves and stems**. A disease can be identified by:
- Gardening manuals & websites
 - Test kits containing monoclonal antibodies
 - Taking infected plants to a laboratory to ID the pathogen

Deficiency of Mineral Ions

Nitrate ions --> Needed by plants for protein synthesis and growth. Lack of nitrate ions results in stunted growth of plants.
Magnesium ions --> Needed by plants to produce chlorophyll. Lack of magnesium ions results in chlorosis (yellowing of leaves due to lack of chlorophyll)

4.3.3.2 Plant defence responses

Type of plant defence used (mechanical, physical or chemical)	What is the plant being defended against?	Describe the defence being used	
Mechanical	Herbivores eating it	Thorns or hairs	
Chemical	Pathogens/bacteria Herbivores/animals	The chemical released is antibacterial or poisonous	
Physical	Herbivores and pathogen entry	Dead bark coating which falls off	
Physical	Insects such as aphids	Waxy cuticle/cellulose cell walls are hard to penetrate	



The presence of pests



Stunted growth



Chlorosis



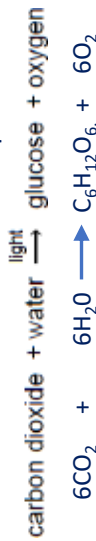
Thorns

Knowledge Organiser – 4.4 Bioenergetics

4.4.1 Photosynthetic reaction

- Captures light energy from the sun and uses it to produce chemical potential energy
- transfer of light energy to chemical potential energy in cells
- **endothermic** reaction.
- Trapped by chlorophyll in chloroplasts

The reaction can be shown in these equations:



Key Terms Photosynthesis Definitions

Photosynthesis	The endothermic reaction that transfers light energy to chemical potential energy. In it, simple molecules (CO ₂ and H ₂ O) are converted into more complex molecules (glucose) that can be used for food.
Nitrates	Ions containing nitrogen and oxygen. These are found in the soil; plants need nitrates to produce amino acids.
Rate	As always, rate means how quickly something happens.
Light intensity	The amount/strength of light. Use this term instead of 'amount of light'.
Chlorophyll	The green pigment in leaves that absorbs light for photosynthesis. Chlorophyll is found in chloroplasts.

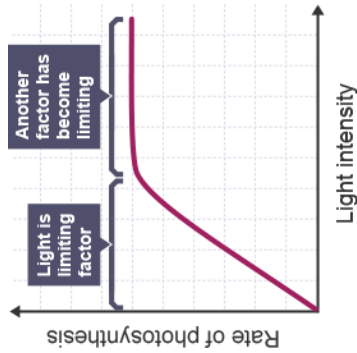
4.4.1.3 Uses of glucose from photosynthesis

- Used in respiration in the cells of the plant/algae
- Converted into insoluble **starch** for storage.
- Produces **fats or oils (lipids)** for storage. Eg Nuts & seeds
- Used to produce **cellulose**, which strengthens the cell wall.
- Used to produce **amino acids**, to synthesise proteins. To produce amino acids, plants also require **nitrates** from the soil.

4.4.1.2 Rate of Photosynthesis

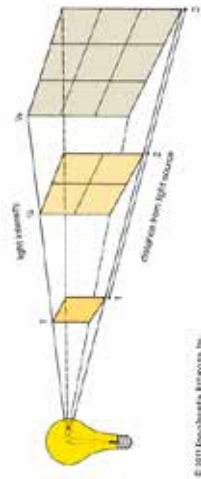
The following factors affect the rate of photosynthesis:

- **Temperature:** because all chemical reactions speed up as the temperature increases. As photosynthesis is controlled by enzymes which are affected by temperature



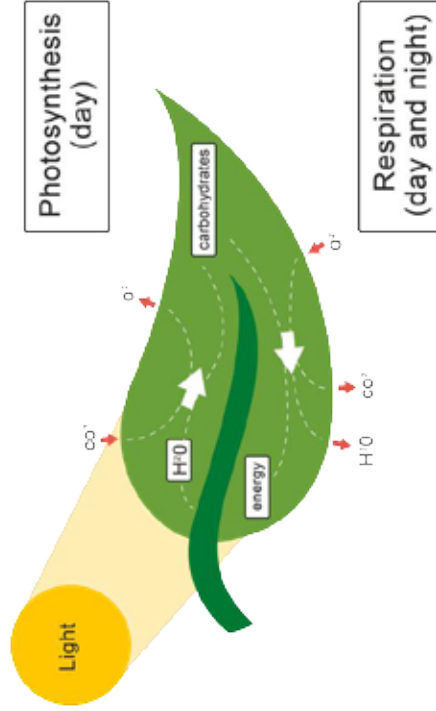
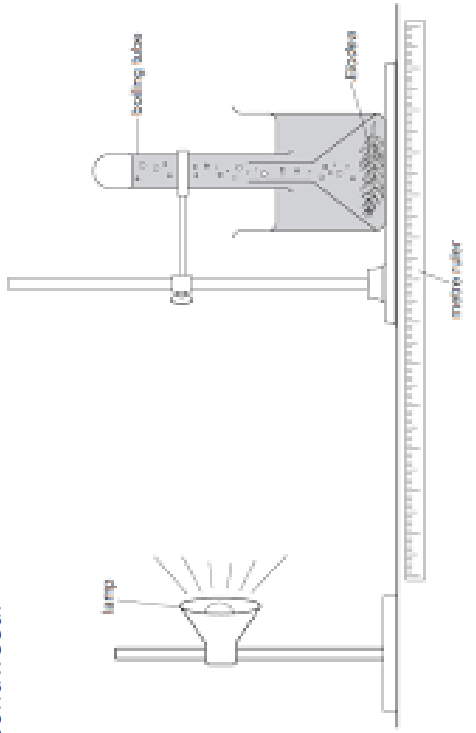
- **Carbon dioxide concentration:** the higher the concentration of CO₂ in the air, the more is available for photosynthesis, so the rate increases as concentration increases.
- **Light intensity:** as the equation shows, photosynthesis requires light energy. So, the higher the light intensity, the higher the rate of photosynthesis.

$$\text{light intensity} = \frac{\text{distance from source}^2}{\text{area of surface}}$$



- **Amount of chlorophyll:** more chlorophyll means more light can be absorbed.

RPA: investigate the effect of light intensity on the rate of photosynthesis using an aquatic organism such as pondweed.



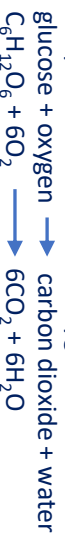
Knowledge Organiser – 4.4 Bioenergetics

4.4.2 Respiration

- the chemical potential energy stored in food molecules is released through **oxidation** reactions
- The energy released allows living cells to do **work including**:
 - Chemical reactions to build larger molecules from smaller ones
 - Movement.
 - Keeping warm.
- There are two types of respiration: **aerobic and anaerobic**.

4.4.2.1 Aerobic and anaerobic respiration

Aerobic respiration occurs when oxygen is used in the reaction



aerobic respiration releases much more energy than anaerobic respiration.

Anaerobic respiration occurs when there is insufficient oxygen available for complete oxidation of the glucose.

The reaction differs depending on the organism

In *animals*:



In *plants and yeast*: glucose $\rightarrow$ ethanol and carbon dioxide



In yeast, anaerobic respiration is called fermentation. Used for:

- making bread (the CO₂ makes it rise)
- making alcoholic drinks (since ethanol is a type of alcohol).

4.4.2.2 Response to exercise

During exercise, more energy is required by the body than when resting, due to increased muscle contractions.

The body reacts to this increased **demand** for energy:

- heart rate, breathing rate, and volume of each breath all increase.**
- these **increase the amount of oxygenated blood** reaching the muscles.
- oxygenated blood provides the **extra oxygen and glucose** needed for **respiration in muscle cells**, to transfer more energy to meet demand.

If insufficient oxygen reaches muscles but exercise continues, the muscle cells use **anaerobic respiration** to transfer energy.

- incomplete oxidation of glucose takes place
- lactic acid** is produced which is a poison
- lactic acid builds up and causes an **oxygen debt** causing **fatigue**.
- breathing deeply after exercise repays the oxygen debt.

4.4.2.3 Metabolism

Metabolism is the sum of ALL the chemical reactions happening in a cell or in the whole body.

- Metabolism relies on energy transferred by respiration.
- chemical reactions in cells are controlled by enzymes.
- Reactants are used to make products: new molecules are synthesised.

metabolism includes these reactions:

- Conversion of glucose to glycogen (animals), or to starch or cellulose (plants).

- Formation of lipid (fat) molecules from one molecule of glycerol and three molecules of fatty acids

- In plants, the use of glucose and nitrate ions to make amino acids.

These amino acids are then used to synthesise proteins.

- Respiration, both aerobic and anaerobic.
- Breaking down excess proteins into urea for excretion



4.4.2.2 Response to exercise (HT)

HT: oxygen debt is the amount of extra oxygen needed to react with lactic acid in muscles and remove it from cells.

- The blood flow through muscles removes lactic acid and transports it to the liver to be converted back into glucose.

Key Terms	Respiration Definitions
Aerobic	Using oxygen
Anaerobic	Not using oxygen
Oxidation	A reaction with oxygen. In this case, food molecules like glucose reacting with oxygen.
Fatigue	Tiredness. Fatigue in muscles is caused by a build-up of lactic acid, which is produced during anaerobic respiration (when there is insufficient oxygen).
Oxygen debt	After exercise, the lactic acid has built up and caused an extra need for oxygen – called the oxygen debt.
Lactic acid	Chemical produced by the incomplete oxidation of glucose (anaerobic respiration).

Knowledge Organiser – 4.5 Homeostasis

4.5.1 Homeostasis

Homeostasis is the regulation of the internal conditions of a cell or organism to **maintain optimum** conditions for function in **response to internal and external changes**.

In humans this includes **autonomic control** of:

- **blood glucose concentration**
- **body temperature**
- **water levels.**

All control systems include:

- cells called **receptors**, which detect stimuli (changes in the environment)
- **coordination centres** (such as the brain, spinal cord and pancreas) that receive and process information from receptors
- **effectors**, muscles or glands, which bring about responses which restore optimum levels.

4.5.2 The human nervous system

The nervous system enables humans to **react to their surroundings** and to **coordinate their behaviour**.

Information from receptors passes along cells (neurons) as electrical impulses to the **central nervous system (CNS)**.

- CNS is the brain and spinal cord.
- CNS coordinates the response of effectors eg **muscles contracting** or **glands secreting hormones**.

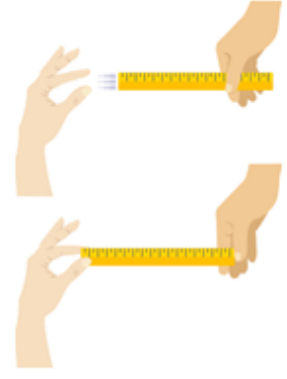
stimulus → receptor → coordinator → effector → response



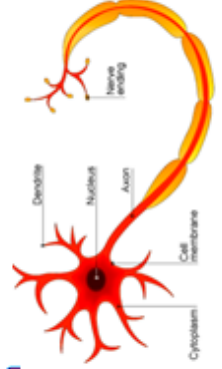
Definition

Enzyme	Protein which catalyses or speeds up a chemical reaction
evaporation	Process in which a liquid changes state and turns into a gas.
glucose	Simple sugar used by cells for respiration.
glycogen	The storage form of glucose in animal cells.
hormone	Chemical messenger produced in glands and carried in blood to specific organs in the body.
Insulate	To help maintain the temperature.
Insulin	hormone that regulates the level of sugar in the blood
nerve impulses	Electrical signals that travel along the nerve fibre from one end of the nerve cell to the other.
Obesity	Medical term for being very overweight, due to accumulation of body fat.
Vasoconstriction	Narrowing of the skin arterioles to reduce blood flow and reduce heat loss by radiation.
vasodilation	Increase in diameter of the skin arterioles to increase blood flow & increase heat loss by radiation.

RPA: Plan and carry out an investigation into the effect of a factor on human reaction times



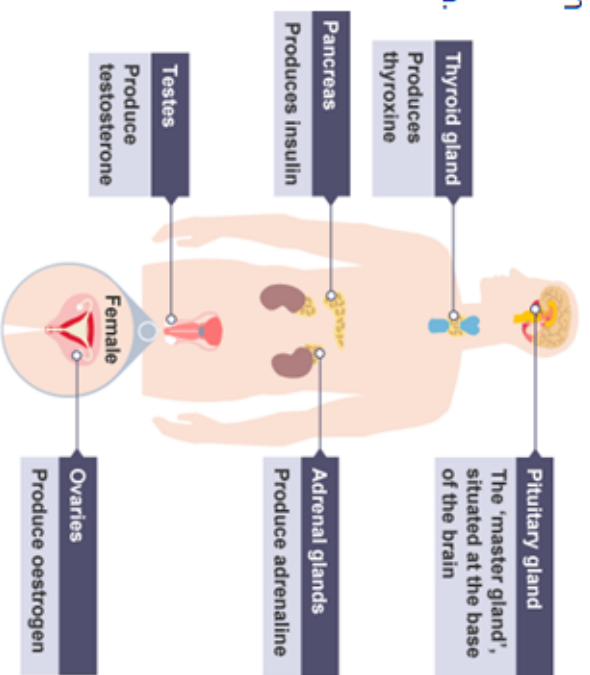
Receptor in the skin detects a stimulus
Sensory neurone sends electrical impulses to relay neurone, which are located in the spinal cord. They connect sensory neurones to motor neurones.
Motor neurone sends electrical impulses to an effector.
Effector produces a response eg muscle contraction



Knowledge Organiser – 4.5.3 Hormonal coordination in humans

4.5.3.1 Human endocrine system

- The endocrine system is composed of glands which secrete chemicals called hormones directly into the bloodstream.
- Hormones carried by blood to a target organ where it produces an effect.
- Compared to the nervous system the effects are slower but act for longer.



- Pituitary gland** in the brain
- 'master gland' which secretes several hormones into the blood in response to body conditions.
- These hormones act on other glands to stimulate other hormones to be released to bring about effects.

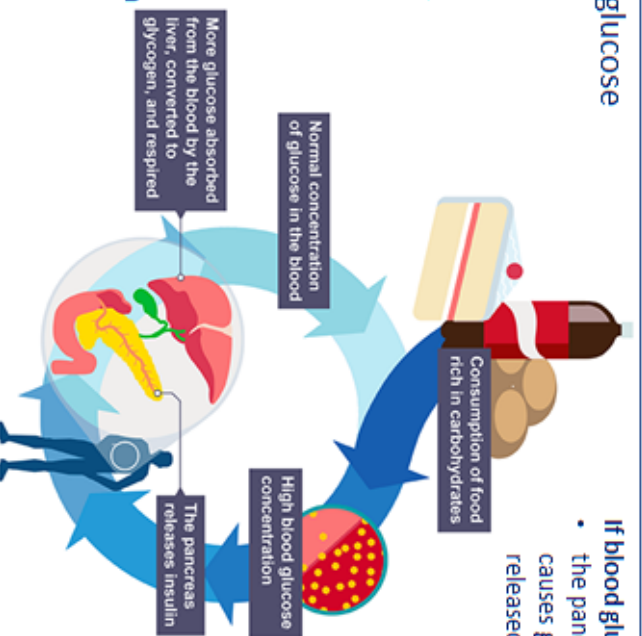
Differences between Hormonal and Nervous coordination		Nervous	Hormonal
Type of signal	Electrical (chemical at synapses)	Chemical	
Transmission of signal	By nerve cells (neurones)	By the bloodstream	
Effectors	Muscles or glands	Target cells in particular tissues	
Type of response	Muscle contraction or secretion	Chemical change	
Speed of response	Very rapid	Slower	
Duration of response	Short (until nerve impulses stop)	Long (until hormone is broken down)	

4.5.3.2 Control of blood glucose concentration

- Monitored and controlled by the pancreas.
- High blood glucose damages cells due to a loss of water by osmosis.

If blood glucose concentration is too high:

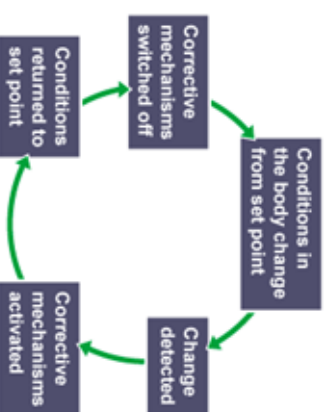
- Pancreas detects the increase
- Pancreas produces the hormone **insulin**.
- Increases **glucose absorption** in liver and muscle cells.
- Excess glucose is converted to **glycogen** for storage in liver and muscle.



- If blood glucose concentration is too low:
- the pancreas produces the hormone **glucagon** that causes **glycogen to be converted into glucose** and released into the blood.

Negative feedback

Glucagon and Insulin interacting to manage glucose levels in the blood is an example of a **negative feedback cycle**.



Diabetes:

Type 1 diabetes is a disorder in which the pancreas fails to produce sufficient insulin. It is characterised by uncontrolled high blood glucose level.

Treatment:

- normally treated with **insulin injections**

Type 2 diabetes the body cells no longer respond to insulin produced by the pancreas.

Obesity is a risk factor for Type 2 diabetes.

Treatment:

- A carbohydrate controlled diet
- Exercise regime

KnowledgeOrganiser – 4.5.3 Hormonal coordination in human reproduction

4.5.3.3 Hormones in human reproduction

Menstruation & Puberty in Females

- During puberty reproductive hormones cause secondary sex characteristics to develop.
- Oestrogen is the main female reproductive hormone produced in the ovary.
- At puberty eggs begin to mature and one is released approximately every 28 days. This is called ovulation.

Puberty in Males

- Males start to produce testosterone at puberty.
- Testosterone is the main male reproductive hormone produced by the testes
- Testosterone stimulates sperm production.

Several hormones are involved in the menstrual cycle of a woman.

Hormone	Produced	Role
FSH (follicle stimulating hormone)	Pituitary gland	Causes an egg to mature in an ovary. Stimulates the ovaries to release oestrogen
Oestrogen	Ovaries	Stops FSH being produced (so that only one egg matures in a cycle). Repairs, thickens and maintains the uterus lining. Stimulates the pituitary gland to release LH.
LH (luteinising hormone)	Pituitary gland	Triggers ovulation (the release of a mature egg)
Progesterone	Ovaries	Maintains the lining of the uterus during the middle part of the menstrual cycle and during pregnancy.

4.5.3.4 Contraception

Fertility can be controlled by a variety of hormonal and non-hormonal methods of contraception. These include:

- Hormonal **oral contraceptives** inhibiting FSH production so that no eggs mature
- **injection, implant or skin patch** of slow release progesterone to inhibit the maturation and release of eggs over a long period
- **barrier methods** such as condoms and diaphragms which prevent the sperm reaching an egg
- **intrauterine devices** which prevent the implantation of an embryo or release a hormone
- **spermicidal agents** which kill or disable sperm
- **abstaining from intercourse** when an egg may be in the oviduct
- **surgical methods** of male and female **sterilisation**.

4.5.3.5 The use of hormones to treat infertility (HT only) Fertility drugs

- Provide woman with FSH and LH in a 'fertility drug'
- She may then become pregnant in the normal way.

Fertility: The ability to reproduce.

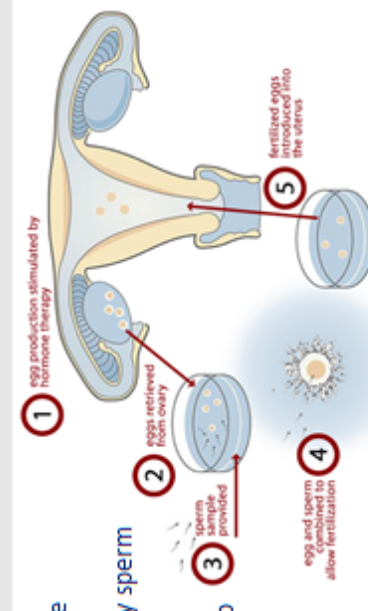
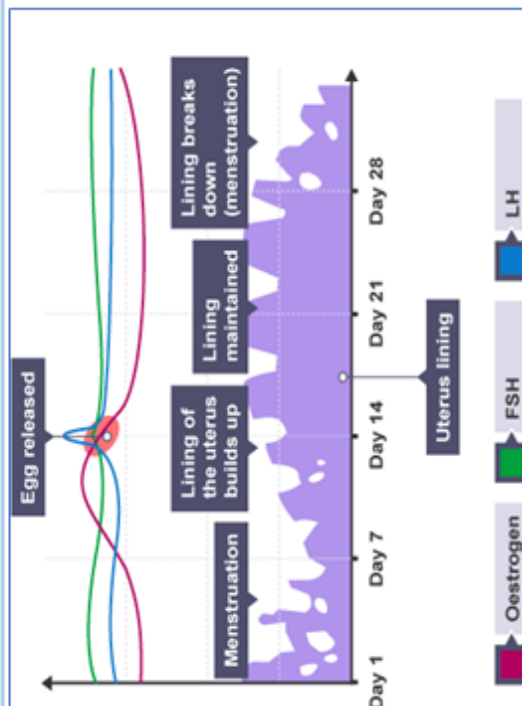
4.5.3.5 The use of hormones to treat infertility (HT only)

In Vitro Fertilisation (IVF) treatment.

- IVF involves giving a mother FSH and LH to stimulate the maturation of several eggs.
- The eggs are collected from the mother and fertilised by sperm from the father in the laboratory.
- The fertilised eggs develop into embryos.
- At the stage when they are tiny balls of cells, one or two embryos are inserted into the mother's uterus (womb).

Negatives of IVF

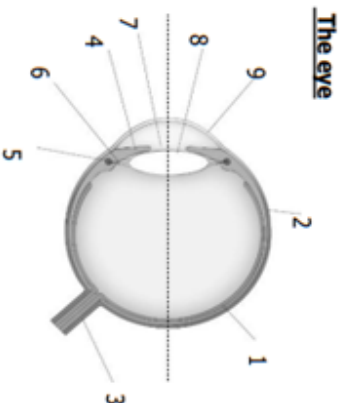
- it is very emotionally and physically stressful
- the success rates are not high
- it can lead to multiple births which are a risk to both the babies and the mother.



Knowledge Organiser – 4.5.2 Separate Biology

The brain	
Cerebral cortex	Outer wrinkly part, responsible for consciousness, intelligence, memory and language
Medulla oblongata	Controls unconscious activities e.g. breathing and heartbeat
Cerebellum	Responsible for muscle coordination

Studying the brain (HT)	
Study people with brain damage	If a part of the brain has been damaged the effect on the patient can tell you what this part does
Electrically stimulate the brain	By observing what stimulating different parts of the brain does its possible to get an idea of what those parts do
MRI scans	MRI scans produce detailed pictures of the brain. Scientists can see which parts are active when people are doing things
The brain is complex and delicate – investigating and treating it is difficult	



Cerebral cortex Medulla Oblongata	Focusing on near and distant objects	
	To look at near objects – ciliary muscles contract , suspensory ligaments slacken , lens becomes fat , increasing amount of refraction	
	To look at distant objects – ciliary muscles relax , suspensory ligaments tighten , lens becomes thin , decreasing amount of refraction	

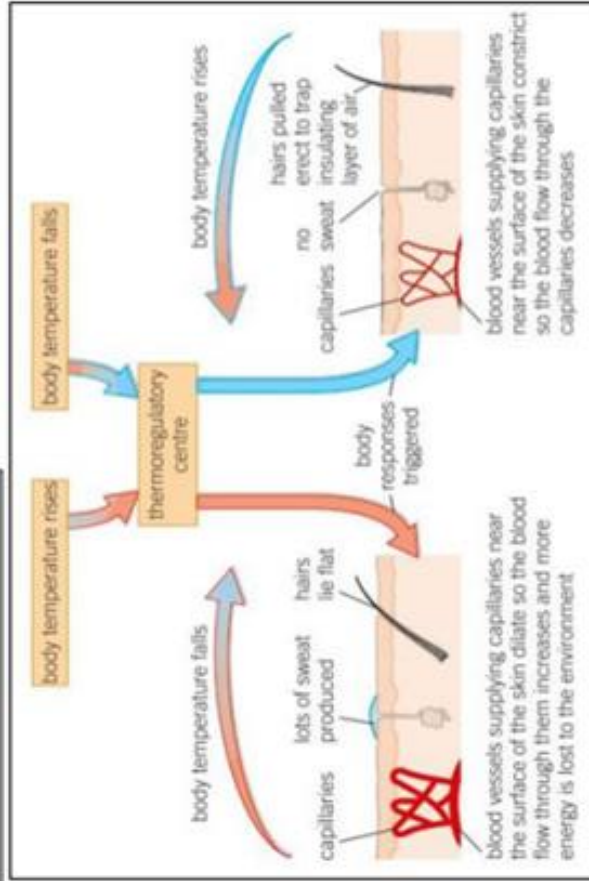
The eye key terms and parts		
Refraction – the bending of light rays when they pass from one medium to another		
Part	Function	
1 Retina	Where an image forms at the back of the eye, contains rods and cones	
2 Sclera	The white part, protects the eye	
3 Optic nerve	Send electrical impulses from the retina to the brain	
4 Iris	Coloured muscle controls the size of the pupil	
5 Ciliary muscles	Contract and relax to change the shape of the lens	
6 Suspensory ligaments	Controls the shape of the lens to focus light rays on the retina	
7 Pupil	Hole located in the centre of the iris of the eye that allows light to strike the retina	
8 Lens	Refracts light to be focused on the retina	
9 Cornea	Refracts light through the pupil	
Rods	Light sensitive receptor cells that let you see in low light conditions	
Cones	Light sensitive receptor cells that let you see colour	

Correcting vision problems			
	Where the image focuses	How to correct it	Why it occurs
Long sighted (HYPEROPIA)	Behind the retina	Convex lens	The lens is too weak or the eyeball is too short
	Where the image focuses	How to correct it	Why it occurs
Short sighted (MYOPIA)	In front of the retina	Concave lens	The lens is too strong, or the eyeball is too long
Contact lenses	Good for sports/activities, almost invisible. Could cause infection if not sterilised properly		
Laser eye surgery	Permanent correction of vision problems, however, surgery carries risks		
Lens replacement	Permanent solution, risk of vision loss		

Knowledge Organiser – 4.5.2 & 3 Separate Biology

Temperature control

Vasodilation	Arterioles (blood vessels) supplying skin capillaries dilate so more blood can flow close to the surface of the skin. Helps transfer heat energy from the skin to the environment to cool you down
Vasoconstriction	Arterioles supplying the skin capillaries constrict so less blood flows under the surface of the skin. Reducing heat loss when you are too cold
Sweating	Sweat glands release sweat when you are too hot. When sweat evaporates it transfers energy to the environment
Shivering	Shivering is when muscles contract rapidly, this need respiration which transfers energy to the body to warm you up
Thermoregulatory centre	Found in the hypothalamus in the brain, detects blood temperature changes and receives information about skin temperature too



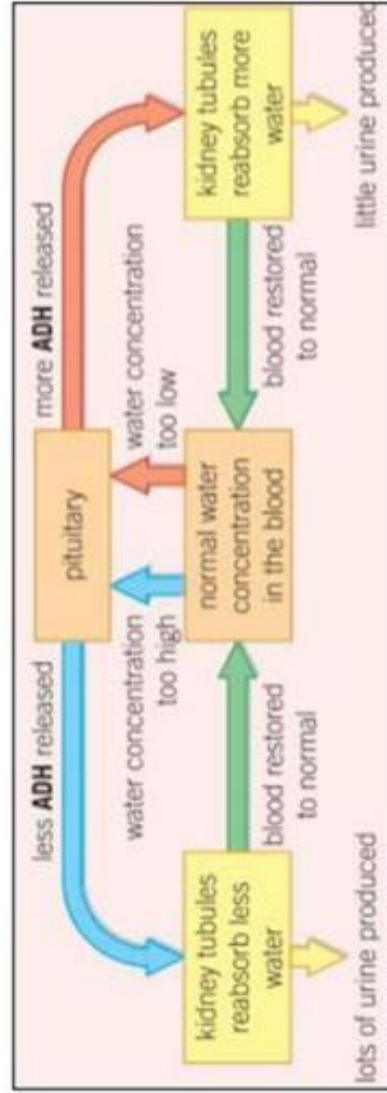
Water and nitrogen control

Urine contains....

Urea	Excess proteins are broken down into amino acids in the liver. These amino acids are turned into ammonia which is toxic so it is quickly turned into urea and excreted from the body in urine
Ions	Excess ions are removed in the urine
Water	Water leaves the body via the lungs during exhalation Water, mineral ions and urea are lost through the skin in sweat Excess water and mineral ions is removed via the kidneys in urine If the body cells lose or gain too much water through osmosis, they do not function efficiently.

Water and nitrogen control - ADH

ADH	Anti-diuretic hormone controls the concentration of the urine
Pituitary gland	Releases more or less ADH depending on how much water is in the body
Negative feedback	Controls water levels in the body



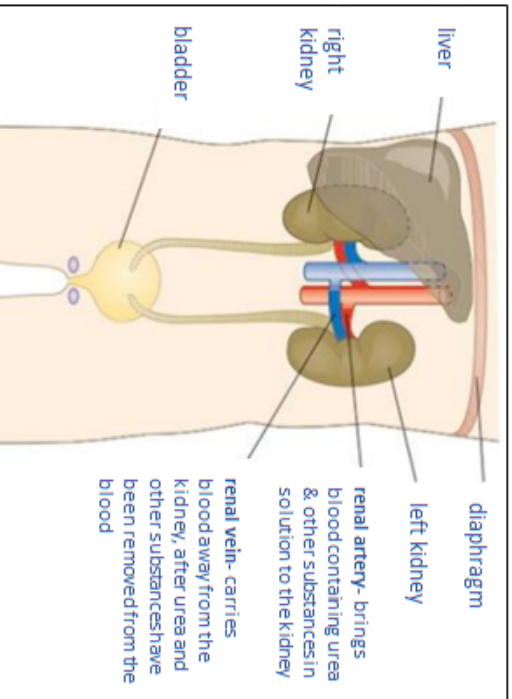
Knowledge Organiser – 4.5.3 & 4.5.4 Separate Biology

4.5.3.3 Maintaining water and nitrogen balance in the body

A kidney produces urine firstly by **filtering** the blood. **Selective reabsorption** then occurs. This means that **all** of the **glucose** is reabsorbed back into the blood, along with **some** of the **ions** and **some** of the **water** depending on the concentration of these within the body.

The kidney **excretes urea** in the urine along with any **excess water and ions**.

Protein molecules are too **large** to pass through the kidney filters so remain in the blood and are not therefore excreted in the urine of a healthy person.



4.5.4.1 – Plant Hormones – Coordination and Control

Tropism – a plant's response to a stimulus

Phototropism – a plant's response to light

Geotropism – a plant's response to gravity

4.5.4.1 A plant's response to light

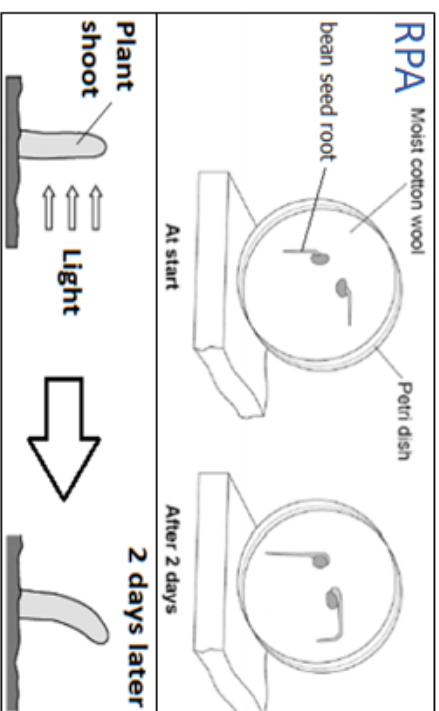
- Auxin (a plant hormone) redistributes unevenly in the shoot
- More auxin gathers on the dark side of the shoot
- Auxin promotes cell elongation in the shoot
- If the plant cells on the dark side have more auxin they will grow more/faster & longer
- This causes the plant to bend towards the light

A plant's response to gravity

- Gravity produces unequal distribution of auxin
- Auxin is pulled to the lower side of the roots (by gravity)
- In the root auxin inhibits cell growth
- The cells on top elongate faster
- This causes the root to bend downward

4.5.4.2 – Use of Plant Hormones

Hormones	Needed for	Used for:
Auxin	cell elongation/ plant growth	killing weeds, growing cuttings with rooting powder, growing cells in tissue culture
Ethene	ripening	speed up ripening of fruit (sprayed over fruit in shipping containers)
Gibberellin	seed germination	controlling seed dormancy and germination, inducing flowering, growing larger fruit



4.5.3.7 – Negative feedback - Thyroxine (HT)

- Hormone produced by the **thyroid gland**.
- Thyroxine stimulates the metabolic rate.
- Important in **growth and development**.
- Controlled by **negative feedback (HT)**
- If levels of thyroxine in blood fall, sensors in the **brain** detect this and **TSH** is released from the pituitary gland.
- TSH stimulates the **production of thyroxine** by the thyroid gland.
- As the level of thyroxine goes up, it is detected by the **sensors** and the level of **TSH** released falls.

Knowledge Organiser – 4.6 Inheritance, variation and evolution

Sexual reproduction involves the joining (fusion) of male and female gametes:

- sperm and egg cells in animals
- pollen and egg cells in flowering plants.
- mixing of genetic information which leads to variety in the offspring.
- The formation of gametes involves meiosis.

Meiosis: non-identical offspring

4.6.1.2 Meiosis

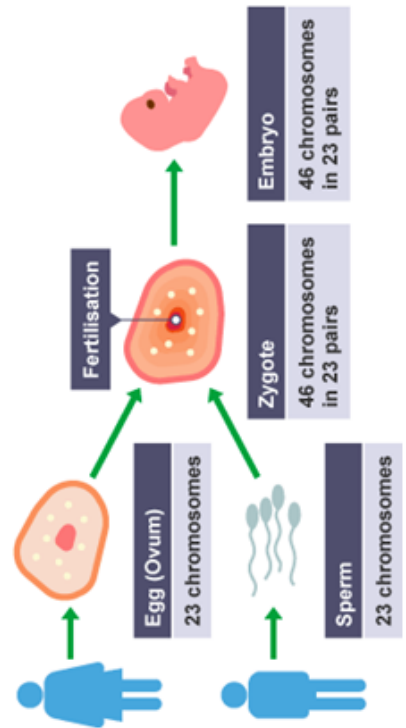
Sexual reproduction uses the process of **meiosis**, which creates gametes. The process of meiosis happens in the male and female reproductive organs.

Meiosis halves the number of chromosomes in gametes

Fertilisation restores the full number of chromosomes.

Cells in reproductive organs divide by meiosis to form gametes:

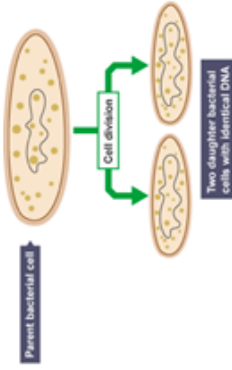
- **copies of the genetic information** are made
- the cell divides **twice** to form **four gametes**, each with a **single set of chromosomes (haploid)**
- all gametes are **genetically different** from each other.
- Gametes **join at fertilisation** to **restore the normal number of chromosomes**.
- The new cell divides by mitosis.
- The number of cells increases.
- As the embryo develops cells differentiate.



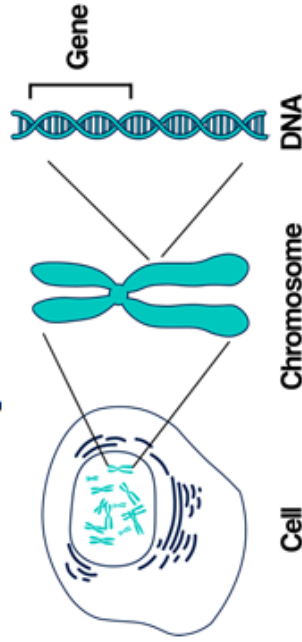
Asexual reproduction involves only one parent

- No fusion of gametes.
- No mixing of genetic information.
- leads to genetically identical offspring (clones).
- Only mitosis is involved.

Mitosis: identical offspring



4.6.1.3 DNA and the genome



DNA Deoxyribonucleic acid

- The **genetic material in the nucleus of a cell** is composed of a chemical called **DNA**.
- DNA is a **polymer** made up of two strands forming a **double helix**.

Chromosome

- The DNA is contained in structures called **chromosomes**.
- Codes for all the characteristics of an organism.

Gene

- A gene is a small section of DNA on a chromosome.
- Each gene codes for a particular sequence of amino acids, to make a specific protein.

Genome

- genome of an organism is the entire genetic material of that organism.
- The whole human genome has now been studied and this will have great importance for medicine in the future.

Definitions

diploid	A cell that contains two sets of chromosomes.
double helix	shape of the DNA molecule with two strands twisted together in a spiral.
gamete	Sex cell (sperm in males and ova/eggs in females).
haploid	A sex cell (gamete) containing one set of chromosomes.
heredity	Genetic information that determines an organism's characteristics, passed on from one generation to another. To do with passing genes to an offspring from its parent or parents.
mitosis	A type of cell division which produces daughter cells identical to the parent.
nucleus	The central part of an atom. It contains protons and neutrons, and has most of the mass of the atom. The plural of nucleus is nuclei.
organism	Living entity, eg animals, plants or bacteria.

Knowledge Organiser – 4.6.1 Inheritance, variation and evolution

4.6.1.4 Genetic inheritance

Some **characteristics** are controlled by a single gene e.g: fur colour in mice; and red-green colour blindness in humans.

- Each **gene** may have different forms called **alleles**.
- The **alleles** present (**genotype**), operate at a molecular level to develop **characteristics** that can be expressed as a **phenotype**.
- A **dominant allele** is **always expressed**, even if only one copy is present.
- A **recessive allele** is **only expressed if two copies are present**.
- If the **two alleles** are the same the organism is **homozygous** for that trait
- If the **alleles are different** they are **heterozygous**.

Punnett square

	pollen ♂	
	B	b
pistil ♀	B	BB purple
	b	Bb purple

Using Punnett Squares to Predict Phenotypic Ratios

Phenotype Ratio:
3:1
purple : white

Genotype Ratio:
25% PP
50% Pp
25% pp
1:2:1 ratio

F₁ self-pollinates

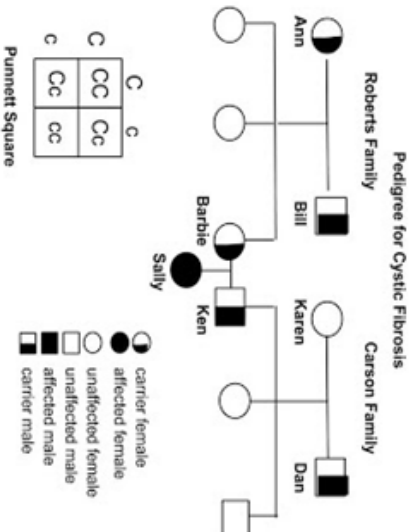
P	P	PP
p	p	pp



4.6.1.5 Inherited disorders

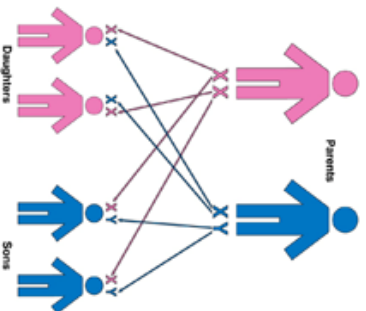
Some disorders are inherited. These disorders are caused by the inheritance of certain alleles.

- **Polydactyly** (having extra fingers or toes) is caused by a dominant allele.
- **Cystic fibrosis** (a disorder of cell membranes) is caused by a recessive allele.



4.6.1.6 Sex determination

- Human body cells contain 23 pairs of chromosomes
- 22 pairs control characteristics only
- 1 pair carries the genes that determine sex.
- **Females:** sex chromosomes - XX
- **Males:** chromosomes are different - XY



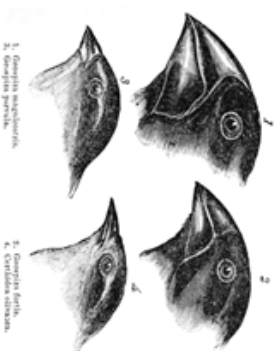
4.6.2 Variation and evolution

Differences in the characteristics of individuals in a population is called variation and may be due to differences in:

- the genes they have inherited (**genetic** causes)
- the conditions in which they have developed (**environmental** causes)
- a **combination of genes and the environment**.
- Usually extensive genetic variation within a population of a species
- All variants arise from mutations and **most have no effect on the phenotype; some influence phenotype; very few determine phenotype**.
- **Mutations occur continuously**. Very rarely a mutation will lead to a new phenotype.
- If a new phenotype is suited to an environmental change it can lead to a relatively rapid change in the species.

Evolution:

- 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**.
- Evolution occurs through **natural selection of variants** that give rise to **phenotypes** best suited to their **environment**.
- If two populations of one species become so different in phenotype that they can **no longer interbreed to produce fertile offspring** they have formed two **new species**.



Knowledge Organiser – 4.6.2 Selective breeding & Genetic Engineering

4.6.2.3 Selective breeding or Artificial selection

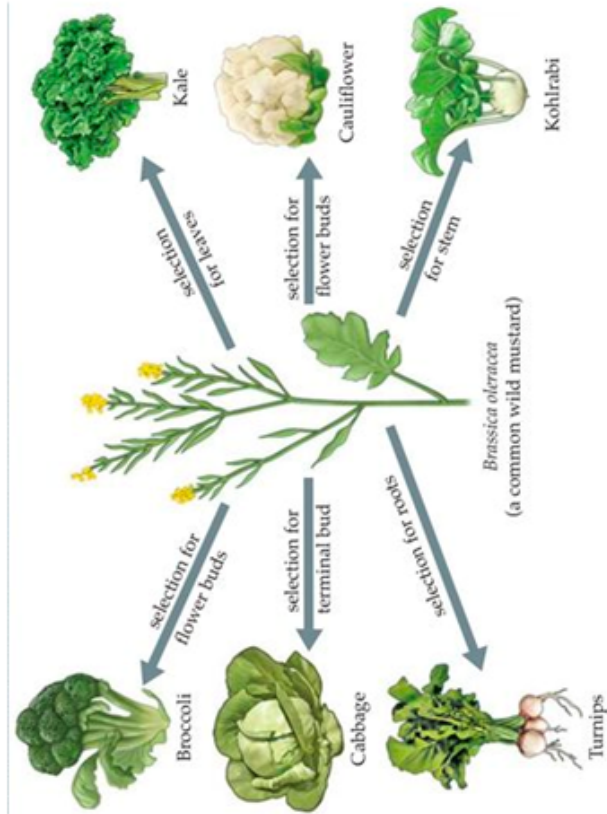
Selective breeding (artificial selection) is the human breeding of plants and animals for particular genetic characteristics.

Involves:

- **choosing parents with the desired characteristic** from a mixed population.
- They are **bred together**.
- From the **offspring those with the desired characteristic are bred together**.
- **continues over many generations** until **all** the offspring show the **desired characteristic**.

Characteristics might include:

- **Disease resistance** in food crops.
- Animals which produce **more meat or milk**.
- Selective breeding **can lead to 'inbreeding'** where some breeds are particularly prone to disease or inherited defects.



4.6.2.4 Genetic engineering

Genetic engineering involves modifying the genome of an organism by introducing a gene from another organism to give a desired characteristic.

- **Plant crops have been genetically engineered to be resistant to diseases** or to produce bigger better fruits.
- **Bacterial cells have been genetically engineered** to produce human **insulin** to treat diabetes.
- **Genes** from the chromosomes of humans and other organisms **can be 'cut out' and transferred to cells of other organisms**.

GM Crops

- Crops that have had their genes modified in this way are called **genetically modified (GM) crops**.
- GM crops include ones that are resistant to insect attack or to herbicides.
- GM crops generally show increased yields.

Negatives

- Concerns about GM crops include the effect on populations of wild flowers and insects.
- Some people feel the effects of eating GM crops on human health have not been fully explored.

Positives

- Modern medical research is exploring the possibility of genetic modification to overcome some inherited disorders.
- Much faster than selective breeding
- More productive crops, resistant to climate change and other environmental challenges

Process of genetic engineering (HT only):

- **enzymes** are used to **isolate** the required gene
- this **gene is inserted into a vector**, usually a bacterial plasmid or a virus
- the **vector is used to insert the gene into the required cells**
- genes are **transferred to the cells of animals, plants or microorganisms** at an early stage in their development so that they develop with desired characteristics.

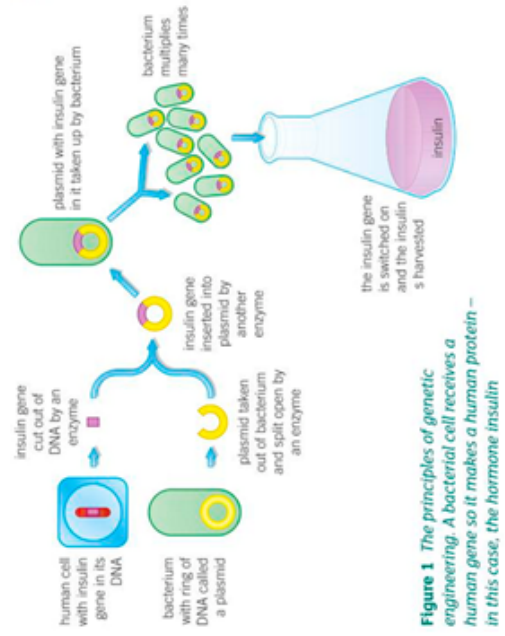


Figure 1 The principles of genetic engineering. A bacterial cell receives a human gene so it makes a human protein – in this case, the hormone insulin

Knowledge Organiser – 4.6.3 Development of understanding of genetics & evolution

Evidence for evolution

- The theory of evolution by natural selection is now widely accepted.
- Evidence for Darwin's theory is now available as it has been shown that characteristics are passed on to offspring in genes.
- There is further evidence in the fossil record
- And by knowledge of how resistance to antibiotics evolves in bacteria.

Fossils are the 'remains' of organisms from millions of years ago, which are found in rocks.

Fossils may be formed:

- from **parts of organisms that have not decayed** because one or more of the conditions needed for decay are absent
- when parts of the organism are **replaced by minerals as they decay**
- as **preserved traces of organisms**, such as footprints, burrows and rootlet traces.
- Many **early forms of life were soft-bodied**, which means that they have left few traces behind.
- What traces there were have been mainly **destroyed by geological activity**. This is why scientists cannot be certain about how life began on Earth.
- We can learn from fossils how much or how little different organisms have changed as life developed on Earth.



Extinctions occur when there are no remaining individuals of a species still alive.

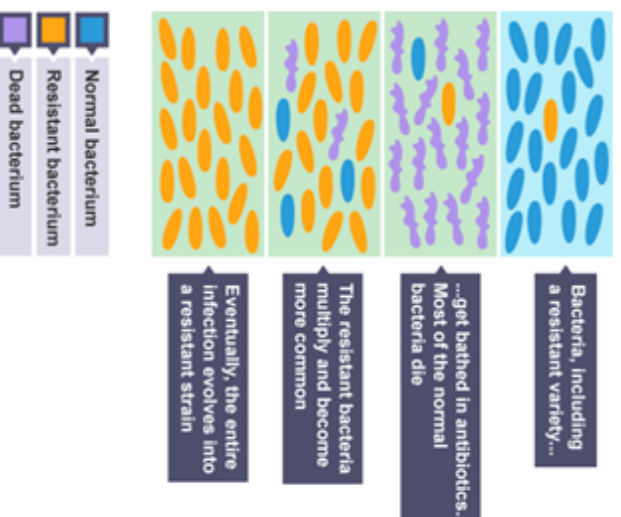
4.6.3.4 Resistant bacteria

- Bacteria can evolve rapidly because they reproduce at a fast rate.
- Mutations of bacterial pathogens produce new strains.
- Some strains might be resistant to antibiotics, and so are not killed.
- They **survive and reproduce**, so the population of the resistant strain rises.
- The resistant strain will then spread because people are not immune to it and there is no effective treatment.

E.g. MRSA is resistant to antibiotics.

To reduce the rate of development of antibiotic resistant strains:

- doctors should not prescribe antibiotics inappropriately, such as treating non-serious or viral infections
- patients should complete their course of antibiotics so no bacteria survive to mutate and form resistant strains
- the agricultural use of antibiotics should be restricted.
- The development of new antibiotics is costly and slow. It is unlikely to keep up with the emergence of new resistant strains.



4.6.4 Classification of living organisms

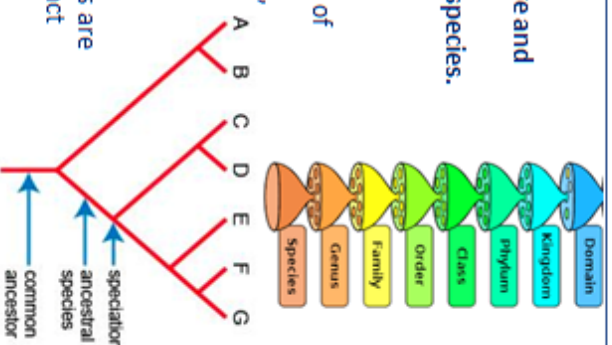
- Traditionally living things have been classified into groups depending on their structure and characteristics in a system developed by Carl Linnaeus.
- Linnaeus classified living things into **kingdom, phylum, class, order, family, genus and species**.
- Organisms are named by the **binomial system of genus and species**.

- As evidence of internal structures became more developed due to improvements in microscopes, and the understanding of biochemical processes progressed, new models of classification were proposed.

- Due to evidence available from chemical analysis **there is now a 'three-domain system'** developed by Carl **Woese**.

- **Archaea** (primitive bacteria usually living in extreme environments)
- **Bacteria** (true bacteria)
- **Eukaryota** (which includes protists, fungi, plants and animals).

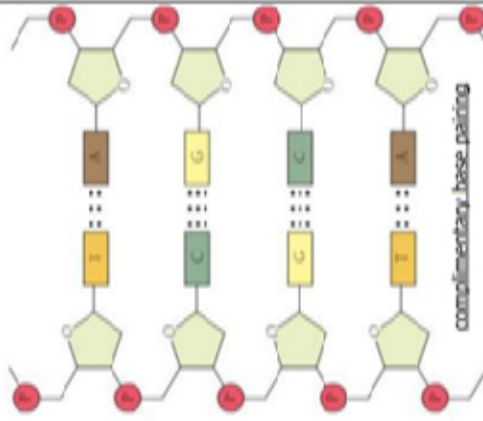
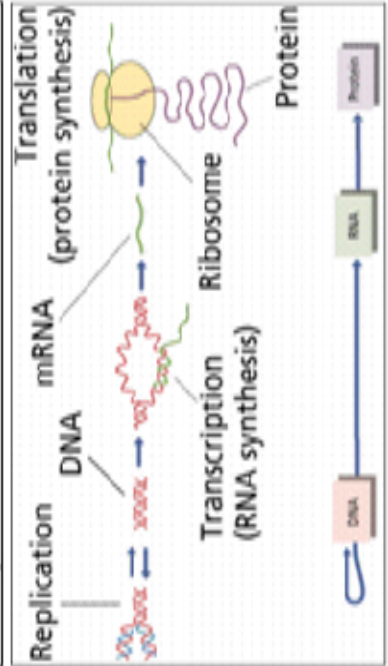
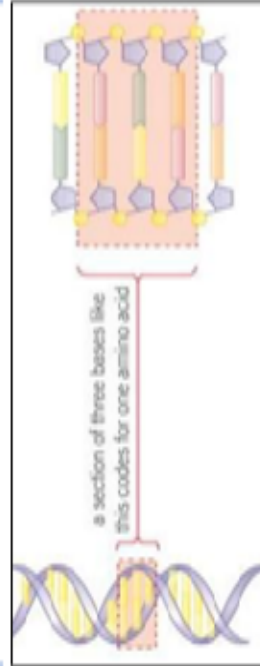
- **Evolutionary trees** are a method used by scientists to show how they believe organisms are related. They use current classification data for living organisms and fossil data for extinct organisms.



Knowledge Organiser – 4.6.1.5 DNA structure & 4.6.2.5 Cloning (sep biology)

4.6.1.5 DNA structure

- ☐ DNA strands are polymers made up of lots of repeating units called nucleotides
- ☐ Each nucleotide consists of one sugar molecule, one phosphate molecule and one base
- ☐ The sugar and phosphate molecules in the nucleotides form a **backbone** to the DNA strands. The sugar and phosphate molecules **alternate**.
- ☐ One of four different bases **A, T, C or G** joins to each sugar. Each base links to a base on the **opposite** strand in the **helix**
- ☐ A always pairs up with T, and C always pairs up with G. This is called **complementary base pairing**.
- ☐ It's the **order of bases** in a gene that decides the **order of amino acids** in a protein
- ☐ Each amino acid is coded for by a sequence of **three bases** in the gene
- ☐ The amino acids are joined together to make various **proteins**, depending on the order of the gene's bases.



Mutations (HT)

- A mutation: A random change in the DNA
- Cause? Exposure to certain substances/some radiation types
- Types? Insertions, deletions, substitutions
- Enzyme active site is altered.

4.6.2.5 Cloning

Tissue culture: using small groups of cells from part of a plant 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 a parent plant.

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

4.6.1.3 Advantages and disadvantages of sexual and asexual reproduction

Advantages of Sexual Reproduction:

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.

Advantages of Asexual Reproduction:

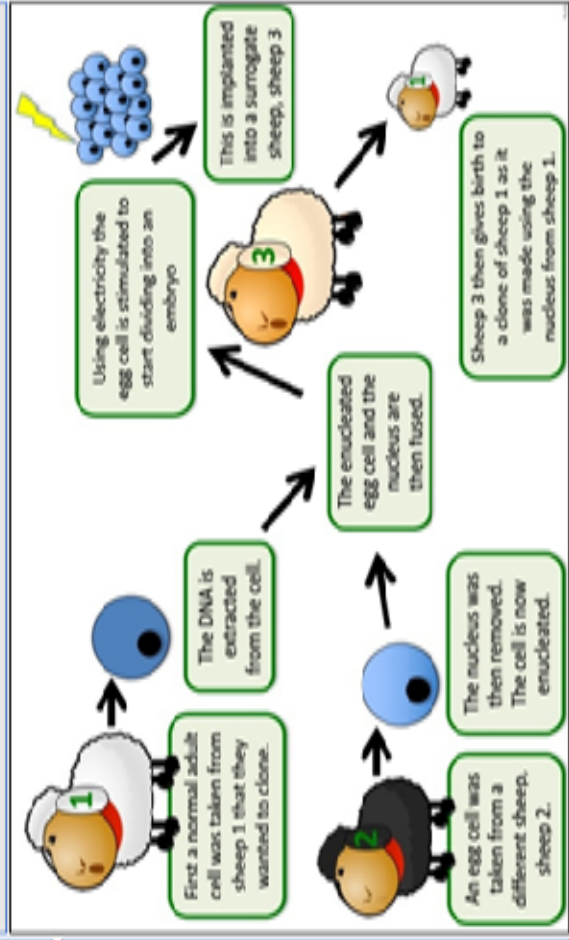
Only one parent needed / More time and energy efficient as do not need to find a mate / Faster than sexual reproduction / Many identical offspring can be produced when conditions are favourable.

Examples of organisms that carry out both types of reproduction:

Malaria parasites reproduce sexually in mosquitoes and asexually in their human hosts / Many fungi reproduce asexually by spores but can also reproduce sexually to give variation / Many plants produce seeds sexually but also reproduce asexually e.g. strawberries by runners or daffodils by bulb division

Protein synthesis (HT) – Key Terms

- o Proteins → Examples include: enzymes, hormones, structural proteins like collagen
- o Transcription → The first part of the process of making a protein. It takes place inside the cell nucleus. Transcription involves copying the DNA.
- o Translation → Takes place in the ribosomes that are found in the cytoplasm. This is where the messenger RNA is "interpreted" and the new protein formed
- o mRNA → Messenger RNA
- o tRNA → Transfer RNA



Knowledge Organiser – 4.6 Genetics & Evolution (sep biology)

4.6.3.1 Theory of evolution - Darwin vs Lamarck

Darwin's idea → Evolution by natural selection

Controversy at the time as people did not believe Darwin at the time because:-

- It went against religious beliefs - DNA/genes/the mechanism of inheritance was not understood at the time
- There was not enough evidence to convince other scientists

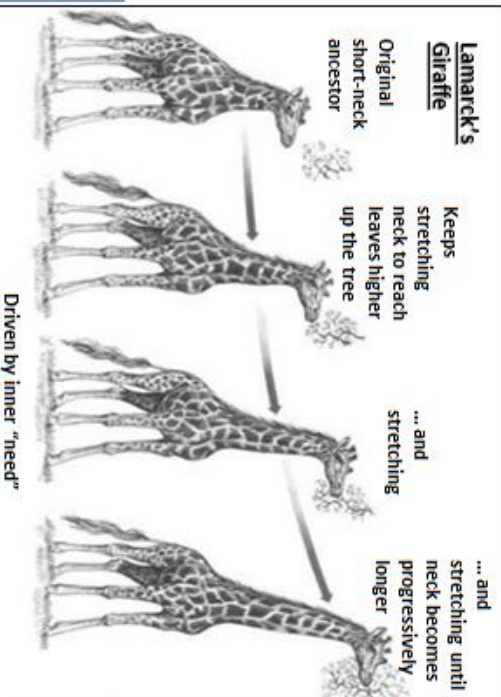
Lamarck's idea → Evolution by acquired characteristics

Organisms that use a characteristic a lot during its lifetime would become more developed e.g. a rabbit using its legs a lot to run would become longer. Then the organisms offspring would inherit this characteristic e.g. the rabbits offspring would also have longer legs.

4.6.3.3 The understanding of genetics

- Mendel was a monk who's research led to the foundation of modern genetics
- Experiments in the mid-19th century → Mendel carried out breeding experiments on pea plants.
- He observed that inheritance of each characteristic is determined by 'units' that are passed on from parents to offspring
- Rejection → Mendel's work was rejected at the time as:
 - he was just a monk (not a scientist), chromosomes / DNA / genes not seen / discovered / known at the time, other theories accepted at the time

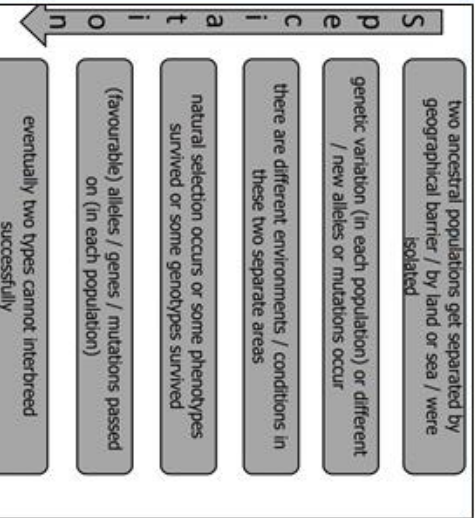
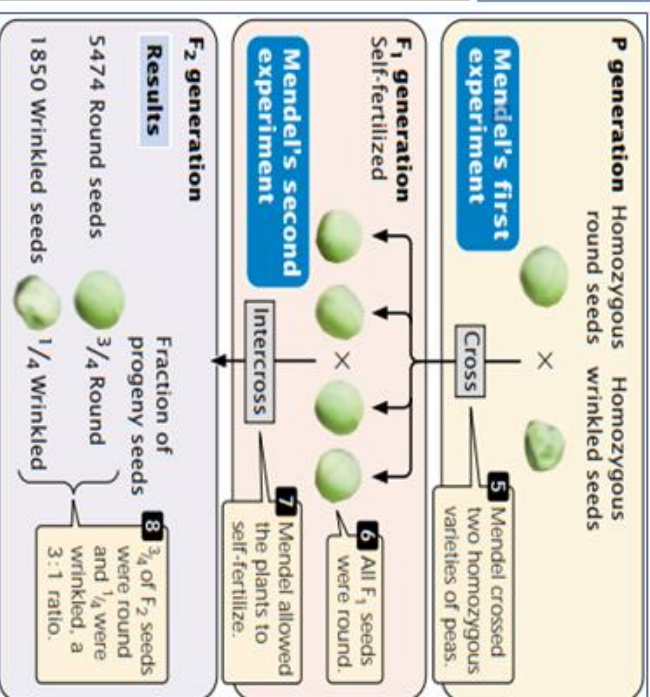
4.6.3.3		Flower Colour	Plant Height	Seed Color	Seed Shape	Pod Colour	Pod Shape	Flower Position
Dominant Trait		Purple						
		Tall		Round		Green		Axial
Recessive Trait		White						
		Short		Wrinkled		Yellow		Terminal



4.6.3.2 Speciation

Species → A group of similar organisms that can reproduce to give fertile offspring

Speciation → The development of a new species



Knowledge Organiser – 4.6.3 Development of understanding of genetics and

Evidence for evolution

- The theory of evolution by natural selection is now widely accepted.
- Evidence for Darwin's theory is now available as it has been shown that characteristics are passed on to offspring in **genes**.
- There is further evidence in the **fossil record**
- And by **knowledge of how resistance to antibiotics evolves in bacteria**.

Fossils are the 'remains' of organisms from millions of years ago, which are found in rocks.

- Fossils may be formed:
- from **parts of organisms that have not decayed** because one or more of the conditions needed for decay are absent
 - when parts of the organism are **replaced by minerals as they decay**
 - as **preserved traces of organisms**, such as footprints, burrows and rootlet traces.
 - Fossils can show how much or how little different organisms have changed as life developed .

Extinctions occur when there are no remaining individuals of a species still alive.



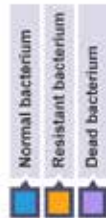
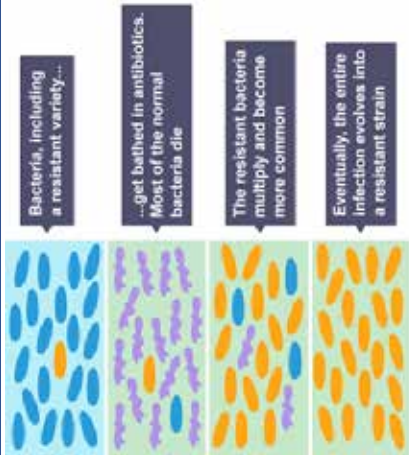
4.6.3.4 Resistant bacteria evolution

- **Bacteria can evolve rapidly because they reproduce at a fast rate.**
- **Mutations** of bacterial pathogens produce new strains.
- **Some strains might be resistant to antibiotics**, and so are not killed.
- They **survive and reproduce**, so the population of the resistant strain rises.
- The **resistant strain will then spread because people are not immune** to it and there is no effective treatment.

E.g. MRSA is resistant to antibiotics.

To reduce the rate of development of antibiotic resistant strains:

- doctors should not prescribe antibiotics inappropriately, eg for viral infections
- patients must complete a course of antibiotics so no bacteria survive to mutate and form resistant strains
- the agricultural use of antibiotics should be restricted.

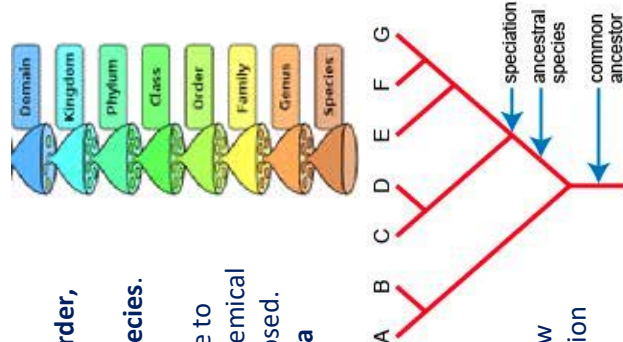


4.6.4 Classification of living organisms

- **Traditionally** living things have been **classified** into groups **depending on their structure and characteristics** in a system developed by Carl Linnaeus.
- Linnaeus classified living things into **kingdom, phylum, class, order, family, genus and species**.
- Organisms are named by the **binomial system of genus and species**.

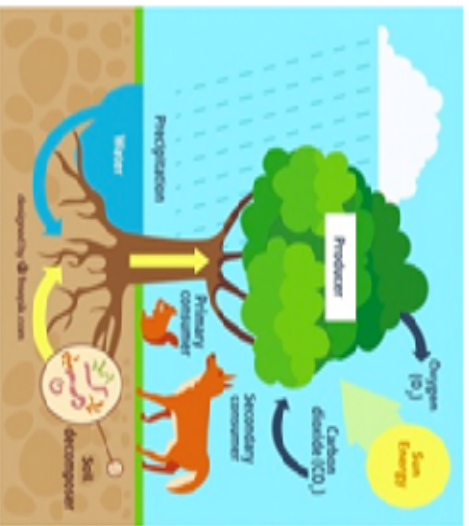
- As evidence of internal structures became more developed due to improvements in microscopes, and the understanding of biochemical processes progressed, new models of classification were proposed.
- Due to evidence available from chemical analysis **there is now a 'three-domain system'** developed by Carl Woese.

- **Archaea** (primitive bacteria usually living in extreme environments)
- **Bacteria** (true bacteria)
- **Eukaryota** (which includes protists, fungi, plants and animals).
- **Evolutionary trees** are a method used by scientists to show how they believe organisms are related. They use current classification data for living organisms and fossil data for extinct organisms.



Knowledge Organiser – 4.7.1 Ecology Adaptations, interdependence and competition

4.7 Ecology



4.7.1.2 Abiotic factors

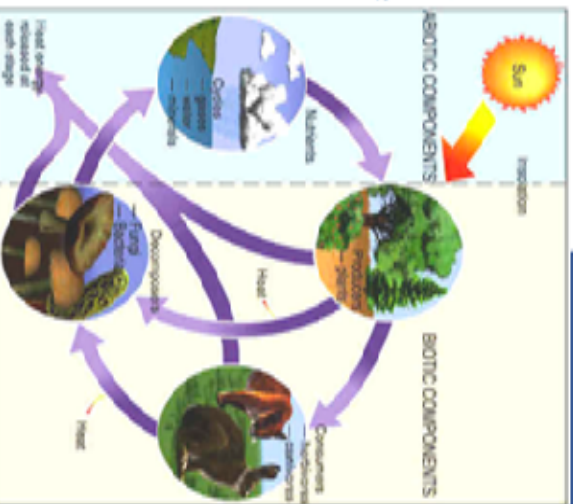
- light intensity
- temperature
- moisture levels
- soil pH and mineral content
- wind intensity and direction
- carbon dioxide levels for plants
- oxygen levels for aquatic animals.

4.7.1.3 Biotic factors

- availability of food
- new predators arriving
- new pathogens
- one species outcompeting another so the numbers are no longer sufficient to breed.

4.7.1.1 Communities

- An ecosystem is the interaction of a community of living organisms (biotic) with the non-living (abiotic) parts of their environment.
- To survive and reproduce, organisms require a supply of materials from their surroundings and from the other living organisms there.
- Plants in a community or habitat often compete with each other:
 - for light, space and for water and mineral ions from the soil.
- Animals often compete with each other:
 - for food, mates, territory
- Within a community each species depends on other species
- if one species is removed it can affect the whole community. This is called **interdependence**.
- A **stable community** is one where all the species and environmental factors are in balance so that **population sizes remain fairly constant**



4.7.1.4 Adaptations

- Organisms are adapted to live in their natural environment
- Organisms have features (adaptations) that enable them to survive in the conditions in which they normally live.
- These adaptations may be structural, behavioural or functional.
- **Extremophiles** are organisms that live in environments that are very extreme, such as at high temperature, pressure, or salt concentration. Eg Bacteria living in deep sea vents

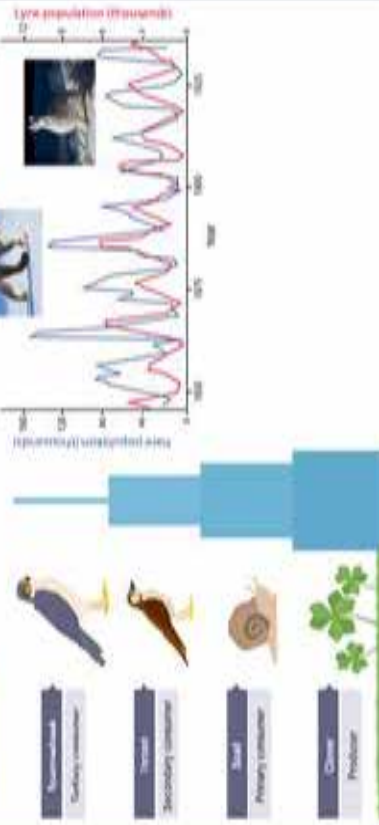


	Definition
abiotic	Non-living elements of an ecosystem, such as climate, temperature, water, and soil type.
biotic	Living elements of an ecosystem, eg plants, animals.
community	All the organisms that live in a habitat
ecosystem	The living organisms in a particular area, together with the non-living components of the environment.
food chain	A sequence (usually shown as a diagram) of feeding relationships between organisms, showing which organisms eat what and the movement of energy through trophic levels.
gene	The basic unit of genetic material inherited from our parents. A gene is a section of DNA which controls part of a cell's chemistry - particularly protein production.
indicator species	The presence, abundance or absence of these organisms provides information such as the level of pollution in the environment.
interdependence	Refers to the fact that all organisms that live in an ecosystem depend upon each other, for food, protection, shelter, etc, in order to survive.
interspecific competition	The competition which occurs between organisms of different species for a common resource.
intraspecific competition	The competition between organisms within the same species.
nitrate	The chemical absorbed from the soil by plants to produce their protein.
pathogen	Microrganism that causes disease.
population	All of the members of a single species that live within a geographical area.
predator	An animal that hunts, kills & eats other animals
prey	Organisms that predators kill for food.
producer	Plants that begin food chains by making energy from carbon dioxide and water.
species	A type of organism that is the basic unit of classification. Individuals of different species are not able to interbreed successfully.

Knowledge Organiser – 4.7.2 Organisation of an ecosystem

4.7.2.1 Levels of organisation

- **Photosynthetic organisms** are the producers of biomass for life on Earth.
- **Feeding relationships within a community can be represented by food chains.** All food chains begin with a producer which synthesises molecules. This is usually a green plant or alga which makes glucose by photosynthesis.
- **Producers** are eaten by **primary consumers**, which in turn may be eaten by **secondary consumers** and then **tertiary consumers**.
- Consumers that kill and eat other animals are **predators**, and those eaten are **prey**.
- **In a stable community the numbers of predators and prey rise and fall in cycles.**



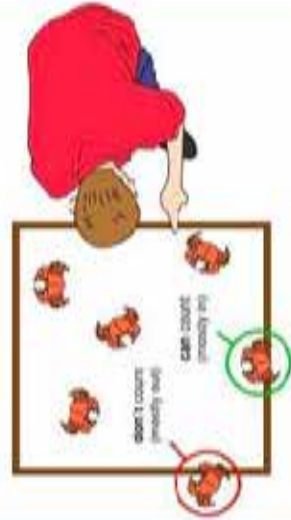
Definitions

- mean** The mean is calculated by adding all of the data and dividing by the number of items
- Mode** The value that occurs most often.
- median** The 'middle' value in the list of numbers
- quadrat** A square frame of known area used for sampling the abundance and distribution of slow or non-moving organisms.
- transect** A line created, for instance, with a tape measure, along which sampling occurs.
- yield** the mass of product made in a chemical reaction. The percentage yield is a measure of the yield obtained compared to the maximum possible yield.

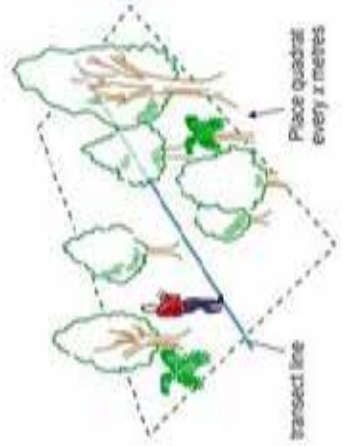
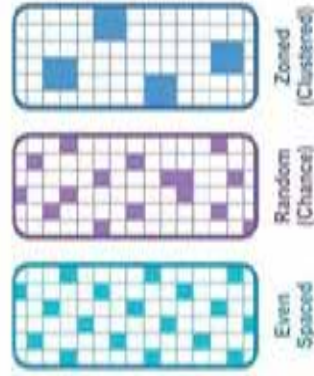
RPA: measure the population size of a common species in a habitat.

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

Quadrat Counting Method



Types of Sampling Distributions

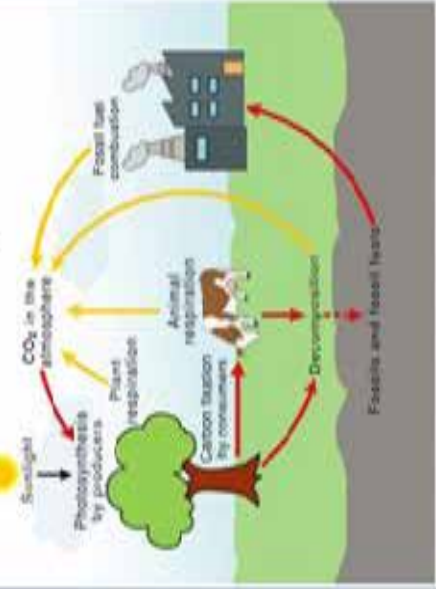


4.7.2.2 How materials are cycled

The water cycle



Carbon Cycle



Knowledge Organiser – 4.7.3 Biodiversity and the effect of human interaction on ecosystems

4.7.3.1 Biodiversity

- **Biodiversity** is the **variety of all the different species of organisms on earth, or within an ecosystem.**
- **Greater biodiversity ensures the stability of ecosystems** by reducing the dependence of one species on another for food, shelter and the maintenance of the physical environment.
- Many human activities are reducing biodiversity



4.7.3.2 Waste management

- **Rapid growth in the human population** and an increase in the standard of living mean that **increasingly more resources are used and more waste is produced.**
- Unless waste and chemical materials are properly handled, more **pollution** will be caused.

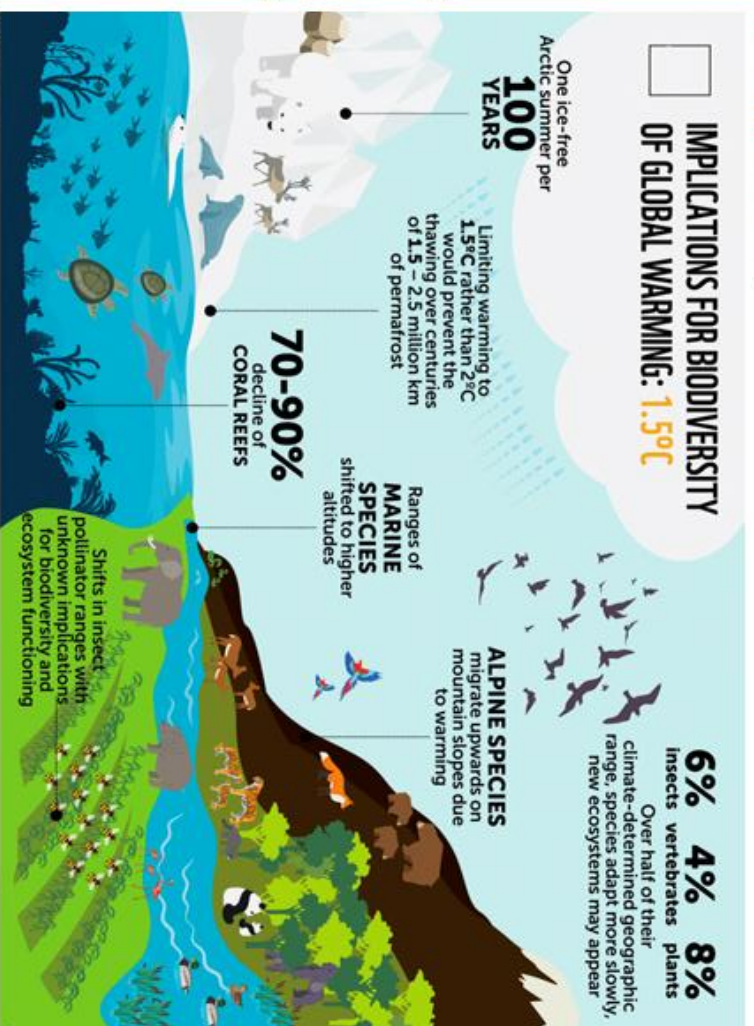
Pollution can occur:

- in **water**, from sewage, fertiliser or toxic chemicals
- in **air**, from smoke and acidic gases
- on **land**, from landfill and from toxic chemicals.
- Pollution kills plants and animals which can **reduce biodiversity.**



4.7.3.5 Global warming

IMPLICATIONS FOR BIODIVERSITY OF GLOBAL WARMING: **1.5°C**



4.7.3.3 Land use

- Humans **reduce the amount of land available** for other animals and plants by **building, quarrying, farming and dumping waste.**

For example:

- The **destruction of peat bogs**, and other areas of peat to produce garden compost, **reduces the area of this habitat** and thus the variety of different plant, animal and microorganism species that live there (**biodiversity**).
- The **decay or burning** of the peat **releases carbon dioxide** into the atmosphere.

4.7.3.4 Deforestation

- Large-scale deforestation in tropical areas has occurred to:
 - provide land for cattle and rice fields
 - grow crops for biofuels



4.7.3.6 Maintaining biodiversity

Scientists and concerned citizens have put in place programmes to reduce the negative effects of humans on ecosystems and biodiversity.

These include:

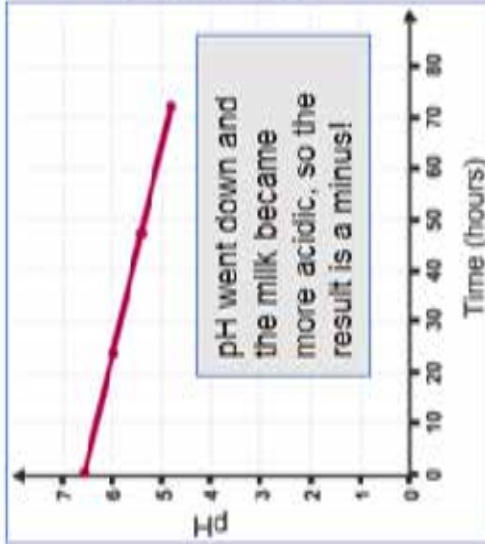
- breeding programmes for endangered species
- protection and regeneration of rare habitats
- reintroduction of field margins and hedgerows in agricultural areas where farmers grow only one type of crop
- reduction of deforestation and carbon dioxide emissions by some governments
- recycling resources rather than dumping waste in landfill.



Knowledge Organiser – 4.7.2.3 Decomposition & RPA (Separate Biology)

4.7.2.3 Decomposition / Decay: Key Terms

- **Compost** - Decomposed organic matter
- **Decomposition** - The breakdown of organic matter by microbes (bacteria/fungi) or detritus feeders (worms)
- **Conditions for decay** - Warm, plenty of oxygen, moisture, plenty of microbes
- **Biogas** - Methane gas produced by anaerobic decay of waste material, methane is used as a fuel for cooking, heating
- **Biogas generator** - Need constant temperature, 2 types: batch and continuous



$$\text{rate of change} = \frac{\text{vertical change}}{\text{horizontal change}}$$

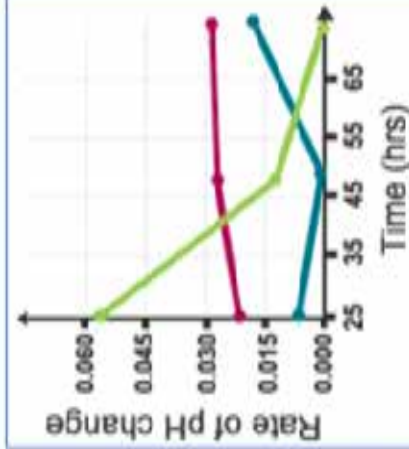
RPA – Skill

The rate of change can be calculated from the above graph by finding the gradient of the trend-line, using the equation above.

For example, after 0 hours in the above graph, the pH is 6.6; after 50 hours it is 5.4.

calculate

$$= \frac{5.4 - 6.6 \text{ pH units}}{50 - 0 \text{ hours}} = \frac{-1.2 \text{ pH units}}{50 \text{ hours}} = -0.024 \text{ pH units/hour (to 2 significant figures)}$$



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

As milk **decays** its pH reduces. This is because bacteria present in milk carry out a chemical process to provide them with energy. This process converts lactose sugar in the milk to lactic acid, and producing this acid reduces the pH of the milk.

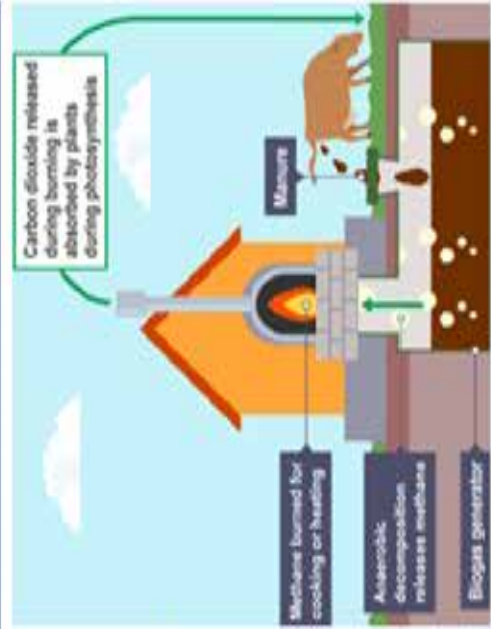
Aim

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

Method

1. Place 20 cm³ of fresh milk into three beakers
2. Decide the three temperatures you will investigate. Write these onto the sides of the beakers. They could be 5, 20 and 35°C.
3. Use universal indicator paper or solution to determine the pH of the milk in the three beakers
4. Cover each beaker in cling film and incubate at the appropriate temperature
5. Use universal indicator paper or solution to determine the pH of the milk in the three beakers after 24, 48 and 72 hours

Use the gradient of a graph to find a rate of change is easier than calculating rate if there's a lot of data/variability in data.



Knowledge Organiser – 4.7.3 Biodiversity & 4.7.4 Trophic Levels (Separate Biology)

4.7.2.4 Impact of environmental change (HT)

- **Temperature:** As you climb up a mountain the temperature reduces. This reduction, together with other **abiotic** and **biotic** factors, determines what **species** of plant are found at different elevations.
- **Availability of water:** All life on Earth needs water. Too much and some species will drown or rot. Too little and all species die.
- **Atmospheric gases:** Gases dissolve in liquids, thus oxygen in the air dissolves in water. It is this dissolved oxygen, together with that produced by plants and algae, that support aquatic life. When levels of pollution increase the levels of dissolved oxygen reduce.
These changes may be seasonal, geographic or caused by human interaction.

4.7.4.1 Trophic levels

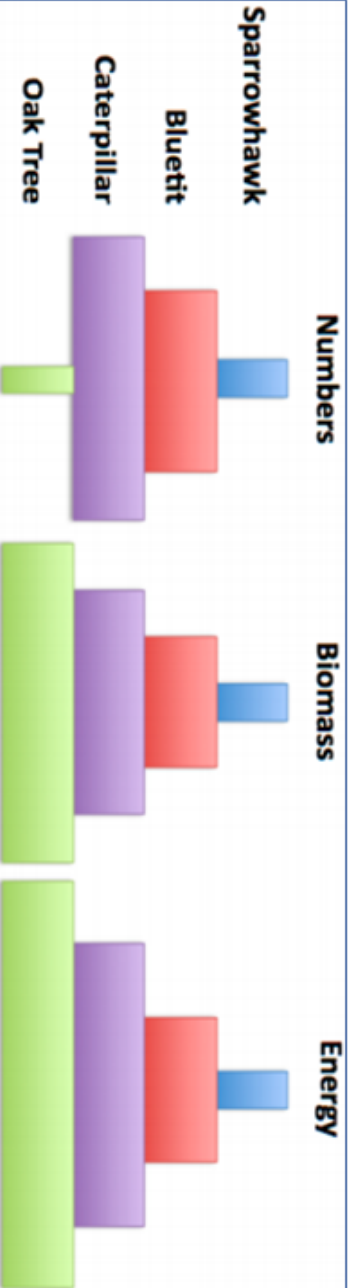
A simple food chain is:

algae → mosquito larvae → dragon fly larvae → perch

efficiency = $\frac{\text{biomass transferred to the next level}}{\text{biomass available at the previous level}} \times 100$

4.7.4.2 Pyramids of biomass

Show the relative mass of each trophic level, must be drawn to scale Biomass The total quantity or mass of organisms in a given area or volume



Key Terms

Meaning

Producers	Green plants - they make glucose during photosynthesis.
Primary consumers	Usually eat plant material - they are herbivores. For example rabbits, caterpillars, cows and sheep.
Secondary consumers	Usually eat animal material - they are carnivores. For example cats, dogs and lions.
Predators	Kill for food. They are either secondary or tertiary consumers.
Prey	The animals that predators feed on.
Scavengers	Feed on dead animals. For example, crows, vultures and hyenas are scavengers.
Decomposers	Feed on dead and decaying organisms, and on the undigested parts of plant and animal matter in faeces.

Organism

Biomass, dry mass (g)

Oak tree	100 000
Caterpillar	5000
Blue tit	30
Sparrow hawk	3

calculate

To calculate the % of the energy in the oak tree that is **passed to the sparrow hawk** here's what to do:
 $3 \div 100\ 000 = 0.00003$
 $0.0003 \times 100 = \underline{0.003\%}$

4.7.4.3 Transfer of biomass

The amount of energy (in the biomass of organisms) is **reduced** at each successive stage in a food chain because:

- All of prey organism is **not consumed** e.g. bones, teeth, hair
- Energy is '**lost**' as the organisms' **waste materials** (faeces and urine)
- Energy is transferred / lost / released during **respiration**
- Energy is transferred / lost as **movement** (kinetic energy)
- Energy is transferred / lost as **heat** (thermal energy)
- Energy is transferred / lost to the **surroundings**

Knowledge Organiser – 4.7.5 Food Production (Separate Biology)

- World's birth rate increased - Diets changing around world - Food transported - New pests and pathogens affect farming - Environmental change e.g. temp rise or rainfall/famine - Cost of agricultural inputs - Conflicts in the world	4.7.5.1 Factors affecting food security
--	---

We need a sustainable way of feeding the world's population

4.7.5.3.Sustainable fisheries do not reduce the overall number of fish, because the number of fish that are caught and killed does not ever exceed the birth of new fish.

- At one point we thought that we could remove as many fish as we wanted from the oceans without any consequence. During this period, we drastically **overfished** some of our oceans and seas and reduced some **populations** to critically low numbers.
- Some scientists think that as much as 85% of the world's fish populations have been overfished.
- Common examples are cod in the North Sea and sole in the Irish Sea and English Channel. Overfishing can cause a critical point in populations that means certain **species** cannot ever recover and will become **extinct**.

To address overfishing many countries eg NZ and Iceland are adopting a more sustainable strategy for fishing:

- Introduced fishing quotas limiting the amount of fish that can be caught and killed from specific species.
- Bigger gaps in nets to ensure juvenile fish can reach reproductive maturity and have offspring before being killed.

4.7.5.2 Farming Techniques: Advantages and disadvantages of intensive farming practices

Advantage	Disadvantage
Higher yields	Costly additives needed
More efficient use of food	Risk of antibiotic resistance
Quality control easier	Considered unethical by some people

Organic farming :- Many people object to intensive farming because it reduces biodiversity and increases pollution. More recently some farms have become **organic** to address this. Organic farmers do not use machines to the same extent as intensive farming. They do not apply **pesticides** to their crops and use natural fertilisers such as **compost** and **manure**. They rotate their crops to avoid monoculture

4.7.5.4 Role of biotechnology

- Producing **protein** from fungus is much more efficient than from meat from livestock.
- Only about 10% of the energy found in grass is transferred to the animals like cows that eat it. 1000 g of plant carbohydrate can produce up to 14 g of beef, 49 g of chicken or 136 g of mycoprotein.
- Additionally, fermenters can be used to produce protein in places where grass and livestock cannot grow.

The fungus is grown in large containers called **fermenters**. The conditions inside are maintained to promote maximum growth:

- The pH and temperature are maintained at the **optimum**
- The temperature is controlled by a water jacket
- Sterile oxygen is added to make sure that **aerobic respiration** occurs
- A food source like glucose syrup is added
- The mixture inside is stirred to make sure all the oxygen and nutrients are equally distributed



Quorn

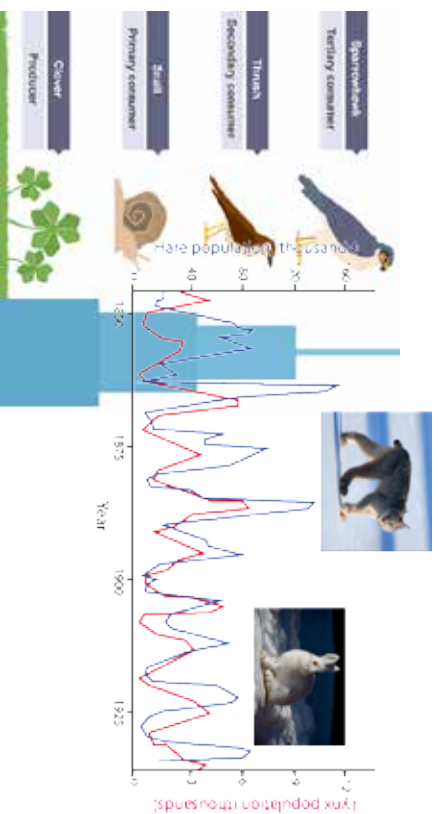
4.7.5.4 Role of biotechnology

Humans have used biotechnology for thousands of years in **agriculture** and used selective breeding to produce better foods and medicines. More recent examples of biotechnology include **cloning** and **genetic modification**. Biotechnology can help us meet the food demands of our ever increasing **population**.

Knowledge Organiser – 4.7.2 Organisation of an ecosystem

4.7.2.1 Levels of organisation

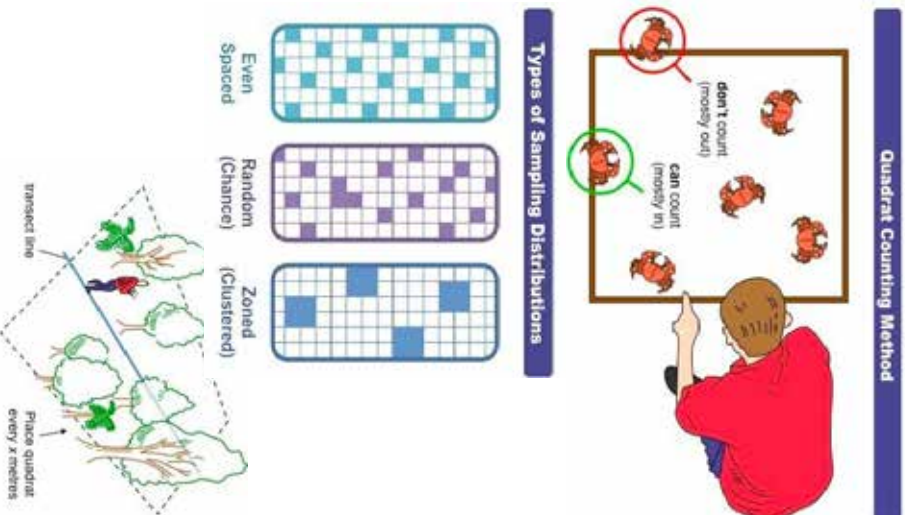
- **Photosynthetic organisms** are the producers of **biomass** for life on Earth.
- **Feeding relationships within a community can be represented by food chains.** All food chains begin with a producer which synthesises molecules. This is usually a green plant or alga which makes glucose by photosynthesis.
- **Producers** are eaten by **primary consumers**, which in turn may be eaten by **secondary consumers** and then **tertiary consumers**.
- Consumers that kill and eat other animals are **predators**, and those eaten are **prey**.
- **In a stable community the numbers of predators and prey rise and fall in cycles.**



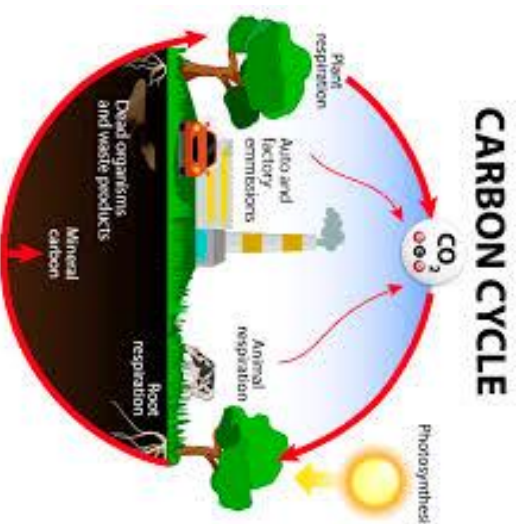
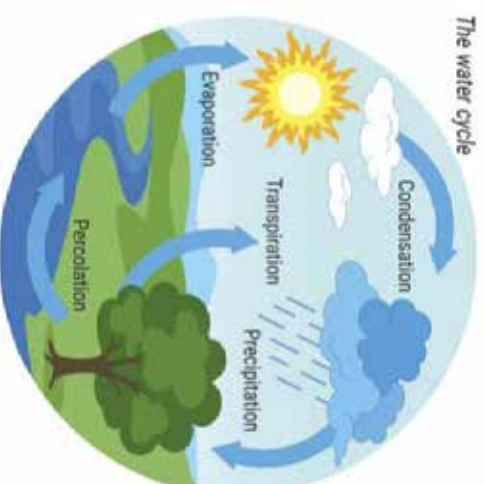
Definitions	
mean	The mean is calculated by adding all of the data and dividing by the number of items
Mode	The value that occurs most often.
median	The 'middle' value in the list of numbers
quadrat	A square frame of known area used for sampling the abundance and distribution of slow or non-moving organisms.
transect	A line created, for instance, with a tape measure, along which sampling occurs.
yield	The mass of product made in a chemical reaction. The percentage yield is a measure of the yield obtained compared to the maximum possible yield.

RPA: 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.



4.7.2.2 How materials are cycled



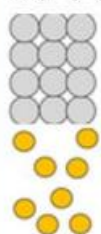
Knowledge Organiser – 5.1 Atomic structure & the periodic table

5.1.1.1

Atoms, elements & compounds

An **Atom** is the **smallest part of an element** that can exist.

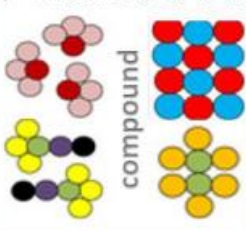
Made from only one type of atom



element

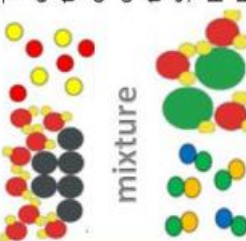


Two or more elements chemically bonded together.



compound

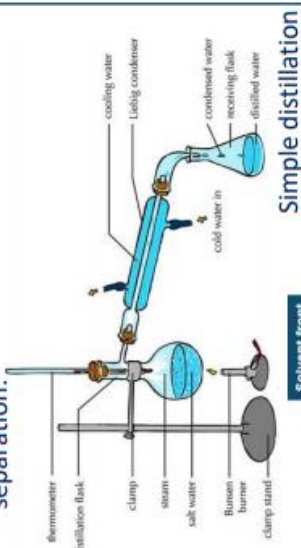
Two or more elements that are NOT chemically combined together.



mixture

5.1.1.2 Mixtures

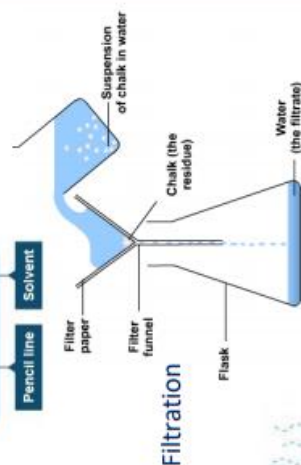
- Mixtures can be separated by physical processes such as **filtration**, **crystallisation**, **simple distillation**, **fractional distillation & chromatography**.
- These physical processes **do not involve chemical reactions and no new substances are made**.
- Examples of the specified processes of separation:



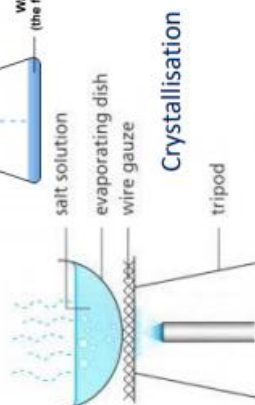
Simple distillation



Chromatography



Filtration

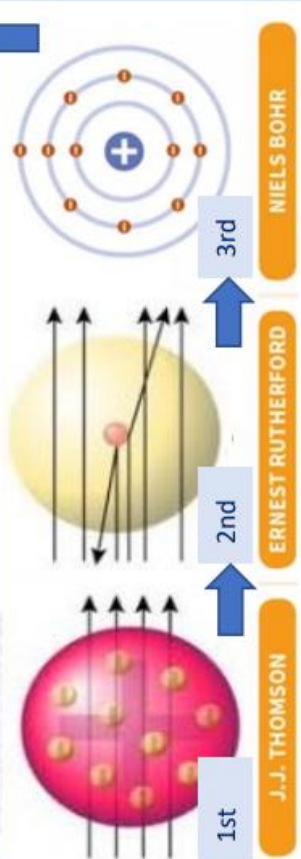
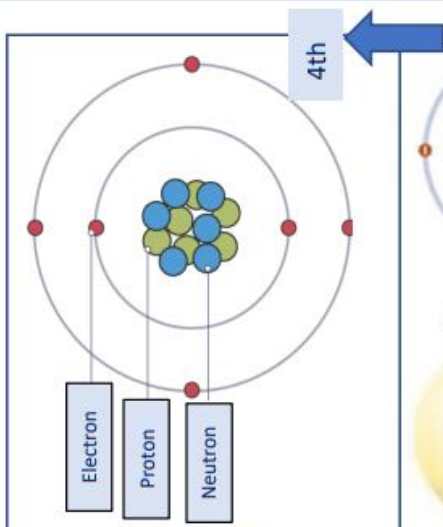


Crystallisation

5.1.1.3 The development of the model of the atom

The Nuclear Model

In 1932 James Chadwick found evidence for the existence of particles in the nucleus with mass but no charge. These particles are called **neutrons**. This atomic model is still used today.



J.J. THOMSON

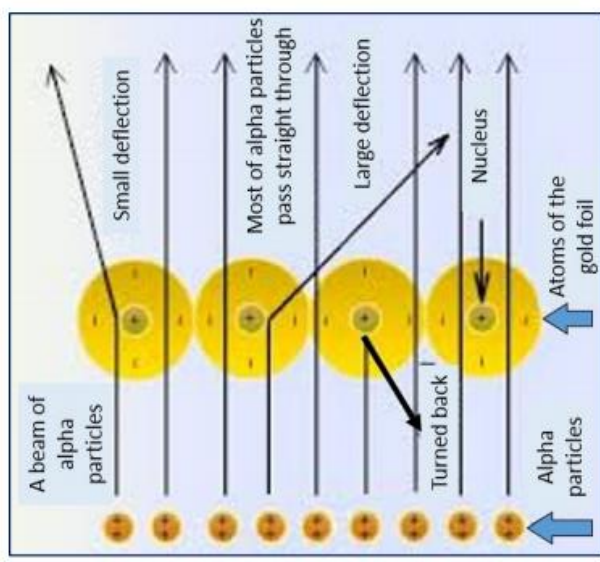
ERNEST RUTHERFORD

NIELS BOHR

- 1904 - electron discovered**, placed in a sphere of positive charge (the **plum pudding model**)
- 1911 - gold scattering experiment** discovered mass was concentrated in a central **positive nucleus** (the nuclear model)- further experiments led to discovery of **protons**
- 1913 - Suggested** electrons orbit the nucleus in **shells**. The shells are at certain distances from the nucleus.

Ernest Rutherford's Gold scattering experiment

- Positive alpha particles** fired at gold leaf
- Most passed straight through** suggesting the atom was mainly empty space
- Some deflected at angles** suggesting the presence of electrons
- Some bounced straight back** suggesting a positive nucleus repelled the alpha particles.



61

Chemistr

- Ch

ience

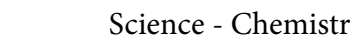


Sci

mist

ce - Che

Scie



Knowledge Organiser – 5.2 Structure & bonding

5.2.1.1 Chemical bonds

There are three types of strong chemical bonds: ionic, covalent and metallic.

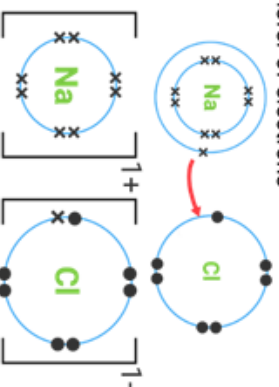
Ionic bonding: particles are oppositely charged ions. Ionic bonding occurs in compounds formed from metals combined with non-metals

Covalent bonding: the particles are atoms which share pairs of electrons. Covalent bonding occurs in most non-metallic elements and in compounds of non-metals

Metallic bonding: the particles are atoms which share delocalised electrons. Metallic bonding occurs in metallic elements and alloys.

5.2.1.2 Ionic Bonding

transfer of electrons



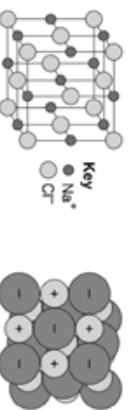
- Between a metal atom and a non-metal atom
- Metals lose electrons to form positive ions
- Non-metals gain electrons & form negative ions
- Electrons **transferred** (ions formed)
- Strong **electrostatic** forces
- Giant **lattice** structures
- High melting/boiling points
- If **molten** or in **solution** ions will conduct electricity

5.2.1.3 Ionic compounds

- An ionic compound is a **giant structure of ions**.
- Ionic compounds are held together by **strong electrostatic forces of attraction** between oppositely charged ions.
- These **forces act in all directions in the lattice** and

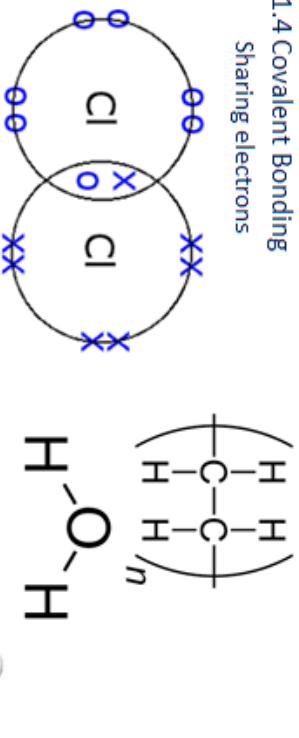
this is called **ionic bonding**.

Eg: structure of sodium chloride



5.2.1.4 Covalent Bonding

Sharing electrons



- Between two non-metal atoms
- Electrons are **shared**
- A **covalent** bond is one pair of shared electrons
- Covalent bonds are ALWAYS STRONG

5.2.2.1. The three states of matter

- **Freezing** take place at the **melting point**
- **Boiling and condensing** take place at the **boiling point**.
- **Particle theory** can help to explain melting, boiling, freezing and condensing.
- The **amount of energy needed to change state** from solid to liquid and from liquid to gas **depends on the strength of the forces** between the particles of the substance.
- The **stronger the forces between the particles the higher the melting point and boiling point of the substance**.

5.2.2.3 Properties of ionic compounds

- have **high melting points and high boiling points** because of the **large amounts of energy needed to break the many strong bonds**.
- When melted or dissolved in water, ionic compounds **conduct electricity** because the **ions are free to move and so charge can flow**.

5.2.2.4 Properties of Small molecules

- Usually **gases or liquids with low melting point & low boiling point**.
- **Weak intermolecular forces** (because they are small molecules) which are overcome when substance melts or boils.
- e.g. gases, water
- Do not conduct electricity as no overall electric charge.

5.2.2.5 Polymers

- **Long** molecules with atoms linked by **strong covalent bonds**.
- Solid at room temperature as **relatively strong intermolecular forces**.
- **Repeating** units e.g. plastics

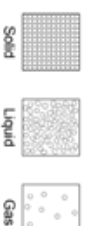
5.2.2.6 Giant covalent structures

- **Giant lattices**
- High melting point and boiling point
- Strong covalent bonds which must be overcome to melt or boil.
- e.g. silicon dioxide, diamond, graphite

5.2.2.2. State symbols

In chemical equations, the three states of matter are shown as (s), (l) and (g).

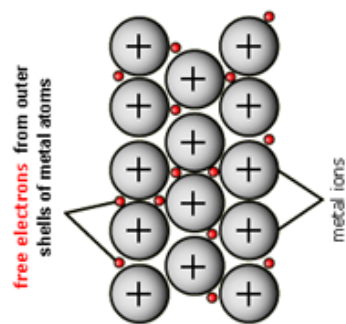
(aq) for aqueous solutions eg salt water or acid solutions.



Knowledge Organiser – 5.2 Structure & bonding

5.2.1.5 Metallic Bonding

- Bonding between atoms of a metal
- Delocalised** electrons (negative) & metal ions (positive)
- Shared delocalised electrons form strong metallic bonds
- Delocalised electrons **conduct** heat and electricity
- Pure metals are soft: layers of atoms can slide over each other



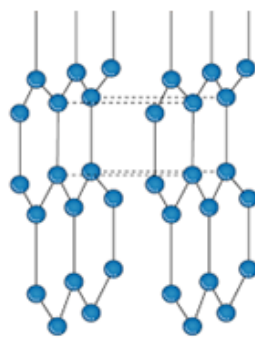
5.2.2.7 Properties of metals and alloys

- Metals have **giant structures of atoms** with **strong metallic bonding**. Therefore most metals have **high melting and boiling points**.
- In **pure metals**, atoms are **arranged in layers**, which allows metals to be **bent and shaped**. (malleable)
- Pure metals** are too soft for many uses and so are **mixed with other metals to make alloys which are harder**.
- In **alloys**, different atoms **disrupt** the layers
- Alloys are **harder** than pure metals

5.2.2.8 Metals as conductors

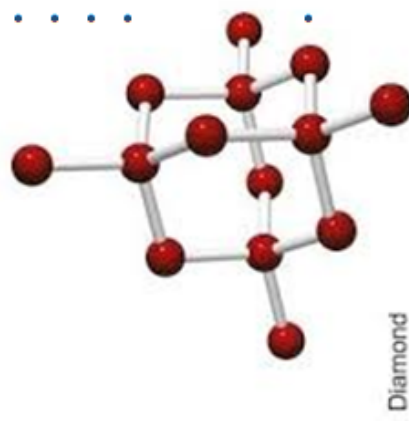
- Metals are **good conductors of electricity** because the **delocalised electrons** in the metal **carry electrical charge** through the metal.
- Metals are **good conductors of thermal energy** because **energy is transferred by the delocalised electrons**.

5.2.3 Structure & bonding of carbon



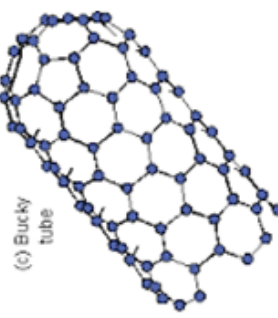
Graphite

- Giant lattice (in layers)
- Each C forms **3 bonds**
- Layers of hexagonal rings with no bonds between layers
- Weak forces** between layers to slide off easily (used as lubricant, graphite pencil)
- Giving **1 delocalised electron**
- Good conductor as has the delocalised electron can **move and carry the charge**.

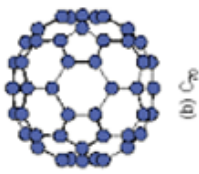


Diamond

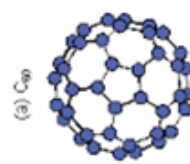
- Diamond: Giant lattice**
- Each C forms **4 bonds**
 - Strong** covalent bonds
 - Very high mpt/bpt
 - Does **not** conduct electricity as has **no delocalised electrons** to move and carry the charge.
 - Hard, used in **drill bits**



(c) Bucky tube



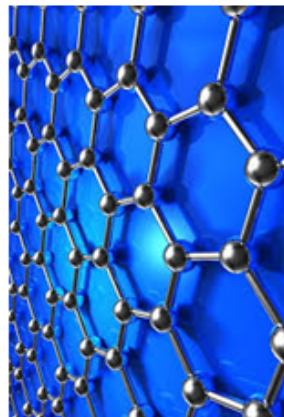
(b) C₆₀



(a) C₆₀

Graphene

- A **single layer** of graphite
- Useful in **electronics and composites**
- 3 covalent bonds leaving free electrons to conduct electricity



Fullerenes

- Hollow shapes
- Hexagonal rings, but may also contain rings of 5 or 7 Cs
- Buckminsterfullerene (C₆₀) spherical.
- Carbon nanotubes are **cylindrical**. Very useful for **nanotechnology, electronics**

Note: carbon is a non-metal so the bonds between carbon atoms must be **COVALENT**.

Knowledge Organiser – Structure & Bonding Separate Chemistry

Nanoscience

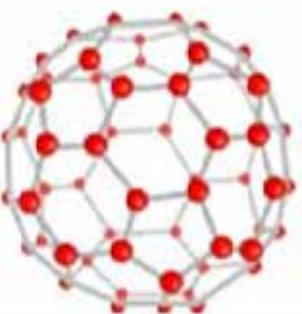
- Structures are 1 – 100nm in size
- A few hundred atoms big
- Smaller than fine particles (PM_{2.5})
- Coarse particles (PM₁₀) are also called "dust"
- As the side of a cube DECREASES by a factor of 10, the surface area to volume ratio INCREASES by a factor of 10
- Nanoparticles have a high SA to V ratio so they have different properties than the same material in bulk.
- Smaller quantities are needed as they're more effective.

Carbon Nanotubes are tiny carbon cylinders that are very long compared to their width. Nanotubes can conduct electricity as well as strengthening materials without adding much weight. The properties of carbon nanotubes make them useful in electronics and nanotechnology.



Name of Particle	Diameter
nanoparticle	1-100nm
fine particles (PM _{2.5})	100-2500nm
coarse particles (PM ₁₀)	2500-10000nm

Molecules of carbon that are shaped like hollow tubes or balls, arranged in hexagons of five or seven carbon atoms. They can be used to **deliver drugs into the body**.



Buckminsterfullerene has the formula C₆₀

As nanoparticles are so **small**, it makes it possible for them to be inhaled and enter the lungs. Once inside the body, nanoparticles may **initiate harmful reactions** and toxic substances could bind to them because of their large surface area to volume ratio. Nanoparticles have many applications. These include medicine, cosmetics, sun creams and deodorants. They can also be used as catalysts.

Modern nanoparticles are a relatively new phenomenon therefore it is difficult for scientists to truly determine the risks associated with them.

Knowledge Organiser – 5.3 Quantitative Chemistry (Separate Only)

4.3.3.1 Percentage Yield

The law of conservation of mass states that no atoms are gained or lost in a chemical reactions, BUT, it is not always possible to obtain calculated amounts of a product because:

- The reaction may be reversible so will not go to completion
- Some of the product may be lost when it is separated from the mixture e.g. when filtering
- Some of the reactants may react in ways different to the expected reaction.

4.3.3.1 Percentage Yield is calculated using the equation:

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

4.3.3.1 Example of % yield

1.8g copper sulphate crystals are made during a reaction. The theoretical yield for this reaction is 2.0g. Calculate the percentage yield of copper sulphate.

Answer:

$$\% \text{ yield} = \frac{1.8\text{g}}{2.0\text{g}} \times 100$$

$$\% \text{ yield of CuSO}_4 \text{ crystals} = 90\%$$

4.3.3.2 Reaction Pathways (HT)

There is often more than one way to make a substance. Reaction pathway describe the reactions that have taken place to form the desired product. Choosing a particular pathway is dependent upon a number of factors:

- Percentage yield
- Atom economy
- Rate of reaction
- Position of the equilibrium
- Usefulness/toxicity of any by-product

The raw materials needed for a particular reactions may affect its chosen pathway. E.g. crude oil is a **finite** resource, however plant sugars are **renewable** and can be replenished as long as other plants are replanted. Pathways involving renewable resources are **favourable**.

4.3.3.2 Atom Economy

The % atom economy can be calculated using the equation:

$$\frac{M_r \text{ of desired product}}{\text{Sum of } M_r \text{ of ALL reactants}} \times 100$$

The atom economy is a measure of the amount of starting materials (reactants) that end up as **useful products**. It is important for sustainable development and for economic reasons to use reactions with high atom economy. However, not all atoms end up as the desired product and may form other products. We call these **by-products**.

4.3.3.2 Atom Economy e.g: When glucose ($M_r = 180$) is fermented, ethanol ($M_r = 46$) is made.



Calculate the atom economy for this reaction if ethanol is what the manufacturer requires.

Answer:

$$\text{Atom economy} = \frac{2 \times 46}{180} \times 100 \quad \text{Atom economy} = 51.1\%$$

Example in Context: Ethanol can be made through fermentation of glucose or the hydration of ethene. Use the data in the table and your own knowledge to **evaluate** the 2 methods and **conclude** which is the best method for ethanol production?

Method	% yield	Atom economy (%)	Rate of reaction
Fermentation	15	51.1	low
hydration	95	100	high

REACTION PATHWAYS

FERMENTATION

- Lower yield
- Lower atom economy BUT CO₂ can be used to make fizzy drinks
- Lower rate of reaction
- Glucose is from plants → Renewable

HYDRATION

- Favourable to try to get 75% yield
- 100% Atom Economy
- Fast rate of reaction
- Ethene is from crude oil → non-renewable

So you wish

Knowledge Organiser – 5.3 Quantitative Chemistry (Separate Only)

4.3.5 Volume of gases (HT)

The volume of one mole of ANY gas at room temperature and pressure (20°C and 1 atmospheric pressure) is **24dm³** !!

Conversion: 24dm³ → x 1000 → 24 000cm³

To calculate a known volume of gas:

Volume = amount in moles x molar volume

E.g. Determine the volume of 0.55 mol of carbon monoxide (CO) at room temp and pressure.

Answer:

$$\begin{aligned}\text{Volume} &= \text{amount in mol} \times \text{molar volume} \\ &= 0.55 \text{ mol} \times 24 \text{ dm}^3 \\ &= \underline{13.2 \text{ dm}^3}\end{aligned}$$

4.3.5 Rearranging the equation:

Number of moles of gas = $\frac{\text{volume of gas (dm}^3\text{)}}{24 \text{ (dm}^3\text{)}}$

OR = $\frac{\text{volume of gas (cm}^3\text{)}}{24\,000 \text{ cm}^3}$

- How many **moles** of gas are found in 48 dm³ of CO₂(g)?
Moles = 48dm³ / 24 dm³ = 2 moles
- Calculate the **volume** of gas (in cm³) in 1.5 moles of N₂O₄
Volume = 1.5 mol x 24 000 cm³ = 36000cm³

E.g. 1) Determine the amount of hydrogen gas that occupies 198cm³ at room temp and pressure.

Number of moles of gas = $\frac{\text{volume of gas (dm}^3\text{)}}{\text{molar volume (dm}^3\text{)}}$

$$\begin{aligned}\text{Amount in mol} &= \frac{198 \text{ cm}^3}{24\,000 \text{ cm}^3} \\ &= \underline{0.0083 \text{ mol}}\end{aligned}$$

Calculating a volume from a mass (HT)

When 3.5g of sodium reacts with water it produces sodium hydroxide and hydrogen gas.



- a) Determine the molar amount of sodium (A_r = 23)

$$\begin{aligned}\text{Amount in mol} &= \frac{\text{mass (g)}}{\text{atomic mass}} \\ &= 3.5\text{g} / 23 \\ &= \underline{0.15 \text{ mol}} \text{ of sodium}\end{aligned}$$

- b) Determine the molar amount of hydrogen.

According to the equation, the molar ratio of sodium : hydrogen is **2 : 1**
Therefore, 0.15 mol of Na produces **0.075 mol** of hydrogen gas.

- c) Determine the volume of hydrogen gas.

$$\begin{aligned}\text{volume} &= \text{amount in mol} \times \text{molar volume} \\ &= 0.075 \text{ mol} \times 24 \text{ dm}^3 \\ &= \underline{1.8 \text{ dm}^3}\end{aligned}$$

Molar ratios: H₂ + Cl₂ → 2HCl

When hydrogen reacts with chlorine, hydrogen chloride is produced. In terms of the molar ratio, 10cm³ of hydrogen would react with 10 cm³ chlorine:- a molar ratio of 1:1.
The molar ratio between hydrogen and the hydrogen chloride is, however, 1 : 2.
So 10cm³ of hydrogen would make 20cm³ of hydrogen chloride.

Calculating a mass from a volume (HT)

Sodium reacts with chlorine to produce sodium chloride.



Determine the mass of sodium chloride (M_r 58.5) That can be produced from 685cm³ of chlorine.

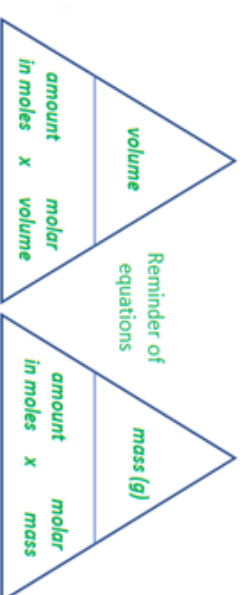
Amount of chlorine in 685cm³ is:

$$\begin{aligned}\text{Number of moles of gas} &= \frac{\text{volume of gas (cm}^3\text{)}}{24\,000 \text{ cm}^3} \\ \text{mol of chlorine} &= \frac{685 \text{ cm}^3}{24\,000 \text{ cm}^3} \\ &= \underline{0.029 \text{ mol}}.\end{aligned}$$

Mole ratio of chlorine : sodium is 1 : 2
Therefore 0.029 mol of chlorine would produce (0.029 mol x 2) = **0.058 mol** of sodium chloride.

$$\begin{aligned}\text{Mass of NaCl} &= \text{moles of NaCl} \times \text{Mr of NaCl} \\ &= 0.058 \text{ mol} \times 58.5 \\ &= \underline{3.393\text{g}}\end{aligned}$$

Answer: 3.393g of sodium chloride will be made from 686cm³ of chlorine gas.



Knowledge Organiser – 5.3 Quantitative Chemistry

5.3.1.1 Conservation of mass and balanced chemical equations

Reacting masses

In all chemical reactions the **total mass of reactants used is equal to the**

total mass of the products made: Reactants → Products

5.3.1.2 Relative Formula Mass (M_r)

Relative atomic mass

Different atoms have different masses.

Atoms have such a small mass it is more convenient to know their masses compared to each other.

Carbon is taken as the standard atom and has a relative atomic mass (A_r) of 12.

Relative formula mass

To find the relative formula mass (M_r) of a compound, you just add together the A_r values for all the atoms in its formula.

Example 1:

Find the M_r of carbon monoxide (CO).

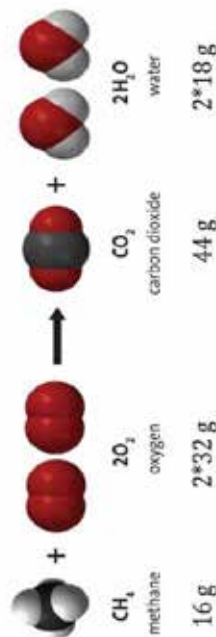
The A_r of carbon is 12 and the A_r of oxygen is 16
So the M_r of carbon monoxide is $12 + 16 = 28$.

Example 2:

Find the M_r of carbon dioxide (CO₂)

The A_r of carbon is 12 and the A_r of oxygen is 16, but there are 2 atoms of oxygen in the formula.

So the M_r of Carbon dioxide is $12 + 16 + 16 = 44$



Mass of reactants (80g)

Mass of products (80g)

5.3.1.3 Mass change when a reactant or product is a gas

Apparent loss of gain in mass
when a **gas** is a product or reactant and is **gained** or **released** to the atmosphere in an **non-enclosed system**.

5.3.1.4 Chemical Measurements

Measurements have uncertainty.

You need to be able to look at the range of measurements about the mean (average) as a measure of uncertainty.

5.3.2.5 Limiting reactants (HT only)

- In a chemical reaction involving two reactants, it is common to use an excess of one of the reactants to ensure that all of the other reactant is used.
- The **reactant that is completely used up** is called the **limiting reactant** because it limits the amount of products.

5.3.2 Amounts of substances in relation to masses of pure substances (HT only)

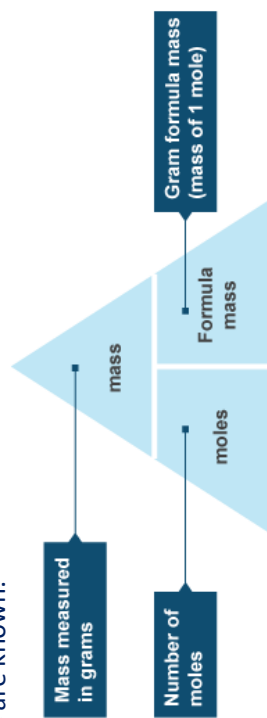
The Mole:

- The unit for amount of substance is called the **mole**, shown as **mol**. One mole of atoms, *ions* or *molecules* is around 6×10^{23} (6 followed by 23 zeroes). This is called Avogadro constant.
- This is the same number as the number of carbon atoms in 12 g of carbon.

This equation shows how **molar mass**, **number of moles** and **mass** are related:

$$\text{number of moles} = \text{mass} \div \text{molar mass}$$

This can be rearranged to find the mass if the number of moles and molar mass are known, or to find the molar mass if the mass and number of moles are known.



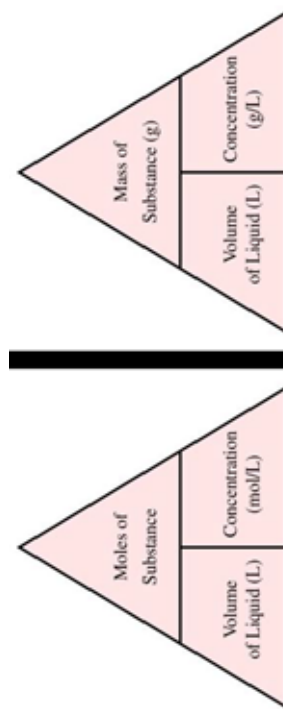
Finding the number of moles

Example

What is the number of moles of carbon dioxide molecules in 22 g of CO₂?
 A_r of C = 12, A_r of O = 16

The relative formula mass M_r of carbon dioxide = $12 + 16 + 16 = 44$

This means that the molar mass of carbon dioxide = 44 g/mol
number of moles = $22 \div 44 = 0.5$ mol



Knowledge Organiser – 5.3 Quantitative Chemistry

Spec	Question	Answer
5.3.1.1	What is the law of conservation of mass?	The law of conservation of mass states that no atoms are lost or made during a chemical reaction so the mass of the products equals the mass of the reactants.
5.3.1.1	What does the conservation of mass mean in terms of chemical reactions?	This means that chemical reactions can be represented by symbol equations which are balanced in terms of the numbers of atoms of each element involved on both sides of the equation.
5.3.1.2	What is the relative formula mass (Mr) of a compound?	The relative formula mass (Mr) of a compound is the sum of the relative atomic masses of the atoms in the numbers shown in the formula
5.3.1.2	What happens to the sum of the relative formula masses of the reactants in the quantities shown equals the sum of the relative formula masses of the products in the quantities shown.	The sum of the relative formula masses of the reactants in the quantities shown equals the sum of the relative formula masses of the products in the quantities shown.
5.3.1.3	How can we explain a change in mass?	This can usually be explained because a reactant or product is a gas and its mass has not been taken into account.
5.3.1.3	Give 2 examples of reactions where there appears to be a change in mass	• when a metal reacts with oxygen the mass of the oxide produced is greater than the mass of the metal • thermal decompositions of metal carbonates carbon dioxide is produced and escapes into the atmosphere leaving the metal oxide as the only solid product.
5.3.1.4	When there is uncertainty about a result, what 2 things should you do?	• represent the distribution of results and make estimations of uncertainty • use the range of a set of measurements about the mean as a measure of uncertainty.
5.3.2.1	What are chemical amounts measured in and what is its unit?	Chemical amounts are measured in moles. The symbol for the unit mole is mol.

Spec	Question	Answer
5.3.2.1 HT	What is the mass of one mole equal to?	The mass of one mole of a substance in grams is numerically equal to its relative formula mass. One mole of a substance contains the same number of the stated particles, atoms, molecules or ions as one mole of any other substance.
5.3.2.1 HT	What is Avogadro's number, including its value?	The number of atoms, molecules or ions in a mole of a given substance is the Avogadro constant. The value of the Avogadro constant is 6.02×10^{23} per mole
5.3.2.2 HT	How many moles of reactants and products in: $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$	one mole of magnesium reacts with two moles of hydrochloric acid to produce one mole of magnesium chloride and one mole of hydrogen gas.
5.3.2.3 HT	How are the balancing numbers in a symbol equation calculated?	The balancing numbers in a symbol equation can be calculated from the masses of reactants and products by converting the masses in grams to amounts in moles and converting the numbers of moles to simple whole number ratios.
5.3.2.4 HT	What is a limiting reactant and how does the limiting reactant affect the amount of products produced?	The reactant that is completely used up is called the limiting reactant because it limits the amount of products. The effect of a limiting quantity of a reactant on the amount of products it is possible to obtain in terms of amounts in moles or masses in grams.
5.3.2.5 HT	How is the concentration of a solution measured?	The concentration of a solution can be measured in mass per given volume of solution, eg grams per dm ³ (g/dm ³).
5.3.3.1 HT	Why is it not always possible to obtain the calculated amount of product?	• the reaction may not go to completion because it is reversible • some of the product may be lost when it is separated • some of the reactants may react in ways different to the expected reaction.
5.3.3.1 HT	How do you calculate percentage yield?	% Yield = $\frac{\text{Mass of product actually made}}{\text{Maximum theoretical mass of product}} \times 100$
5.3.3.2 HT	How is percentage atom economy calculated?	The percentage atom economy of a reaction is calculated using the balanced equation for the reaction as follows: = $\frac{\text{Relative formula mass of desired product from equation}}{\text{Sum of relative formula masses of all reactants from equation}} \times 100$
5.3.4 HT	What information do you need to calculate the concentration of a solution?	If the volumes of two solutions that react completely are known and the concentration of one solution is known, the concentration of the other solution can be calculated.
5.3.5 HT	What is the volume of one mole of any gas at room temp and pressure?	. The volume of one mole of any gas at room temperature and pressure (20oC and 1 atmosphere pressure) is 24 dm ³

Knowledge Organiser – 5.4 Chemical Changes (Separate Chemistry)

Titration Method - RPA

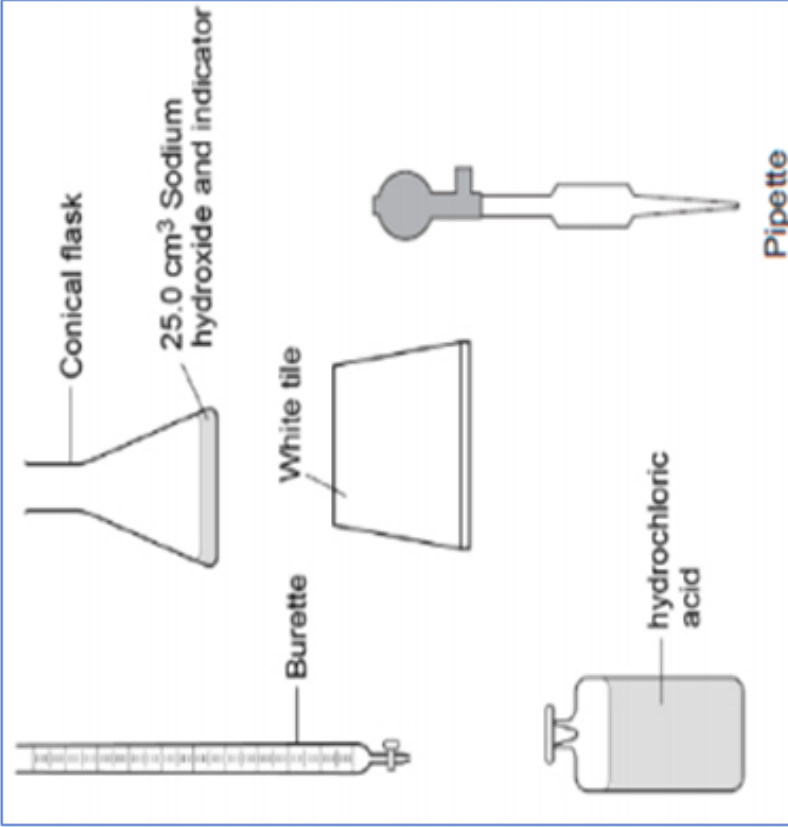
A Volumetric pipette is used to measure out a fixed volume of solution
A burette is used to measure the volume of the solution added

- Wash a **volumetric pipette** with **distilled water** followed by some of the **alkali**
- Using the **pipette**, measure **25cm³ alkali** (eg **NaOH**) into a conical flask
- Add a few drops of indicator (eg **phenolphthalein**) to the solution in the conical flask and swirl. The mixture should turn **pink**.
- Place a **white tile** under the flask
- Rinse a **burette** with **distilled water** followed by some of the **acid**, allowing some of the acid to pass **through the tap** (filling the **jet**)
- Fill the burette up to the mark using the **acid** (eg **hydrochloric acid**) & place **over the conical flask**
- Record **initial reading** on the **burette**
- Open tap to **slowly** release acid into the conical flask whilst **swirling**
- Keep on repeating this until the indicator permanently changes colour (**end point**) (eg phenolphthalein goes **colourless**)
- Record **final volume** reading on the **burette** by reading the bottom of the **meniscus**.
- Work out the volume of acid (**titre**) that was run into the flask
- Repeat the whole process at **least three times** until you get **concordant** titres (within **0.1cm³** of each other)
- Calculate the **mean** titre
- Use results to calculate **concentration of the alkali in mol/dm³**

The pipette allows the same volume of acid to be added each time, helping to make the results repeatable.

- Make sure the burette is vertical.
- Take the readings from the bottom of the meniscus.
- Near to the end-point, rinse the inside of the flask with distilled water.
- Add the acid drop by drop.

Accuracy



Knowledge Organiser – 5.4 Chemical Changes (Separate Chemistry)

Using the results from a titration experiment, it is possible to calculate the concentration of a solution or the volume of solution needed to neutralise the acid or alkali

Titration calculations RPA – Past paper question 1:

A student titrated hydrochloric acid with **25cm³** of **0.10 mol/dm³** sodium hydroxide solution. The equation for the titration is:



	Titre 1	Titre 2	Titre 3	Titre 4	Titre 5
Volume HCl cm ³	13.60	12.10	11.10	12.15	12.15

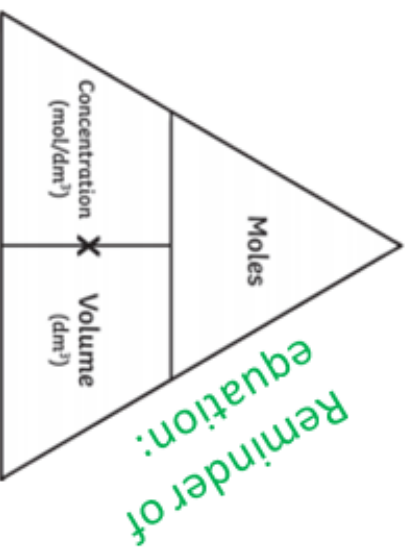
Use concordant results in the table to calculate:

- The **mean titre**
- Concentration** of the hydrochloric acid solution

Answer:

- Concordant results are those within 0.10 cm³ of each other.

$$\text{Mean titre} = \frac{12.10 + 12.15 + 12.15}{3} = \underline{12.13}$$



Draw a table like this and fill it in with the information you know from the question. Change cm³ to dm³.

	ACID	ALKALI
No. of moles		
Conc. (mol/dm ³)		
volume (dm³)		

Answer

b)	ACID	ALKALI
No. of moles	Step 2	Step 1
Conc. (mol/dm ³)	Step 3	0.1
volume (dm ³)	Mean= 0.01213	0.025

Step 1 - work out moles of alkali:

$$\text{Moles} = \text{conc} \times \text{volume} = 0.1 \times 0.025 = \underline{0.0025 \text{ mol}}$$

Step 2 – work out moles of other reactant:

$$\text{Mole ratio of 1NaOH to 1HCl so same number} = \underline{0.0025 \text{ mol}}$$

Step 3- work out con of other reactant:

$$\text{Conc} = \frac{\text{moles}}{\text{volume}} = \frac{0.0025 \text{ mol}}{0.01213 \text{ dm}^3} = \underline{0.206 \text{ mol/dm}^3}$$

b)	ACID	ALKALI
No. of moles	0.0025 mol	0.0025 mol
Conc. (mol/dm ³)	<u>0.206</u>	0.1
volume (dm ³)	Mean= 0.01213	0.025

Knowledge Organiser – 5.4 Chemical Changes (Separate Chemistry)

Titration calculations RPA – Past paper question 2:

A student titrated **20cm³** of **1.0 mol/dm³** sulfuric acid with **25cm³** sodium hydroxide solution. The equation for the titration is:

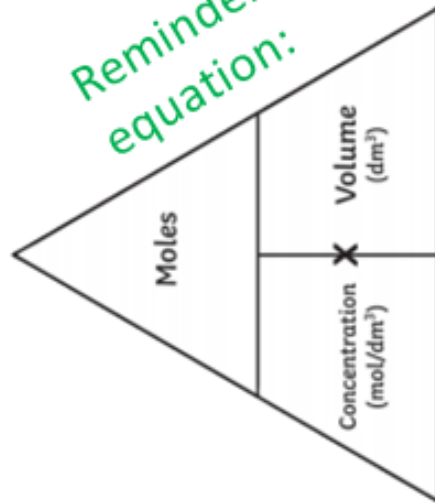


What was the concentration of **sodium hydroxide**?

Draw a table like this and fill it in with the information you know from the question. Change cm³ to dm³.

	ACID	ALKALI
No. of moles		
Conc. (mol/dm ³)	1.0	
volume (dm ³)	20cm ³	25cm ³

Reminder of equation:



Answer

	ACID	ALKALI
No. of moles	Step 1	Step 2
Conc. (mol/dm ³)	1.0	Step 3
volume (dm ³)	0.020	0.025

Step 1- work out moles of acid:

$$\text{Moles} = \text{conc} \times \text{volume} = 1.0 \times 0.020 = 0.02 \text{ mol}$$

Step 2 – work out moles of other reactant:

Mole ratio of 1acid : 2 alkali so = 0.04 mol

Step 3- work out con of other reactant:

$$\text{Conc} = \frac{\text{moles}}{\text{volume}} = \frac{0.04 \text{ mol}}{0.025 \text{ dm}^3} = 1.6 \text{ mol/dm}^3$$

	ACID	ALKALI
No. of moles	0.02 mol	0.04 mol
Conc. (mol/dm ³)	1.0	1.6
volume (dm ³)	0.020	0.025

Knowledge Organiser – 5.4 Chemical Changes

5.4.1 Reactivity of metals

Metals react with oxygen to produce metal oxides.

The reactions are **oxidation reactions** because the metals gain oxygen.

5.4.1.2 The reactivity series

- When metals react with other substances the metal atoms form positive ions.
- The reactivity of a metal is related to its tendency to form positive ions.
- Metals can be arranged in order of their reactivity in a reactivity series.
- The metals potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper can be put in order of their reactivity from their reactions with water and dilute acids.
- A more reactive metal can displace a less reactive metal from a compound.

potassium	most reactive	K
sodium		Na
calcium		Ca
magnesium		Mg
aluminium		Al
carbon		C
zinc		Zn
iron		Fe
tin		Sn
lead		Pb
hydrogen		H
copper		Cu
silver		Ag
gold		Au
platinum	least reactive	Pt

5.4.1.3 Extraction of metals and reduction

- Unreactive** metals are found as pure elements (eg gold) but most are compounds.
- Those below carbon can be **extracted** from oxides using carbon.
- Those above carbon need to be extracted using **electrolysis**.

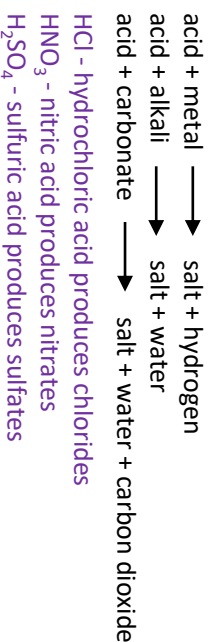
5.4.1.4 Oxidation and reduction in terms of electrons (HT only)



- Oxidation** involves gain of oxygen
- Reduction** involves loss of oxygen
- Oxidation is Loss of electrons
- Reduction is Gain of electrons

5.4.2.1 Reactions of acids with metals

Acids react with some metals to produce salts and hydrogen.

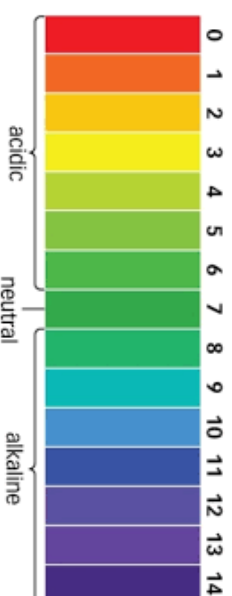


(HT only)

- explain in terms of gain or loss of electrons, these are redox reactions
- identify which species are oxidised and which are reduced in given chemical equations.

5.4.2.2 Neutralisation of acids and salt production

- Acids are neutralised by alkalis (eg soluble metal hydroxides) and bases (eg insoluble metal hydroxides and metal oxides)



5.4.2.4. The pH scale and neutralisation

- Acids produce hydrogen ions (H^+)** in aqueous solutions.
- Aqueous solutions of alkalis contain **hydroxide ions (OH^-)**.
- The **pH scale**, from 0 to 14, is a measure of the **acidity** or **alkalinity** of a solution, and can be measured using **universal indicator** or a **pH probe**.
- A solution with pH 7 is neutral.
- In **neutralisation reactions** between an acid and an alkali, **hydrogen ions react with hydroxide ions to produce water**.

HIGHER TIER

Strong acids (HCl , HNO_3 , H_2SO_4) fully ionise

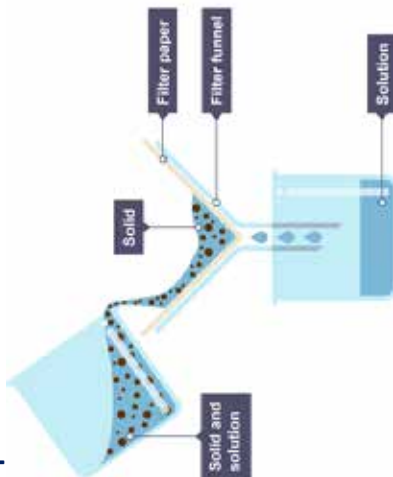
Weak acids (ethanoic, citric, carbonic) partially ionise

Knowledge Organiser – 5.4 Chemical Changes

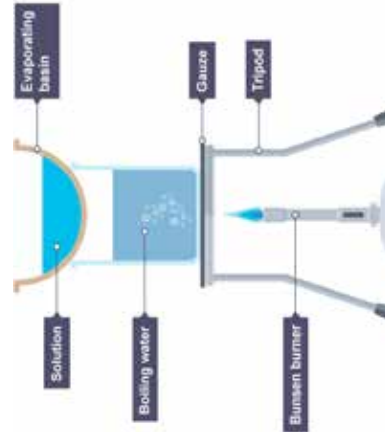
5.4.2.3 Soluble salts

- Soluble salts can be made from acids by reacting them with solid insoluble substances, such as metals, metal oxides, hydroxides or carbonates.
- The solid is added to the acid until no more reacts and the excess solid is filtered off to produce a solution of the salt.
- Salt solutions can be crystallised to produce solid salts.

RPA Preparation of a soluble salt



- Add excess solid to acid
- React
- Filter off unreacted solid



- Warm over water bath then leave to evaporate
- Allow to crystallise. Dry the pure crystals

5.4.3. Electrolysis

5.4.3.1 The process of electrolysis

- Ionic compounds can be electrolysed when liquid or molten, as the ions are then free to move
- An electric current is passed through the electrolyte
- Positive ions move to the negative electrode (cathode)
- Negative ions move to the positive electrode (anode)
- Aluminium is extracted by electrolysis from a mixture of aluminium oxide and cryolite

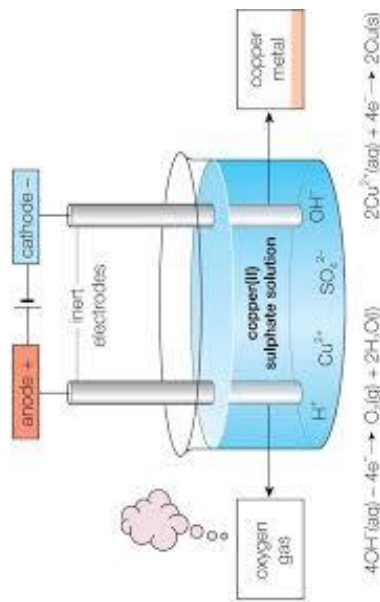
5.4.3.2 Electrolysis of molten ionic compounds

- When a simple ionic compound (eg lead bromide) is electrolysed in the molten state using inert electrodes
- the metal (lead) is produced at the cathode
- the non-metal (bromine) is produced at the anode.

5.4.3.3 Using electrolysis to extract metals

- Metals** can be **extracted** from molten compounds using **electrolysis**.
- Electrolysis is used **if the metal is too reactive to be extracted by reduction** with carbon or if the metal reacts with carbon.
- Large amounts of energy** are used in the extraction process to melt the compounds and to produce the electrical current.
- Aluminium** is manufactured by the **electrolysis of a molten mixture of aluminium oxide and cryolite using carbon** as the **positive electrode (anode)**.

RPA Electrolysis of aqueous solution



5.4.3.4. Electrolysis of aqueous solutions

- The ions discharged when an aqueous solution is electrolysed using inert electrodes depend on the relative reactivity of the elements involved.
- At the negative electrode (cathode), hydrogen is produced if the metal is more reactive than hydrogen.
- At the positive electrode (anode), oxygen is produced unless the solution contains halide ions when the halogen is produced.
- This happens because in the aqueous solution water molecules break down producing hydrogen ions and hydroxide ions that are discharged.

5.4.3.5 Representation of reactions at electrodes as half equations (HT only)

During **electrolysis**, at the **cathode** (negative electrode), **positively charged ions gain electrons**. ie **reductions reactions**
At the **anode** (positive electrode), **negatively charged ions lose electrons**. ie **oxidations**. Reactions at electrodes can be represented by half equations, for example:

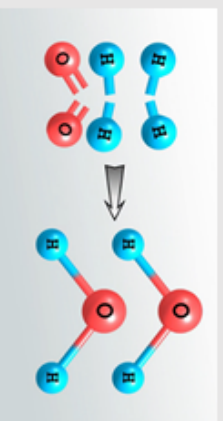


Knowledge Organiser – 5.5 Energy Changes (separate chemistry)

5.5.1.3 Energy change of reactions (HT only)

During a chemical reaction:

- **Energy must be put in to break bonds** in the reactants.
- **Energy is given out** when **bonds in the products are formed**.



- If **overall energy change is negative** = **exothermic** reaction.
- If **overall energy change is positive** = **endothermic** reaction.

In **exothermic** reactions, the **energy released from forming new bonds** is **greater** than the energy needed to break existing bonds. In **endothermic** reactions, the **energy needed to break existing bonds** is **greater** than the energy released from forming new bonds.

The **difference between the sum of the energy needed to break bonds** in the reactants and the **sum of the energy released when bonds in the products are formed** is the **overall energy change of the reaction**.

Example:

Bond	Average bond energy (kJ mol ⁻¹)
H — H	436
O — H	463
O = O	498

Bonds broken:

- 2 x H-H = 2 x 436 = 872 kJ/mol
- O=O = 498 kJ/mol
- Total = 872 + 498 = 1370 kJ/mol

Bonds formed:

- 4 x H-O = 4 x 463 = 1852 kJ/mol
- Total = 1852 kJ/mol

- **Exothermic** energy change is **negative**
- **Endothermic** energy change is **positive**.

Total energy change = reactants - products:

$$1370 \text{ kJ/mol} - 1852 \text{ kJ/mol} = -482 \text{ kJ/mol}$$

4.5.2.1 Cells and Batteries

Chemical cells use chemical reactions to transfer energy by **electricity**.

The **voltage** of a cell depends upon a number of factors, including what the **electrodes** are made from, and the substance used as the **electrolyte**.

- ☐ In non-rechargeable cells, eg alkaline cells, a voltage is produced until one of the reactants is used up. When this happens, we say the battery 'goes flat'.
- ☐ In rechargeable cells and batteries, like the one used to power your mobile phone, the chemical reactions can be reversed when an external circuit is supplied.

- A simple cell can be made by connecting two different metals in contact with an electrolyte.
- A number of cells can be connected in series to make a battery, which has a higher voltage than a single cell.
- If we connect different combinations of metals to make a cell, we find that the voltage changes.

What affects the voltage of a cell?

Here is a simple reactivity series:



4.5.2.2 Fuel cells

Fuel cells work in a different way than chemical cells. Fuel cells produce a **voltage** continuously, as long as they are supplied with:

- ✓ a constant supply of a **suitable fuel**
- ✓ oxygen, eg from the air

The fuel is **oxidised** electrochemically, rather than being burned, so the reaction takes place at a lower temperature than if it was to be burned. Energy is released as electrical energy, not **thermal energy** (heat).

Hydrogen-oxygen fuel cells:

Hydrogen-oxygen fuel cells are an alternative to rechargeable cells and batteries. In a hydrogen-oxygen fuel cell, hydrogen and oxygen are used to produce a voltage. Water is the only product. The overall reaction in a hydrogen-oxygen fuel cell is:



4.5.2.2 Electrode half equations (HT)

At the negative electrode:



At the positive electrode:



When you add these two half equations together, you get the following overall equation:



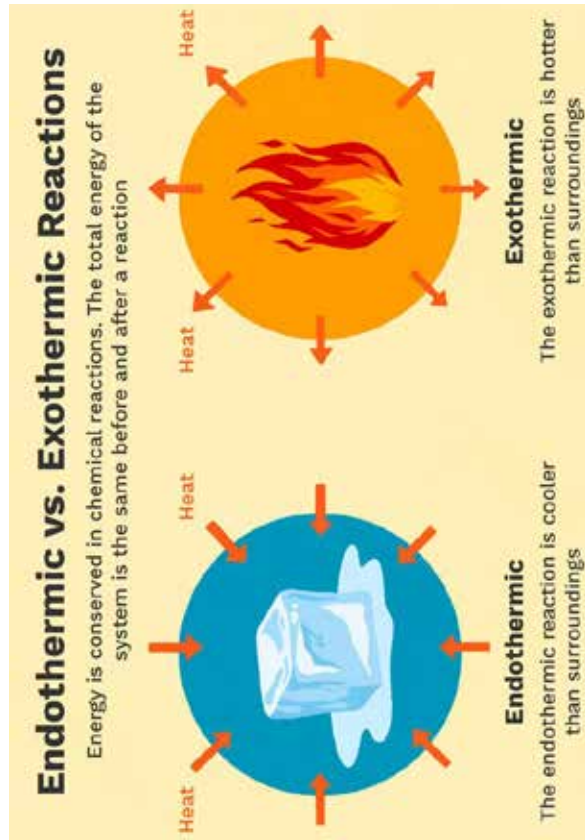
The hydroxide ions, electrons and two H₂O molecules will now cancel because they are on both sides, leaving the overall equation: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

Knowledge Organiser – 5.5 Energy Changes

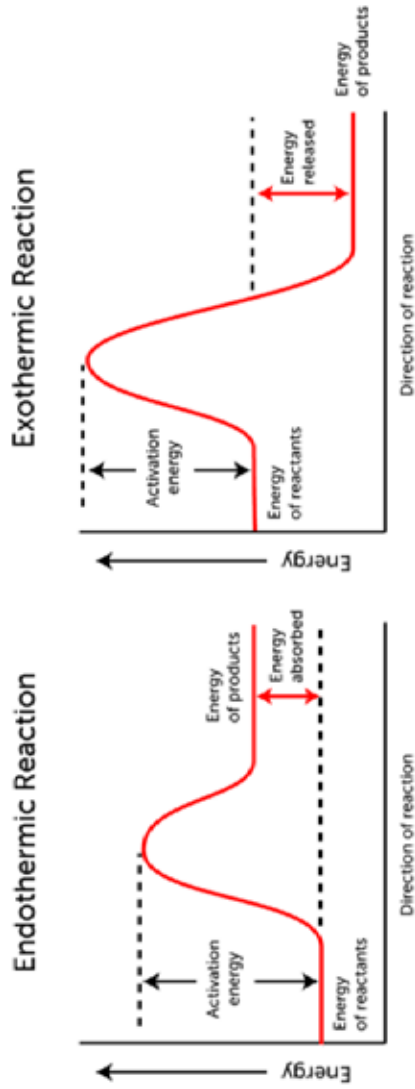
5.5.1 Exothermic and endothermic reactions

5.5.1.1 Energy transfer during Exothermic and endothermic reactions

- **Energy is conserved** in chemical reactions.
- The amount of energy in the universe at the end of a chemical reaction is the same as before the reaction takes place.
- If a **reaction transfers energy to the surroundings** the **product** molecules must have **less energy than the reactants, by the amount transferred**.
- **Exothermic reactions give out energy to the surroundings.**
Exo = exit.
 - Examples: combustion, neutralisation, hand warmers.
- **Endothermic reactions take in energy from the surroundings.**
Endo = enter.
 - Examples: thermal decomposition, reaction of citric acid and sodium hydrogencarbonate and sports injury packs.

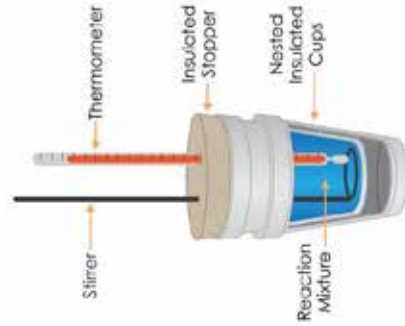


5.5.1.2 Reaction Profiles



- In an **endothermic** reaction profile the **products finish higher in energy** than the reactants.
- In an **exothermic** reaction profile the **products finish lower in energy** than the reactants.
- **Activation energy** is the **minimum** energy required for a reaction to happen when particles collide.
- The **overall energy change** is the difference between the relative energy of the reactants and the products.

RPA Investigate the variables that affect temperature in reacting solutions



The variables you could change are:

- Type of reactant (metal, carbonate, alkali)
- Type of acid used.
- Concentration of acid.
- Size of reactant pieces (if solid).
- Concentration of alkali.

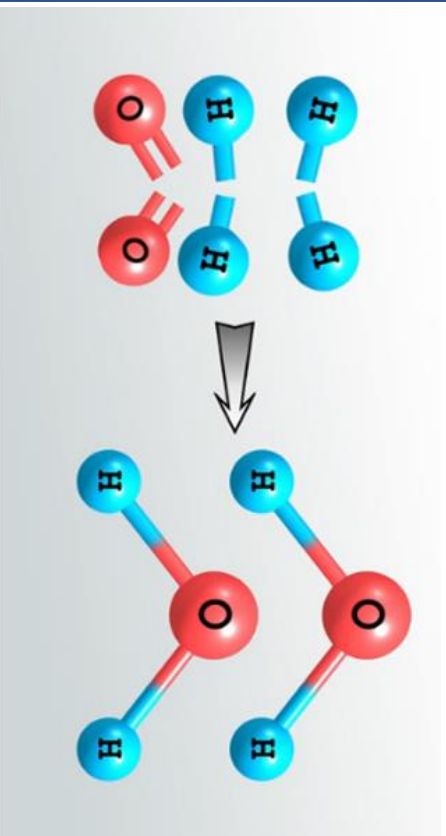
If one of these variables is changing, then all others stay the same.

Knowledge Organiser – 5.5 Energy Changes

5.5.1.3 Energy change of reactions (HT only)

During a chemical reaction:

- **Energy must be put in to break bonds in the reactants.**
- **Energy is given out when bonds in the products are formed.**



- If overall energy change is negative = exothermic reaction.
- If overall energy change is positive = endothermic reaction.

- In exothermic reactions, the energy released from forming new bonds is greater than the energy needed to break existing bonds.
- In endothermic reactions, the energy needed to break existing bonds is greater than the energy released from forming new bonds.
- The difference between the sum of the energy needed to break bonds in the reactants and the sum of the energy released when bonds in the products are formed is the overall energy change of the reaction.

Example:

Bond	Average bond energy (kJ mol ⁻¹)
H—H	436
O—H	463
O=O	498

Bonds broken:

- $2 \times \text{H-H} = 2 \times 436 = 872 \text{ kJ/mol}$
- $\text{O=O} = 498 \text{ kJ/mol}$
- Total = $872 + 498 = 1370 \text{ kJ/mol}$

Bonds formed:

- $4 \times \text{H-O} = 4 \times 463 = 1852 \text{ kJ/mol}$
- Total = 1852 kJ/mol

Total energy change = reactants - products:

$$1370 \text{ kJ/mol} - 1852 \text{ kJ/mol} = -482 \text{ kJ/mol}$$

Knowledge Organiser

5.6 The Rate & Extent of Chemical Change

5.6.1.1 Calculating rates of reactions

The rate of a reaction is a measure of how quickly a **reactant** is used up, or a **product** is formed.

Rate is calculated by:

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

OR...

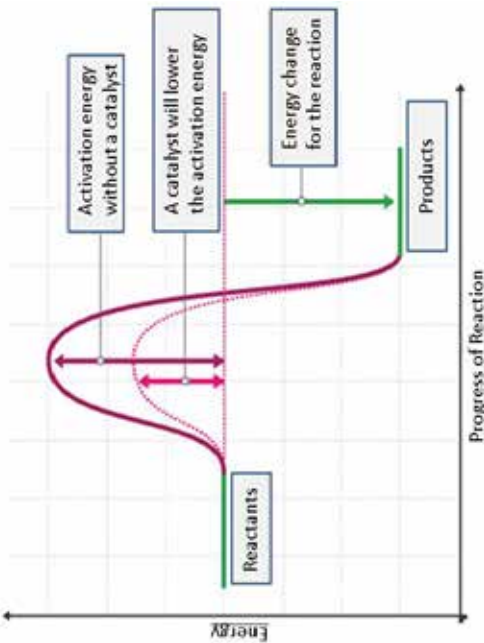
$$\text{mean rate of reaction} = \frac{\text{quantity of product formed}}{\text{time taken}}$$

Eg If 4 moles of a **product** were made during ten seconds, the average rate of reaction would be $4 \div 10 = 0.4 \text{ mol/s}$

Or, if 40g of a **reactant** was used up during 10 seconds, the average rate of reaction would be $40\text{g} \div 10 = 4 \text{ g/s}$

Or, if 50 cm³ of **product** was made during 25 seconds, the average rate of reaction would be $50\text{cm}^3 \div 25 = 2\text{cm}^3/\text{s}$

5.6.1.3 Collision theory and activation energy



A catalyst provides an alternative **reaction pathway**

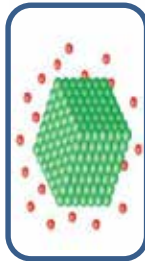
- that has a lower **activation energy**
- does not change the frequency of collisions
- does increase the frequency of successful collisions
- more particles have energy greater than the activation energy
- therefore more successful collisions

5.6.1.2 Factors affecting rates of reactions

SLOWER



Lower temperature



Small surface area



Lower concentration



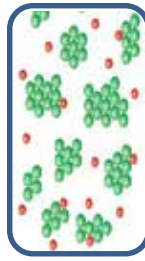
Lower pressure

Less chance of reactant particles colliding

FASTER



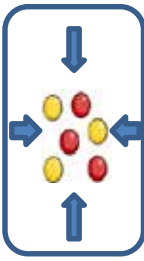
Higher temperature



Large surface area

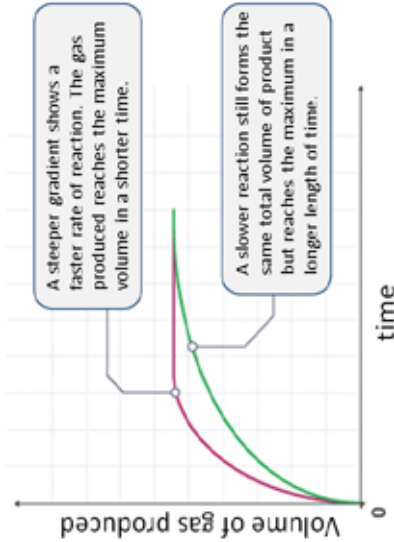


Higher concentration



Higher pressure

More chance of reactant particles colliding



5.6.1.4 Catalysts

A **catalyst** is a substance that:

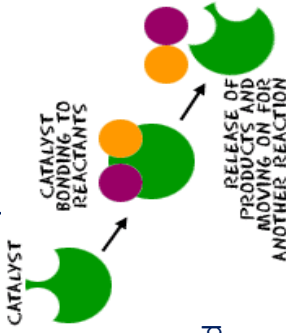
- speeds up the rate of a reaction
- does not alter the products of the reaction
- not chemically changed or used up at end of reaction
- Is only needed in small masses

❖ Not all reactions have suitable catalysts.

Enzymes act as

catalysts in biological systems..

Catalysts are not included in the chemical equation for reaction as they are not used or produced in it.

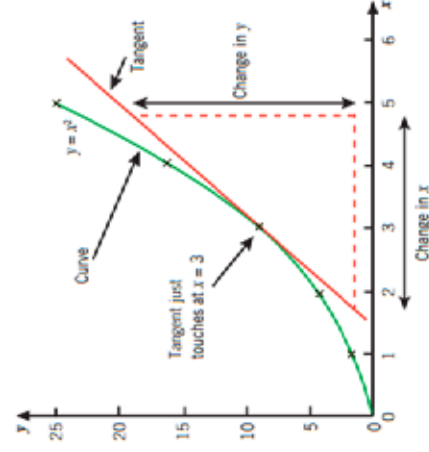


5.6.1.2 Calculating gradient of a graph

For straight line:

Draw a **triangle** against the line, divide the vertical measurement by the horizontal to get the rate of reaction.

For a curve, draw a **tangent** against the line.



Heating ammonium chloride

When heated, white solid ammonium chloride decomposes to form ammonia and hydrogen chloride gas. When cooled, ammonia and hydrogen chloride react to form a white solid of ammonium chloride:



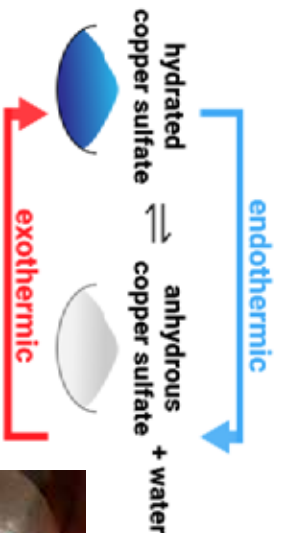
5.6.2.1 Reversible Reactions A

Knowledge Organiser – 5.6 The Rate & Extent of Chemical Change

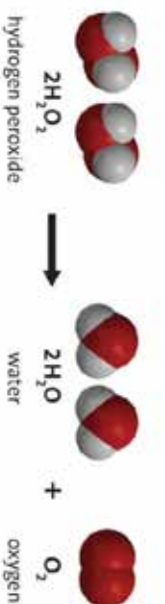
5.6.2.2 Energy changes and reversible reactions

The reaction between **anhydrous** copper(II) sulphate and water is used as a test for water.

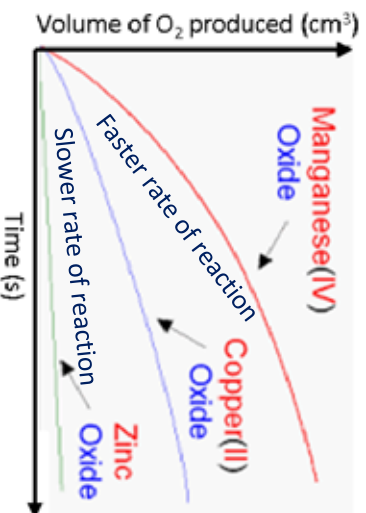
The white solid turns blue in the presence of water.



Testing different catalysts



Manufacturers can try different catalysts for reactions to find the one that forms the products the quickest, therefore making more profit. The results of a trial of 3 metals salts that act as catalysts for the decomposition of H_2O_2 are below.



5.6.2.3 Equilibrium

If a reversible reaction takes place in a closed system (where no reactants can enter and no products can escape), the forwards and backwards reaction reach a state of **equilibrium**, they occur at exactly the same rate.

Example of a reversible reaction:

Nitrogen gas is reacted with hydrogen gas to make ammonia gas. The forward reaction (making ammonia) is **exothermic**.



The backwards reaction (making nitrogen and hydrogen gas is **endothermic**).

The equilibrium position is:

- to the left if the concentrations of N_2 and H_2 are greater than the concentration of NH_3
- to the right if the concentration of NH_3 is greater than the concentrations of N_2 and H_2

5.6.2.4 The effect of changing conditions on equilibrium (HT Only)

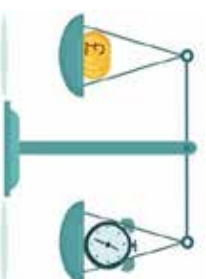
Le Chatelier's principle

The equilibrium position can be changed by changing the reaction conditions through:

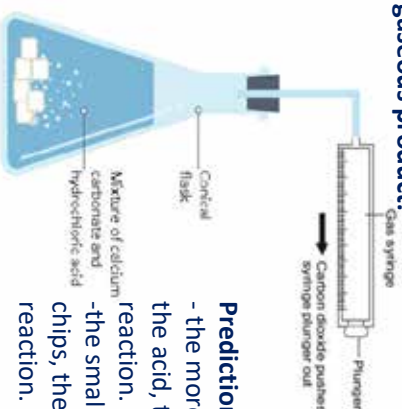
- changing the **pressure**
- changing the **concentration**
- changing the **temperature**

The system will respond to counteract the change.

- ❖ Industry uses this principle regularly to increase the amount of product they make (for the best profits!).



RPA Finding the rate of reaction by volume of a gaseous product:



Prediction

- the more concentrated the acid, the faster the reaction.
- the smaller the marble chips, the faster the reaction.

The reaction is complete when no more gas is being produced.

Hazard	Possible harm	Possible precaution
Hydrochloric acid	Causes skin and eye irritation	Wear eye protection
Fizzing in the reaction mixture	Acidic spray or foam may damage skin and eyes	Use a large conical flask so there is plenty of space inside; do not look over the top when adding the calcium carbonate

RPA: Finding the rate of reaction by turbidity.

Sodium thiosulfate solution reacts with dilute hydrochloric acid. The **sulfur** produced forms a cloudy yellow-white **precipitate** during the reaction. The time taken for this to achieve a given cloudiness provides a way to measure the reaction time.



Prediction – the reaction is faster if the reactants are hotter or more concentrated.

Knowledge Organiser – 5.6 The Rate & Extent of Chemical Change

More details for Higher Tier - If a system is at equilibrium and a change is made to any of the conditions (temperature, concentration, pressure), then that system will respond to counteract the change. This is called **Le Chatelier's Principle**.

Changing the concentration, temperature and pressure of a reaction system can make a big change to where the equilibrium lies, and industry uses this principle regularly to increase the amount of product they make (for the best profits!).

5.6.2.5 Effect of changing concentration on equilibrium (HT Only)

Changing concentration

if you add more reactant, the equilibrium will shift to the right to reduce the concentration of reactant (and make more product)

if you remove some of the product, the equilibrium will shift to the right to increase the concentration of the product

5.6.2.5 Effect of changing temperature on equilibrium (HT Only)

Changing temperature

If the temperature is increased then the equilibrium position will shift to reduce the temperature (so will favour the endothermic reaction)

If the temperature is decreased then the equilibrium position will shift to increase the temperature (so will favour the exothermic reaction)

5.6.2.5 Effect of changing pressure on equilibrium (HT Only)

Changing pressure

If you increase the pressure then the equilibrium will shift to reduce it (by favouring which ever side of the reaction has the fewest molecules of gas)

Pressure



PRESSURE IS INCREASED

The equilibrium position shifts to reduce the pressure

SIDE WITH FEWER GAS MOLECULES FAVOURED

The new equilibrium mixture will contain more C+D and less A+B



PRESSURE IS DECREASED

The equilibrium position shifts to increase the pressure

SIDE WITH MOST GAS MOLECULES FAVOURED

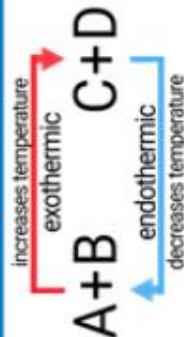
The new equilibrium mixture will contain more A+B and less C+D



Catalysts

Increase the rate of both the forward and backwards reactions equally (so does not change the equilibrium position)

Temperature



TEMPERATURE IS INCREASED

The equilibrium position shifts to reduce the temperature

ENDOTHERMIC REACTION FAVOURED

The new equilibrium mixture will contain more A+B and less C+D



TEMPERATURE IS DECREASED

The equilibrium position shifts to increase the temperature

EXOTHERMIC REACTION FAVOURED

The new equilibrium mixture will contain more C+D and less A+B



Knowledge Organiser – 5.7 Organic Chemistry (Separate Chemistry)

Key terms	
Functional group	An atom or group of atoms that give organic compounds their characteristic reactions.
Homologous series	Family of organic compounds with the same functional group.
Double bond	A covalent bond made by the sharing of two pairs of electrons.
Unsaturated hydrocarbon	A hydrocarbon whose molecule contains at least one carbon-carbon double bond.
Alkene	A hydrocarbon containing at least one double bond . They follow the formula C_nH_{2n} . Used to make polymers .
Bromine water	A chemical that is brown/orange in colour. If added to an alkene it reacts and changes to colourless . Alkenes do not produce a change in colour.
Addition	two molecules add together to form a single product with 100% atom economy.
Oxidising agent	A substance that has the ability to oxidise other substances. Its symbol is [O]

Structure of Alkenes	
Alkenes are unsaturated hydrocarbons. The general formula of the alkenes containing one double bond is C_nH_{2n}	
$ \begin{array}{c} \text{H} & \text{H} \\ & \\ \text{C} & = & \text{C} \\ & \\ \text{H} & \text{H} \end{array} $	$ \begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C} & - & \text{C} = & \text{C} & - & \text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array} $
Ethene	Propene
$ \begin{array}{c} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & \\ \text{H}-\text{C} & - & \text{C} & - & \text{C} = & \text{C} & - & \text{H} \\ & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array} $	$ \begin{array}{c} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ \text{H}-\text{C} & - & \text{C} & - & \text{C} & - & \text{C} = & \text{C} & - & \text{H} \\ & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array} $
Butene	Pentene

Reactions of the alkenes	
It is the C=C double bond that makes the alkenes far more reactive than the alkanes . Alkenes will react with hydrogen, water (steam) and the halogens, by addition of atoms across the C=C double bond so that the double bond becomes a single carbon-carbon bond.	
Combustion	Alkenes will burn in oxygen to produce carbon dioxide and water. $\text{C}_2\text{H}_4 + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 2\text{H}_2\text{O}$ Alkenes release less energy per mole in combustion than alkanes hence the alkanes tend to be used as fuels , whereas the alkenes are not.
Reaction with halogens	Ethene reacts with bromine to form dibromoethane in an addition reaction. $\text{CH}_2=\text{CH}_2 + \text{Br}_2 \rightarrow \text{CH}_2\text{BrCH}_2\text{Br}$ When you test ethene with orange bromine water it turns the bromine water from orange to colourless. 
Reaction with hydrogen	Alkenes reacts with hydrogen in the presence of a nickel catalyst at a temperature of about 150°C to produce an alkane . $\text{C}_2\text{H}_4 + \text{H}_2 \rightarrow \text{C}_2\text{H}_6$ This reaction is used to add hydrogen across double bonds in unsaturated oils making margarine.
Reaction with water (steam)	Ethene reacts with steam in the presence of a catalyst to make ethanol. $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightleftharpoons \text{C}_2\text{H}_5\text{OH}$ The reaction also requires heat and high pressure. The reaction is reversible so unreacted steam and ethane are recycled over the catalyst.

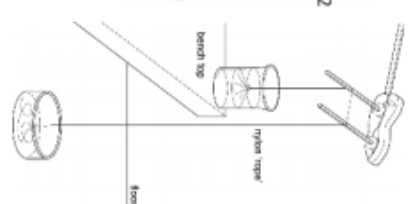
Knowledge Organiser – 5.7 Organic Chemistry (Separate Chemistry)

Structure of Alcohols	
Alcohols contain the -OH functional group.	
$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{O}-\text{H} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Methanol	Ethanol
$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$
Propanol	Butanol
Reactions of the alcohols	
Combustion	Alcohols are flammable and will burn in oxygen with a clean blue flame to produce carbon dioxide and water . $\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$
With sodium	React with sodium metal to produce a solution of sodium alkoxide and hydrogen gas . $2\text{C}_2\text{H}_5\text{OH} + 2\text{Na} \rightarrow 2\text{C}_2\text{H}_5\text{ONa} + \text{H}_2$ If sodium ethoxide, or any other sodium alkoxide is dissolved in water, effervescence (bubbles) are observed and you get a strongly alkaline solution .
Oxidation	Combustion is one way to oxidise an alcohol, however you can also oxidise an alcohol using an oxidizing agent such as potassium dichromate . An alcohol is oxidized to a carboxylic acid when boiled with acidified potassium dichromate. $\text{C}_2\text{H}_5\text{OH} + 2[\text{O}] \rightarrow \text{CH}_3\text{COOH} + \text{H}_2\text{O}$
With water	Alcohols dissolve many of the same substances as water. They also dissolve some organic compounds that water cannot, making them excellent solvents . The first four alcohols dissolve well with water making a neutral solution.
Uses of alcohols	
Alcohols are used as solvents in products such as perfumes, aftershaves and mouthwashes. Ethanol is the main alcohol in alcoholic drinks. Ethanol is also used in spirit burners and as a fuel, for e.g. as a biofuel in cars.	

Manufacture of ethanol	
Fermentation	Ethanol is made by fermenting sugars from plant material with yeast . The reaction is typically carried out between 20-30°C . $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2$ All equipment must be sterile at the start. It also has to be carried out under anaerobic (without air) conditions, otherwise the ethanol would react with oxygen and turn into vinegar. Ethanol made by fermentation is termed a biofuel .
From ethene	Ethanol can also be made from reacting ethene (obtained from cracking of crude oil) and steam in the presence of a catalyst. This method uses up crude oil, a non renewable resource.
Structure of Carboxylic acids	
Carboxylic acids contain the -COOH functional group.	
$\begin{array}{c} \text{O} \\ \\ \text{H}-\text{C}-\text{O}-\text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\ \\ \text{H} \end{array}$
Methanoic acid	Ethanoic acid
$\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{O} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$
Propanoic acid	Butanoic acid
Reactions of Carboxylic acids	
With metal carbonates	Forms a salt, water and carbon dioxide $2\text{CH}_3\text{COOH} + \text{Na}_2\text{CO}_3 \rightleftharpoons 2\text{CH}_3\text{COONa} + \text{H}_2\text{O} + \text{CO}_2$ Effervescence (bubbles) observed as $\text{CO}_{2(g)}$ forms
In water (HT)	Aqueous solutions of carboxylic acids are weak acids & only partially ionise (have higher pH than strong acids of same concentration). $\text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}^+(\text{aq})$
With alcohols	Esters are formed. A sulfuric acid catalyst is required. $\text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \rightleftharpoons \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}$ In this reaction, the ester ethyl ethanoate forms. Esters are sweet/fruity smelling & used in perfumes & food flavourings.

Knowledge Organiser – 5.7 Organic Chemistry (Separate Chemistry)

Section 1: Key terms	
Polymer	Very large covalently bonded molecules with many repeating units (poly means many).
Monomer	Small reactive molecules which join together to make a polymer (mono means one).
Plastics	Made of very large covalently bonded molecules called polymers
Addition polymerisation	The reaction between alkene monomers to form a polymer
Condensation polymerisation	Usually involves a small molecule released in the reaction (like water or HCl), as the polymer forms.
Monosaccharide	Simple carbohydrates made from one sugar unit e.g. glucose.
Polysaccharide	A polymer made from monosaccharide monomers e.g. starch or cellulose).
Protein	Polymers of amino acids
DNA	Deoxyribonucleic acid is made up from monomers called nucleotides
Nucleotides	Monomers used to make DNA. There are four different types that can react to form DNA polymers.
Section 2: Addition poly	
One of the most important ways that chemicals from crude oil are used is to make polymers. Alkenes can be used to make polymers such as poly(ethene) and poly(propene) by addition polymerisation.	
$ \begin{array}{c} \text{H} & \text{H} \\ & \\ n \text{ C} = \text{C} & \longrightarrow \\ & \\ \text{H} & \text{H} \end{array} \longrightarrow \begin{array}{c} \text{H} & \text{H} \\ & \\ -\text{C}- & \text{C}- \\ & \\ \text{H} & \text{H} \end{array} _n $ ethene poly(ethene)	In addition polymers the repeating unit has the same atoms as the monomer because when the C=C bond "opens up" in polymerisation, no other molecule is formed in the reaction.
Uses	
Polyethene is very useful as it is strong, transparent and easily shaped. Used to make drinks bottles, washing up bowls, dustbins and cling film.	
Polypropene forms a very strong tough plastic. Used to make carpets, milk crates and ropes.	

Section 3: Condensation polymerisation (HT)	
As well as addition polymerisation (which requires monomers with a C=C), chemists can also make polymers from another type of reaction called condensation polymerisation . Condensation polymerisation involves monomers with two functional groups . When these types of monomers join together, they usually lose small molecules such as water or HCl, and so the reactions are called condensation reactions. Two products are usually formed.	
Examples	Polyester (used to make clothing) and nylon (used to make rope and stockings).
Forming a polyester	Requires an diol (dialcohol) monomer and a dicarboxylic acid monomer. $ \begin{array}{c} n \text{ HO}-\text{C}(=\text{O})-\square-\text{C}(=\text{O})-\text{OH} + n \text{ HO}-\square-\text{OH} \\ \text{dicarboxylic acid} \qquad \qquad \qquad \text{diol} \\ \downarrow \\ \left[\text{C}(=\text{O})-\square-\text{O}-\square-\text{O} \right]_n + 2n\text{H}_2\text{O} \\ \text{polyester} \qquad \qquad \qquad \text{water} \end{array} $
Forming nylon	Requires a diamine monomer and a dicarboxylic acid monomer. $ \begin{array}{c} n \text{ HO}-\text{C}(=\text{O})-(\text{CH}_2)_4-\text{C}(=\text{O})-\text{OH} + n \text{ H}_2\text{N}-(\text{CH}_2)_6-\text{NH}_2 \\ \text{dicarboxylic acid} \qquad \qquad \qquad \text{diamine} \\ \downarrow \\ \left[\text{C}(=\text{O})-(\text{CH}_2)_4-\text{C}(=\text{O})-\text{N}-(\text{CH}_2)_6-\text{N} \right]_n + 2n\text{H}_2\text{O} \\ \text{Nylon} \qquad \qquad \qquad \text{water} \end{array} $ Nylon thread can be made using the apparatus shown in the diagram 

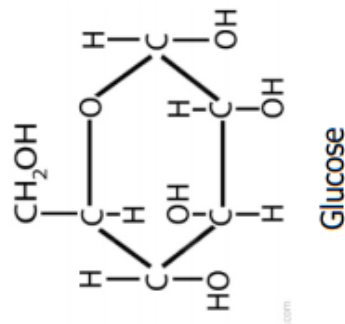
Knowledge Organiser – 5.7 Organic Chemistry (Separate Chemistry)

Natural polymers

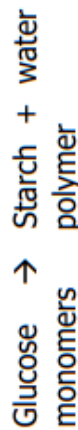
Naturally occurring polymers are found in all living things (e.g. polymers that make up starch, cellulose, proteins and DNA. They are formed during **condensation polymerisation** reactions.

Making polysaccharides from sugars

Simple carbohydrates (monosaccharides) are compounds containing carbon, hydrogen and oxygen e.g. glucose $C_6H_{12}O_6$

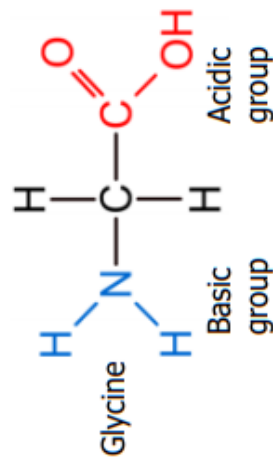


Monosaccharides can bond together to make polymers (polysaccharides). **Starch and cellulose are polysaccharides** made from **glucose** monomers. Plants use the starch they make from glucose as energy stores.

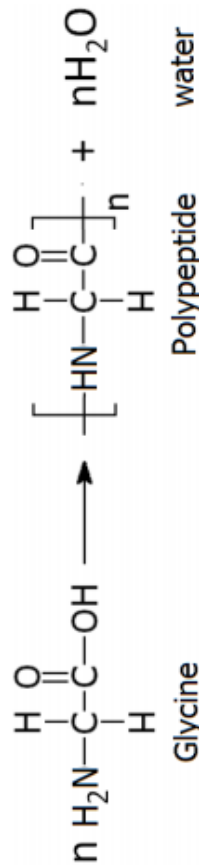


Making polypeptides and proteins from amino acids. (HT)

The monomers of proteins are called **amino acids**. Amino acids have **two functional groups**, one basic (the amine group – NH_2) and one acidic (carboxylic acid group – COOH). The simplest amino acid is glycine.



Many more glycine monomers can link together form a polypeptide molecule. There are about 20 amino acids that join together in a variety of sequences that make up more than 1000 proteins in your body.



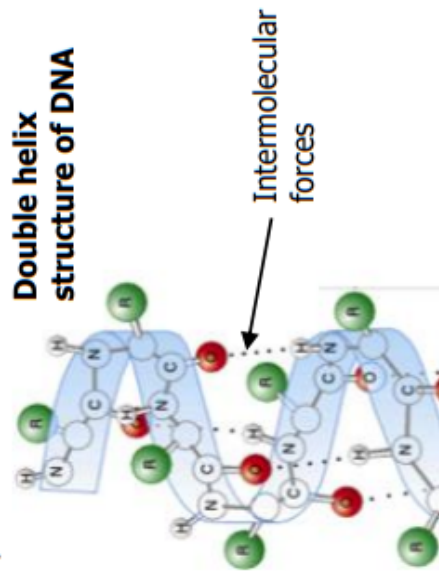
DNA

DNA (**deoxyribonucleic acid**) is a natural polymer **essential for life** because it enables living things to develop and function. It is made up from monomers called **nucleotides**. DNA's structure contains a **genetic code** that determines the different **amino acid sequences** of every protein in living organisms and viruses.

Nucleotide
Based on the sugar **deoxyribose**, bonded to a phosphate group and a base.

How is DNA made By the condensation polymerisation of repeating units of nucleotide monomers. DNA is a **polynucleotide**.

Most DNA molecules are **two polymer chains**, made from **four different nucleotide** monomers, in the form of a **double helix**. The two polymer strands run in opposite directions to each other and are held in place by the **intermolecular forces** down the length of each polymer strand.



There are **four different nucleotide** monomers that can react to form DNA polymers.

Knowledge Organiser – 5.7 Organic Chemistry

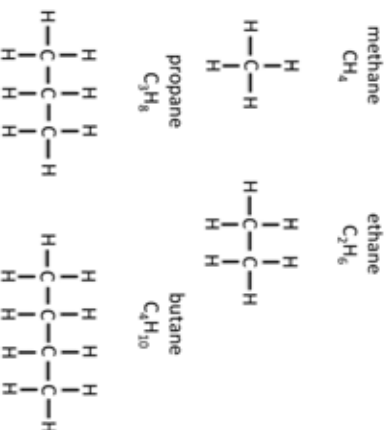
4.3.1.1 Crude oil & hydrocarbons

- Hydrocarbons are **compounds** that contain hydrogen and carbon **atoms** only.
- Crude oil** is a **finite** resource that is found in the Earth's crust. It is the remains of **organisms** that lived and died millions of years ago - mainly plankton which was buried in mud.
- Crude oil is a complex **mixture** of hydrocarbons. The carbon atoms in these molecules are joined together in chains and rings.
- Crude oil is an important source of **fuels** such as petrol, diesel, kerosene, heavy fuel oil and liquefied petroleum gases, & **feedstock** for the petrochemical industry

4.3.1.1 Alkanes



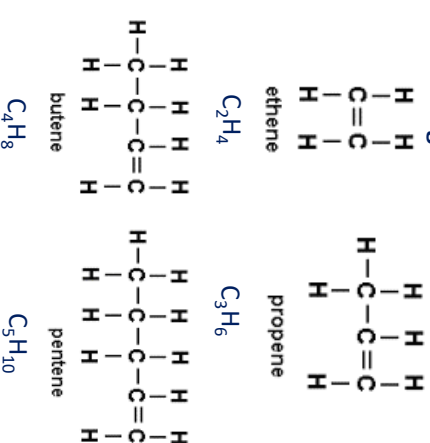
- Saturated hydrocarbons
- contain H and C atoms
- Single covalent bonds between carbon atoms
- Majority of compounds in crude oil are alkanes



4.3.1.1 Alkenes



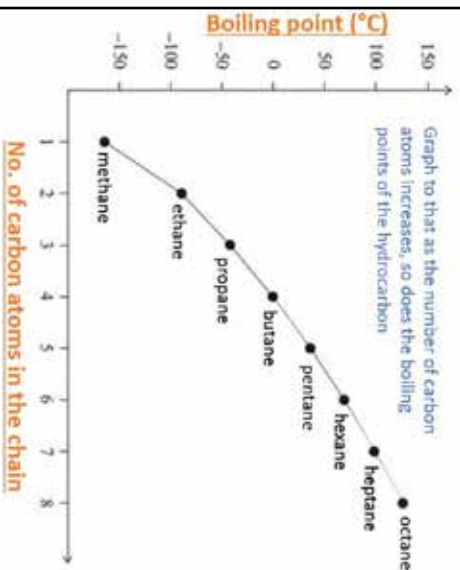
- Unsaturated hydrocarbons
- Contain H and C
- A double covalent bond between some carbon atoms so they are more reactive.
- Formed from alkanes during **cracking**.



5.7.1.2 Petrochemical industry

- Petrochemical:** a substance made from crude oil using chemical reactions
- Solvent:** The liquid in which the solute dissolves to form a solution.
- Lubricant:** A lubricant is anything which reduces the friction between two surfaces.
- Detergent:** A mixture of chemicals which have cleaning properties when dissolved in water, and are able to dissolve grease.
- Feedstock:** A raw material used to provide reactants for industrial reactions.
- Polymer:** A large molecule formed from many identical smaller molecules known as monomers.

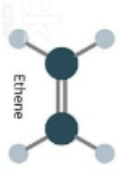
5.7.1.3 Properties of Hydrocarbons: Alkenes



5.7.1.4 Cracking & Alkenes

Hydrocarbons can be broken down (cracked) to produce smaller, more useful molecules.

Cracking products include alkanes and an alkene.

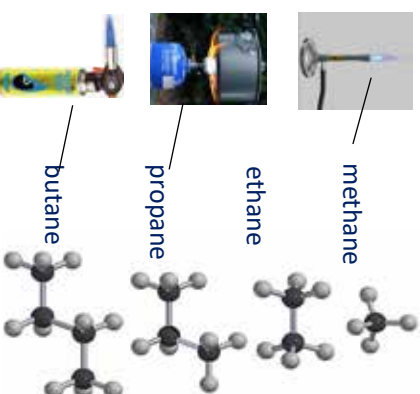


There is a high demand for small molecules and so some of the products of cracking are useful as fuels.



5.7.1.3 Properties of Hydrocarbons: Alkanes

- If a substance is **more** viscous it is thick and sticky. Solids are most viscous.
- If a substance is **less** viscous, it is easier to pour. Gases are least viscous.



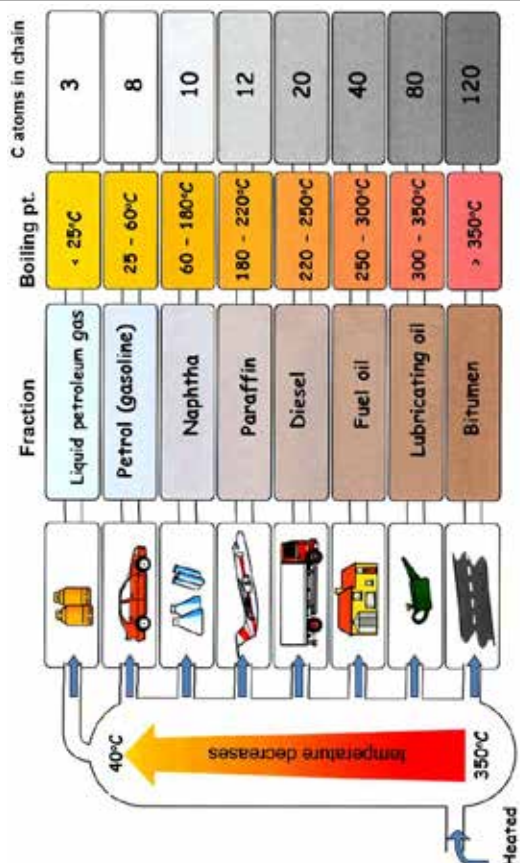
The more carbons there are in the chain, the more **viscous** the hydrocarbon. It becomes thicker. Its **viscosity** increases.

The fewer carbons there are in the chain, the more **volatile** the hydrocarbon is, therefore the easier it is to **ignite**. Its **flammability** increases.

- Flammability is measure of how **easy the hydrocarbon is to ignite and burn**.
- Small hydrocarbons such as methane are more **volatile**. This means they **evaporate easily**.
- This means that they **turn into a gas at a lower temperature** and can **ignite easily**.

Knowledge Organiser – 5.7 Organic Chemistry

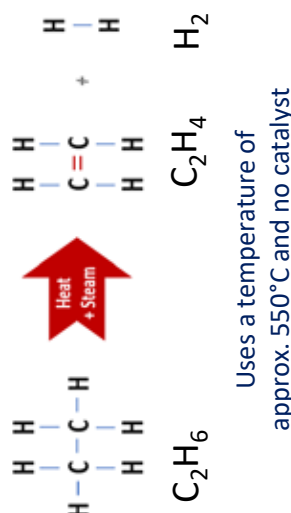
5.7.1.2 Fractional Distillation



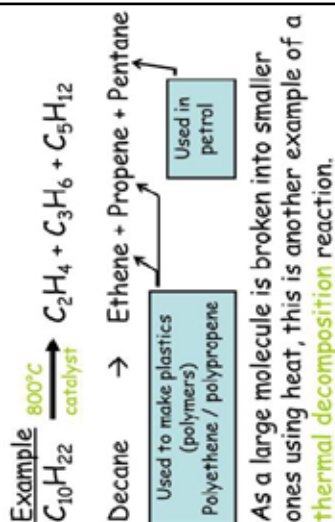
Fractional distillation works because the **different liquids have different boiling points**. When the mixture is heated:

- **vapours rise** through a column which is hot at the bottom, and cooler at the top
- vapours **condense** when they reach a part of the column that is below the temperature of their boiling point
- each liquid is led away from the column to be collected

5.7.1.4 Steam Cracking

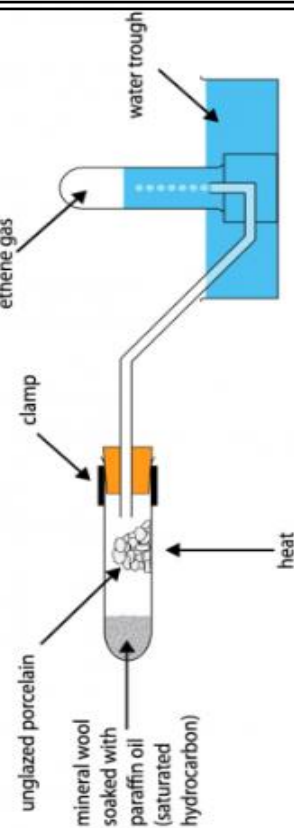


5.7.1.4 Thermal Decomposition



5.7.1.4 Catalytic Cracking

Uses a temperature of approx. 550 °C and a **catalyst** known as a zeolite which contains aluminium oxide and silicon oxide.

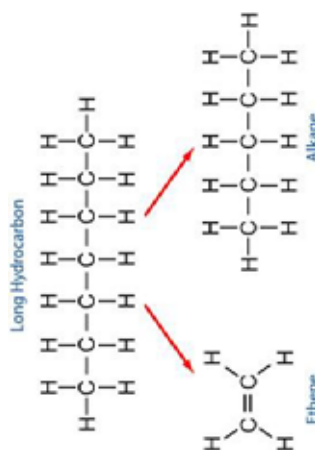


5.7.1.4 Equations for Cracking

Hexane can be cracked to form butane & ethene

Word Equation: hexane → butane + ethane

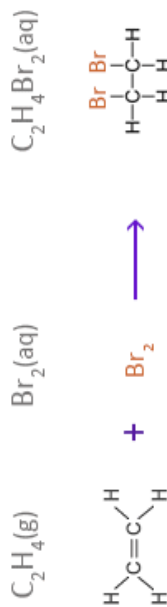
Symbol Equation: $\text{C}_6\text{H}_{14} \rightarrow \text{C}_4\text{H}_{10} + \text{C}_2\text{H}_4$



5.7.1.4 Testing for double bonds



This is the way to test for a double C=C bond in a molecule.

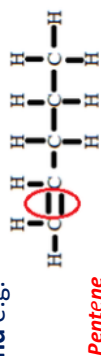


Ethene gas is added to **bromine water**.

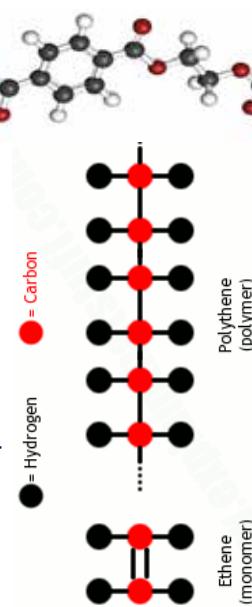
The bromine water is **yellow/orange** at the start. When it reacts with ethene it turns **colourless**.

The double **covalent** bond in the ethene opens up to join with the bromine atoms from the bromine water.

This test works with **any** hydrocarbon that has a **double bond** e.g.



5.7.1.4 How plastics are made



Polymers, whether artificial (such as the plastic shown) or natural, are made of repeating chains of smaller chemical units (**monomers**).

Knowledge Organiser – 5.8 Chemical analysis (Separate Chemistry)

4.8.3.1 Flame Tests

Metal ions when heated produce a **variety** of flame colours. These colours are used to identify the metal ions present in a sample.

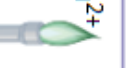
1. Dip **wire loop** into sample.
2. Place loop into **roaring** Bunsen flame
3. Observe **colour** of flame and cross reference

Mixtures sometimes make it difficult to isolate just **one** colour

4.8.3.2 Metal Hydroxides

To identify metal ions, sodium hydroxide solution should be added to the sample. This causes a **precipitate** to form:

- Calcium or magnesium → **white** (doesn't dissolve)
- Aluminium → **white** (dissolves in excess $\text{NaOH}_{(\text{aq})}$)
- Iron (II) → **green**
- Iron (III) → **brown**
- Copper (II) → **blue**

Li^+		crimson
Na^+		yellow
K^+		lilac
Ca^{2+}		orange-red
Cu^{2+}		green

Magnesium sulfate + sodium hydroxide → magnesium hydroxide + sodium sulfate			
Ion		Colour of the Precipitate Produced	
Al^{3+}		white	
Ca^{2+}		white	
Mg^{2+}		white	
Cu^{2+}		blue	
Fe^{2+}		green	
Fe^{3+}		brown	

4.8.3.3 Metal Carbonates

- To identify carbonate ions, place a small volume of **limewater** into test tube.
- Add the sample and a few drops of **hydrochloric acid** (source of H^+ ions) using a **pipette**.
- Seal the test tube with a **bung and delivery tube**.
- Place end of the delivery tube into the limewater.
- If the limewater turns **milky-white**, the gas produced is CO_2 and the sample is a carbonate.



4.8.3.4 Halides

- Using a **pipette**, add a few drops of **nitric acid** solution to the sample, then a few drops of **silver nitrate** solution.
 - Observe the colour of the precipitate.
- | | | |
|---------------------------|-------------------|---------------------------|
| $\text{Cl}^- \rightarrow$ | Chloride → | white precipitate |
| $\text{Br}^- \rightarrow$ | Bromide → | cream precipitate |
| $\text{I}^- \rightarrow$ | Iodide → | yellow precipitate |

4.8.3.5 Sulfates

- Using a pipette, add a few drops of **barium chloride** solution to the sample, then a few drops of **hydrochloric acid**.
- A positive result for sulfate ions will produce a **white precipitate**.



4.8.3.2 Half Equations

These can show what happens in **precipitation** reactions but do **not** show spectator ions (those not involved)

Copper (II)

$\text{Cu}^{2+} + 2\text{OH}^- \rightarrow \text{Cu}(\text{OH})_2$ Cu^{2+} means atom lost 2 electrons, therefore *must* gain 2 electrons; 1 from each OH^- ion.

Iron (III)

$\text{Fe}^{3+} + 3\text{OH}^- \rightarrow \text{Fe}(\text{OH})_3$ Fe^{3+} means Fe atom lost 3 electrons, therefore *must* gain 3 electrons; 1 from each OH^- ion.

Knowledge Organiser – 5.8 Chemical analysis (Separate Chemistry)

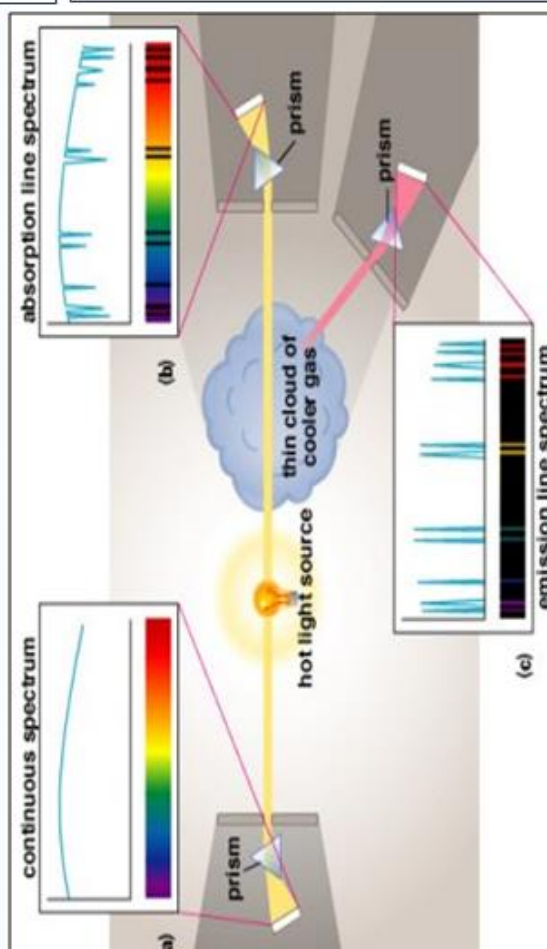
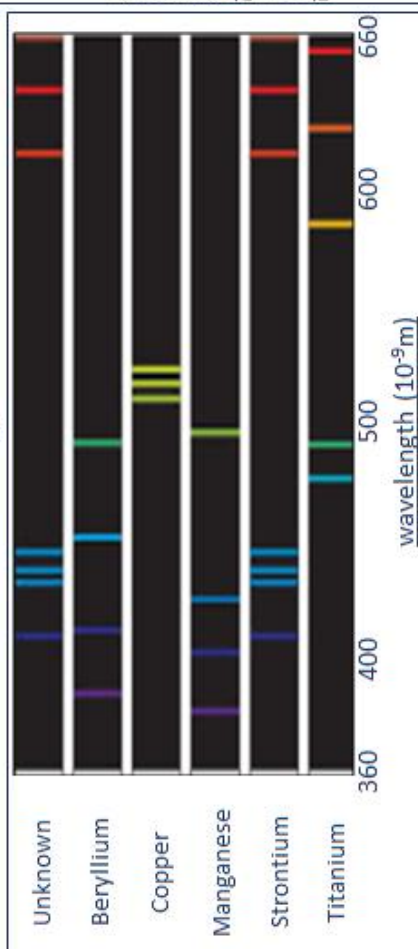
4.8.3.6 Instrumental Methods

The **benefits** are: The **drawbacks** are:

- Rapid results
- Accurate
- Sensitive
- Expensive equipment
- Special training needed

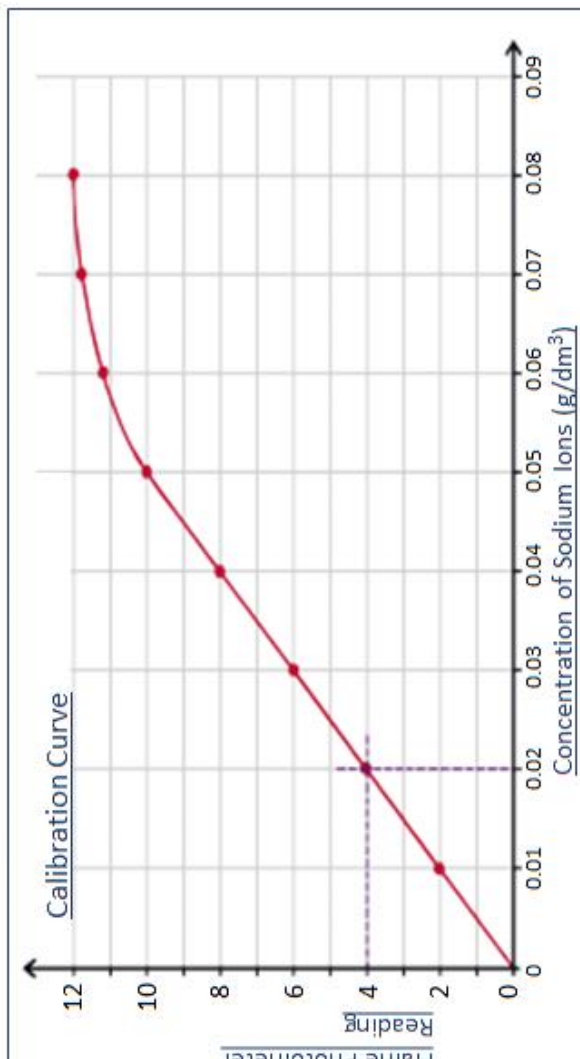
4.8.3.7 Flame Emission Spectroscopy

This is an instrumental method of analysis. It is a technique used to identify metal ions in solution.



4.8.3.7 Calibration Curves

The readings for different concentrations of **metal ions** in solution are taken and can then be used to plot a calibration curve



4.8.3.7 Emission Line Spectrum (pl. spectra)

A **big advantage** of this technique over flame testing is that it can analyse **mixtures** of metal ions in solution....

1. Sample is **heated** in a flame
2. Electrons in the metal ions are **excited** by the thermal energy. As a result, they move to a **higher energy level**.
3. When the electrons **fall back** into a lower energy level, they **release energy** in the form of light.
4. The emitted **wavelengths** of light are analysed instrumentally, by a **spectroscope**.
5. The output is a line spectrum that is **compared** with reference line spectra of **known** metal ions.
6. Each metal ion produces a **unique emission spectrum** so can be **identified** and **concentration** measured.

Knowledge Organiser – 5.8 Chemical analysis

5.8.1.1 Pure substances

- In chemistry a **pure** substance contains only one type of element or one type of compound.
 - Example: pure water only contains H_2O .
- Pure** substances **melt and boil** at specific **temperatures** which can be used to **identify** a substance and test if it is pure.
- In everyday life, a **pure** substance is something that has had nothing else added to it and is in its **natural** state.
 - Example: 'pure' orange juice is not chemically pure but doesn't have any chemicals added that aren't from oranges..

5.8.1.2 Formulations

A **formulation** is a mixture that has been **designed** as useful **product**.

Many products are **complex** mixtures in which each chemical has a particular purpose.

All the ingredients must be mixed in the right quantities so the product has the correct properties.

For example: Fuels, medicine, paint

5.8.1.3 Chromatography

- Chromatography **separates** mixtures and can **identify** substances.

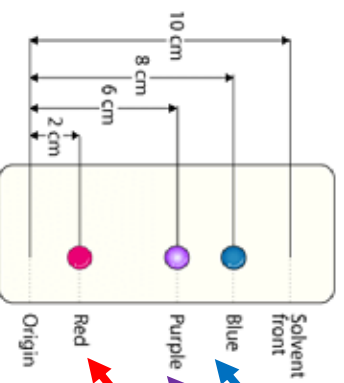
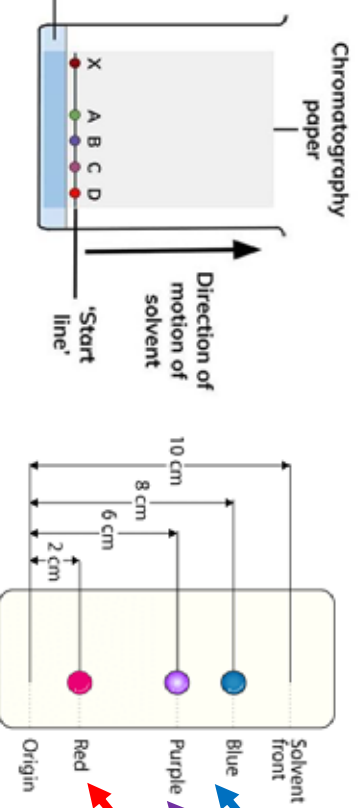
- Two phases are used:
 1. The **mobile** phase (moves) is the **solvent**.
 2. The **stationary** phase (doesn't move) is the paper.
- Separation depends on the distribution between phases. **The more soluble a substance is, the more time it spends in the mobile phase.**

- The R_f value is a ratio of how far the substance has travelled with regard to the solvent.

$$R_f = \frac{\text{distance travelled by the component}}{\text{distance travelled by the solvent}}$$

- Each **pure substance** has a **unique R_f value** in each solvent which can identify it.

RPA : Chromatography



$$R_f \text{ of blue spot} = \frac{8}{10} = 0.8$$

$$R_f \text{ of purple spot} = \frac{6}{10} = 0.6$$

$$R_f \text{ of red spot} = \frac{2}{10} = 0.2$$

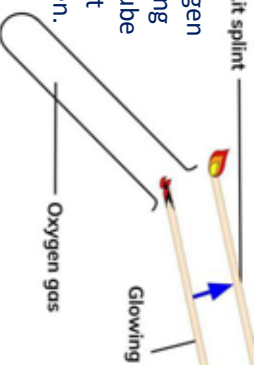
- R_f must be between 0 and 1.
- In an exam you may be asked to measure these so have a ruler and measure to the nearest mm!

Chromatography can identify what substances are in a mixture.

5.8.2 Identification of common gases

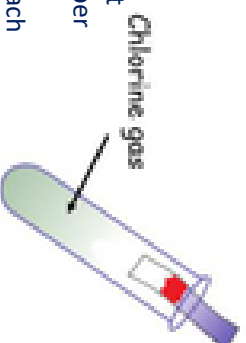
Oxygen

The test for oxygen is to put a glowing splint in a test tube of gas. The splint relights in oxygen.



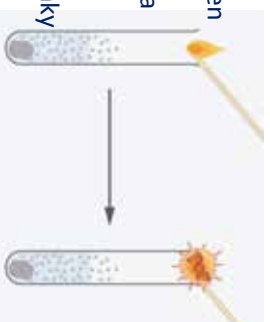
Chlorine

The test for chlorine is to put damp litmus paper in the gas. The chlorine will bleach the paper white.



Hydrogen

The test for hydrogen is to put a burning splint at the end of a test tube of gas. Hydrogen burns rapidly with a squeaky pop.



Carbon dioxide

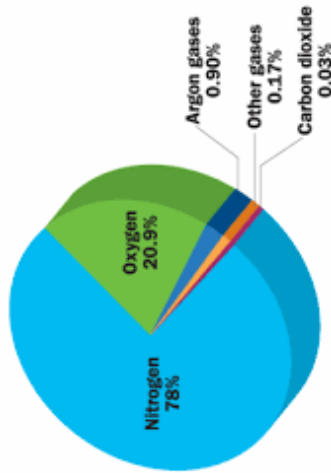
The test for carbon dioxide is to bubble the gas through limewater (calcium hydroxide). The limewater will turn milky (cloudy).



Knowledge Organiser – 5.9 Chemistry of the atmosphere

5.9.1.1 Proportion of different gases in the atmosphere

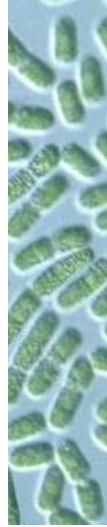
The **atmosphere** today has remained in the same proportions for 200 million years.



5.9.1.3 How oxygen increased

Algae and plants produced the oxygen now present in the atmosphere through **photosynthesis**.

This started 2.7 billion years ago and oxygen has steadily increased allowing more plants and animals to evolve.



5.9.1.1 How carbon dioxide decreased

There are **4** main reasons carbon dioxide **decreased**:

1. **Plants and algae** used CO_2 in **photosynthesis** to produce **oxygen**.



Carbon Dioxide Water Glucose (Energy) Oxygen

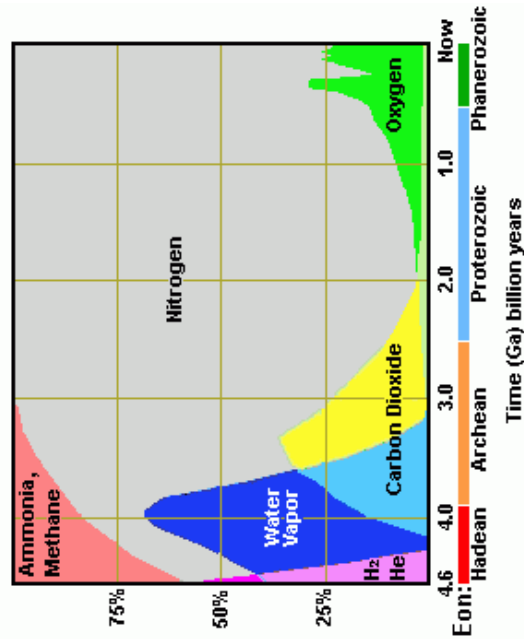
2. CO_2 was used up in the **formation of fossil fuels** (however, we are letting it back out!)
3. CO_2 is trapped when **sedimentary rocks formed**.
4. CO_2 **dissolved** in the newly formed **oceans**.

5.9.1.2 The Earth's early atmosphere

There are several theories about what was in the **early atmosphere** because we are looking 4.6 billion years ago. The main theory suggests:

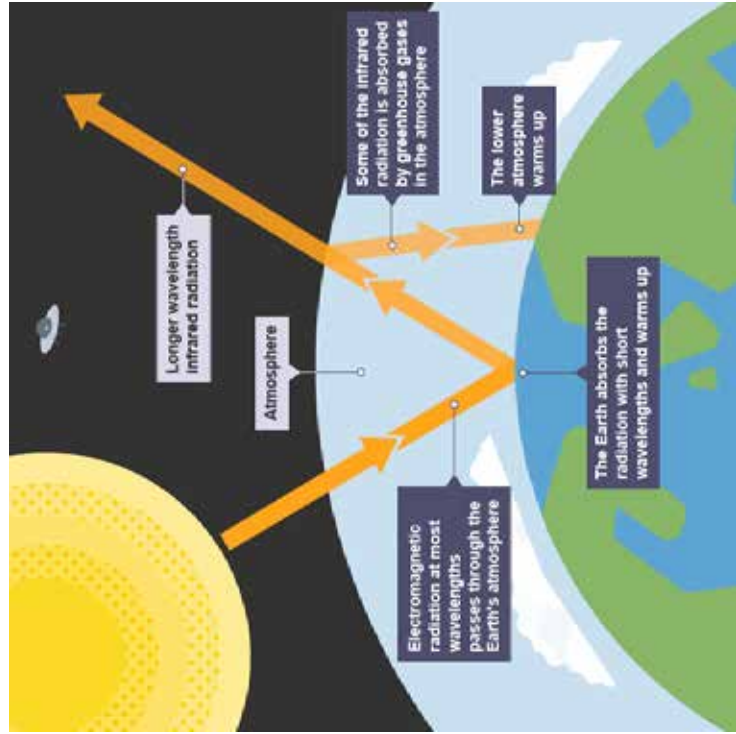
- Initially a large amount of **volcanic activity** released gases to form the early atmosphere
- These gases were a mixture of mainly **carbon dioxide** and **water** with some **nitrogen**, **methane** and **ammonia**.
- Water vapour then **condensed** to form oceans.

% of Atmosphere Composition of Earth's atmosphere



5.9.2.1 Greenhouse gases

Greenhouse gases keep temperatures on Earth high enough to support life. The 3 main gases are **CO_2** , **methane** and **water vapour**.



5.9.2.2 Human activities which contribute to an increase in greenhouse gases in the atmosphere

Humans are increasing the levels of CO_2 and methane.

- Carbon dioxide** can be increased through **burning fossil fuels** and **deforestation**.
- Methane** levels can be increased by **mass livestock farming** and **rice farming**.

To know the fact from fiction about global warming we must look at **peer-reviewed articles**.

Simplified models can often be misrepresented in the media or maybe **biased**.



Showyourstripes.info

Knowledge Organiser – 5.9 Chemistry of the Atmosphere

5.9.2.3 Global Climate Change

An increase in average global temperatures is a major cause of **climate change**. Climate change could cause:

- **Melting ice** which could cause rising sea levels and flooding.
- **Ocean acidification** which could damage sea life.
- **More extreme weather** which could lead to housing damage, wildfires, droughts, flooding etc.
- **Changing climate temperatures** could mean different crop seasons and migrating species.



5.9.2.4 The carbon footprint and its reduction

The **carbon footprint** is the total amount of **CO₂** and other greenhouse gases **emitted** over the **full life cycle** of a product, service or event. To reduce a carbon footprint you need to reduce the amount of **CO₂** and methane you produce.

Find out yours →

<https://footprint.wwf.org.uk/#/>



5.9.3.1 Atmospheric pollutants and their sources

Most **pollutants** come from **combusting fuels**.

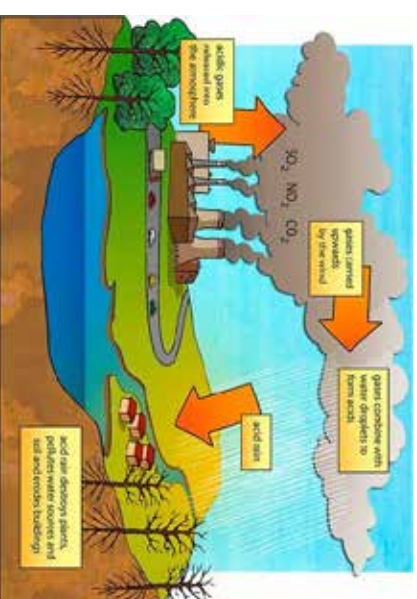
Products released can be

CO₂, H₂O, carbon monoxide, sulphur dioxide, and nitrogen oxides.

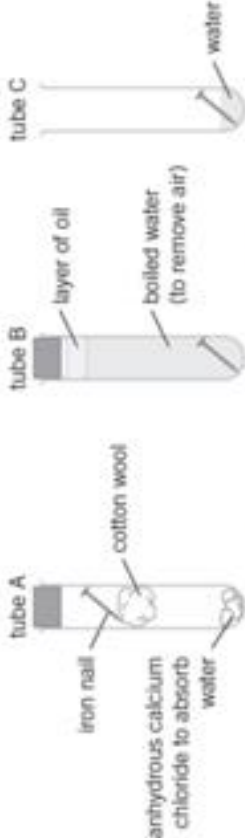
Fuels may also produce solid **particulates** of carbon (soot).

5.9.3.2 Properties and effects of atmospheric pollutants

Product	Carbon monoxide	Sulphur dioxide and nitrogen oxides	Particulates
Problem ?	Colourless, odourless, toxic gas.	Cause acid rain and respiratory problems.	Cause global dimming and health problems.

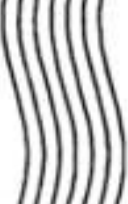


Knowledge Organiser – 5.10 Using resources (Separate Chemistry)

Key Terms		Rusting	
Corrosion	Breakdown of materials due to chemical reactions. It is a form of erosion .	For iron to rust, both air and oxygen are needed. Providing a barrier between iron either air (oxygen) and water protects the iron from rusting. $\text{Iron} + \text{oxygen} + \text{water} \rightarrow \text{hydrated iron(III)oxide}$	
Rusting	The corrosion of iron.		
Rust	Rust is hydrated Iron(III)oxide.	Tube A tests to see if air alone makes iron rust. Tube B tests to see if water alone will make iron rust. Tube 3 tests to see if air and water will make iron rust. Rusting is only observed in tube 3 illustrating that both air and water are needed for iron to rust.	
Sacrificial protection	An effective way to prevent rusting whereby a metal more reactive than iron is attached to or coated on an object.	Sacrificial protection provides protection against rusting . The iron needs to be attached to a more reactive metal (galvanising it) for e.g. Zinc, magnesium or aluminium. The zinc is a stronger reducing agent than iron, so it has a stronger tendency to form positive ions by giving away electrons. As the zinc atoms lose electrons they become oxidised . Therefore any water or oxygen reacts with the zinc instead of the iron (protecting the iron from oxidation).	
Galvanised	Iron or steel objects that have been protected from rusting by a thin layer of zinc metal at their surface.		
Oxidation	Loss of electrons.		
Reduction	Gain of electrons.		
Reducing agent	Tend to get oxidised themselves (and hence reduce other species).		
Alloy	A mixture of two or more elements, at least one of which is a metal. For e.g. Steel is an alloy of Iron and carbon.		
Bronze	Alloy of copper and tin.		
Brass	Alloy of copper and zinc.		
Steels	Alloys of iron containing specific amounts of carbon and/or other metals.		
Hydrated	A substance that contains water in its crystals.		
polymers	A substance made from very large molecules, polymers are made up of many repeating units.		
Thermosetting polymers	Soften and melt when they are heated. Can be remoulded.		
Thermosetting polymers	Do not melt when they are heated. Cannot be remoulded.		
Composites	Two materials combined to make a material with useful properties.		
Ceramics	Materials made by heating clay to high temperatures making hard materials which are excellent insulators.		
		Useful alloys	
Alloys are harder than pure metals because the regular layers are distorted by differently sized atoms and hence cannot slide . Pure iron is too soft for it be useful in its pure form. Steel is an alloy of iron which contains carefully controlled quantities of carbon so that it's hardness is controlled.			
Steels		Properties	Uses
High carbon steel		Very hard but brittle	Cutting tools (chisels)
Low carbon steel		Softer but easily shaped	Bodies of cars
Stainless steel		Chromium-nickel steels resistant to corrosion	Cooking utensils, cutlery
Nickel steel alloys		Resistant to stretching	Bridges, bicycle chains

Knowledge Organiser – 5.10 Using resources (Separate Chemistry)

The properties of polymers

The properties of polymers depends on what monomers they are made from the conditions under which they are made.		
Thermosoftening polymers	Soften or melt easily when heated because their intermolecular forces between the chains are weak .	
Thermosetting polymers	Contain crosslinks (strong covalent bonds) between chains so they do not soften or melt easily.	
High density polyethene	Made using very high pressures and trace of oxygen. Polymer chains are randomly branched, can't pack closely together resulting in a low density .	
Low density polyethene	Made using a catalyst at 50°C and a slightly raised pressure. Made of straight chain molecules which are closely packed, stronger and more dense .	

Glass, ceramic and composites

Glass	The most common form of glass is Soda Glass which is made by heating a mixture of sand (SiO_2), limestone (CaCO_3) and sodium carbonate (soda) at 1500°C. As it cools down the glass turns into a solid. Different types of glass exist depending on amounts of each of the reactants; borosilicate glass involves an extra compound- B_2O_3 . • Atoms arranged irregularly • Transparent, brittle, high melting point, keeps its shape (not flexible)
Ceramics	Wet clay is moulded into a desired shape, then heated in a furnace to 1000°C • Used in bricks, tiles, crockery, bathroom furniture • Atoms are held together in a giant covalent lattice, generally in a regular pattern • Hard but brittle, electrical insulators
Composites	Materials made from two or more different materials, with one material acting as a binder for the other material, reinforcing it . Usually fibres or fragments of one material are held in a 'matrix' (network of atoms) by the other. • Glass-ceramic composites are very hard and tough (not brittle) • Fibreglass (polymer-ceramic) is a low density, tough, flexible material- e.g. used in kayaks • Plywood, carbon fibres and cement are other examples

The Haber process

The Haber process is used to manufacture ammonia, which can be used to produce nitrogen-based fertilisers. The **raw materials** are **nitrogen** (from the air) and **hydrogen** (from natural gas, mainly **methane**).

The nitrogen and hydrogen are purified then passed over an **iron catalyst** at a **high temperature** of 450°C and a **high pressure** (200 atmospheres) to make **ammonia** NH_3 .



The reaction is **reversible** so ammonia can break down again into nitrogen and hydrogen. The ammonia is removed by cooling the gases so that the ammonia liquefies. It can then be separated from the unreacted nitrogen and hydrogen gas.

The unreacted nitrogen and hydrogen gases are recycled back into the reaction mixture so that they can react again on the surface of the iron catalyst.

Knowledge Organiser – 5.10 Using resources (Separate Chemistry)

The Haber process key terms	
Reversible reaction	A reaction in which the products can also form the reactants . Its symbol is $\rightleftharpoons$ Shown as: $A + B \rightleftharpoons C + D$
Exothermic	A reaction that transfers energy to the surroundings
Endothermic	A reaction that takes in energy from the surroundings
Equilibrium (HT)	Equilibrium is reached when the forward and backwards reactions occur at exactly the same rate . The amounts of reactants and products present remain constant . Requires a sealed container .
Le Chatelier's Principle (HT)	When a change in conditions is introduced to a system at equilibrium, the position of equilibrium shifts so as to cancel out the change .

Changing conditions in the Haber Process	
Equation for the Haber process: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ ΔH is negative (exothermic in forwards direction).	
Changing temperature	The Haber process is an exothermic process (ΔH is negative). If the temperature is decreased , the equilibrium moves to the exothermic side and more NH_3 is made.
Changing the pressure	Increasing the pressure results in the equilibrium moving to the right hand side as there are less gas molecules .
Catalyst	The iron catalyst speeds up the rate of the forwards and backwards reaction equally , hence it doesn't affect the yield of ammonia but does result in ammonia being produced quicker .

The Haber compromise (HT)	
Lowering the temperature slows down the rate of reaction, taking longer for ammonia to be produced. Increasing the pressure means stronger, more expensive equipment is needed. This increases the cost of producing ammonia. Hence a compromise is reached achieving an acceptable yield in a reasonable timeframe while keeping costs down . A pressure of 200 atmospheres and a temperature of 450°C .	The Haber compromise graph shows that at 200 atm and 450°C, the yield of ammonia is approximately 35%.

Fertilisers	
Compounds of nitrogen, phosphorus and potassium are used as fertilisers to improve agricultural productivity.	
NPK fertilisers	NPK fertilisers contain compounds of all three elements. Nitrogen for cell growth and making proteins in plants Phosphorus needed to make DNA Potassium needed to make enzymes involved in respiration and photosynthesis.
Synthesis	Fertilisers are made by reacting an acid and base together e.g. Ammonia + nitric acid $\rightarrow$ ammonium nitrate Ammonia + phosphoric acid $\rightarrow$ ammonium phosphate Ammonia + sulphuric acid $\rightarrow$ ammonium sulfate
Obtaining raw materials	Phosphates are obtained from phosphate rocks . Phosphate rocks all contain the phosphate ion PO_4^{3-} . The rocks are insoluble so can't be used directly as fertilisers , but react with acids to make the soluble phosphate compounds. Potassium chloride and potassium sulfate are obtained by mining and are soluble so can be directly used as fertilisers. Nitric acid is required to make nitrate fertilisers (ammonia from the Haber process is oxidised to make nitric acid).
Phosphate rock fertilisers	Phosphate rock + nitric acid $\rightarrow$ phosphoric acid + calcium nitrate Phosphate rock + sulphuric acid $\rightarrow$ calcium phosphate + calcium sulfate Phosphate rock + phosphoric acid $\rightarrow$ calcium phosphate

Knowledge Organiser – 5.10 Using resources

5.10.1.1 Using the Earth's resources

Humans use the Earth's resources to provide warmth, shelter, food and transport. Natural resources provide food, timber, clothing, and fuels. Finite (non-renewable) resources are processed to provide energy and materials. These include fossil fuels and metals. Renewable resources can provide energy and materials as well. These include solar power and sustainable crop growth.

5.10.1.3 Waste water

Urban life and industry produces a lot of waste water. This water must be treated (cleaned) before going back into the environment.

- Sewage waste requires removal of organic matter and harmful microbes.

This treatment includes:

- Screening and grit removal.
- Sedimentation to produce sewage sludge and effluent.
- Anaerobic digestion of sewage sludge.
- Aerobic biological treatment of effluent.

- Industrial waste require removal of organic matter and harmful chemicals.

5.10.1.2 Potable water

Water is essential for life. Humans need water with low levels of dissolved salts and microbes. Safe water is called potable water (not the same as pure water. In the UK rain collects in lakes and rivers. Potable water is produced by:

- Choosing the right body of fresh water.
- Passing the water through filter beds.
- Sterilising using chlorine, ozone, or UV light.

If there isn't much fresh water, sea water can be desalinated by distillation or reverse osmosis but this takes a lot of energy.

Potable water RPA

This practical involves testing a sample of water then purifying the sample.

Step 1: To analyse the water, you use universal indicator to test the pH of 10 cm³ of the water samples. You then evaporate 10 cm³ of the samples and record the mass of solids that were dissolved in the water.

Step 2: Distilling the water. Set up the distillation equipment and gently boil the water. Collect the distilled water in a cooled tube. Test the purity of this water by finding the boiling point.

5.10.2.1 Life cycle assessments

Life cycle assessments (LCAs) are done to assess the environmental impact of products in each of the following stages:

- Extracting and processing raw materials.
- Manufacturing and packaging.
- Use and operation during its lifetime.
- Disposal at the end of its useful life, including transport and distribution at each stage.

It's easy to put numbers on the use of water, resources, energy sources, and some waste production. However, it is less easy to giving numbers to pollutant effects, so it is down to judgement.

This means that LCA is not a purely objective process, there is a little guesswork.

LCAs can be used to evaluate a product but companies may leave parts out to give a misleading representation for advertising (biased)



5.10.2.2 How to reduce resource use

By using less limited materials, the impact on the environment can be reduced.

There are three ways to lessen environmental impact:

- ✓ **Reduce** use of limited resources. Metals, glass, building materials, clay ceramics and most plastics come from limited raw materials. The fuels for the processes come from limited resources. Mining from the Earth causes environmental impact.
- ✓ **Reuse**. Some products, such as glass bottles, can be reused. Glass bottles can be crushed and melted to make different glass products. Other products cannot be reused so are recycled.
- ✓ **Recycle**. Metals, plastics, glass and other materials can be melted and recasted into new products meaning no new materials are needed. Some materials need a lot of separation.

Knowledge Organiser – 5.10 Using resources

Comparative LCAs Used to evaluate which of two alternative products will have a lower negative impact on the environment. For example, we can compare plastic carrier bags and paper carrier bags:		Biological methods of metal extraction (HT) The Earth's supply of metal ores is limited. Eg, high-grade copper ores are becoming harder to find and mine. There are some alternative methods to extract metals from low-grade copper ores that use living organisms. These have advantages and disadvantages compared to the usual extraction methods.
Life cycle stage	Plastic carrier bags Crude oil is a finite resource; fractional distillation, cracking and polymerisation all require a lot of energy. Cheaper to make large quantities of bags from plastic. Lower impact on the environment because plastic bags are usually stronger so they can be reused many times. Can sometimes be collected and recycled; if disposed of as litter, they do not biodegrade; in landfill, may take decades or centuries to degrade.	Paper carrier bags Can be made from recycled paper, or from trees. Making paper from trees requires more energy than recycling paper, but much less than making plastics. More expensive to make bags from paper because the handles must be glued on. Relatively short lifetime; can only be reused a limited number of times. Can be recycled easily; if disposed of in landfill, they biodegrade quickly.
Raw materials		Phytomining Plants absorb mineral ions through their roots. Phytoextraction makes use of this: - plants are grown on a low-grade ore - the plants absorb metal ions through their roots and concentrate these ions in their cells - the plants are harvested and burnt - the ash left behind contains metal compounds Phytoextraction is slow but it: - reduces the need to obtain new ore by mining - conserves limited supplies of high-grade ores - reduces the amount of rock waste that must be disposed of after traditional mining - Can be used to "clean up" industrial wastelands
Manufacture		Bioremediation Certain bacteria can break down low-grade ores to produce an acidic solution containing copper ions. The solution is called a leachate and the process is called bioleaching. Bioleaching does not need high temperatures but it produces toxic substances, including sulfuric acid, which damage the environment.
Use		Processing the metal compounds Iron is more reactive than copper. It can displace copper from the leachate. For example: $\text{Fe(s)} + \text{CuSO}_4(\text{aq}) \rightarrow \text{FeSO}_4(\text{aq}) + \text{Cu(s)}$ Since iron is cheaper than copper, the use of scrap iron is a cost-effective way to produce copper from the leachate. Alternatively, the copper compounds can be dissolved and the solution electrolysed to produce copper metal.
Disposal		

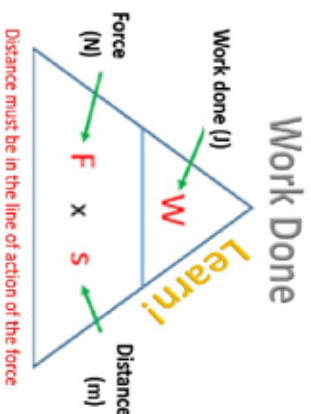
Knowledge Organiser – 6.1 Energy

joule (J) = unit of energy

6.1.1 Energy stores and systems

Energy store	Description	Examples
Magnetic	The energy stored when repelling poles have been pushed closer together or when attracting poles have been pulled further apart .	Fridge magnets, compasses, maglev trains which use magnetic levitation.
Internal (thermal)	Total kinetic and potential energy of the particles in an object, eg the vibrations - also known as the kinetic energy - of particles . In hotter objects , the particles have more internal energy & vibrate faster.	Human bodies, hot coffees, stoves or hobs. Ice particles vibrate slower, but still have energy.
Chemical	The energy stored in chemical bonds , such as those between molecules.	Food, muscles, electrical cells.
Kinetic	Energy of a moving object .	Runners, buses, comets.
Electrostatic	The energy stored when repelling charges have been moved closer together or when attracting charges have been pulled further apart.	Thunderclouds, Van De Graaff generators.
Elastic potential	The energy stored when an object is stretched or squashed .	Drawn catapults, compressed springs, inflated balloons.
Gravitational potential	The energy of an object at height .	Aeroplanes, kites, mugs on a table.
Nuclear	The energy stored in the nucleus of an atom .	Uranium nuclear power, nuclear reactors.

- When a **force** causes a body to move, work is being done on the object by the force.
- Work is the measure of energy transfer when a force (F) moves an object through a distance (d).
- When work is done, **energy** has been transferred from one energy store to another.
- Therefore Energy transferred = work done



Quantity	Unit
Current	A
Energy	J
Mass	kg
Power	W
Time	s
Temp	°C
Height	m
Velocity	m/s
Extension	m
Spring constant	N/m
Force	N
Gravitational field strength	N/kg
Specific heat capacity	J/kg°C

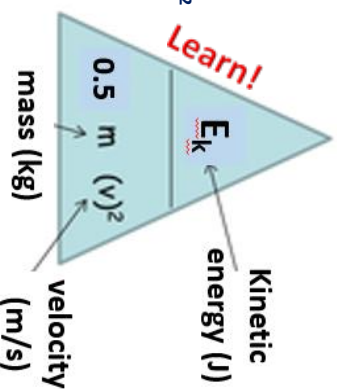
6.1.1.2 Changes in energy

Kinetic energy of a moving object can be calculated using the equation:

kinetic energy = $0.5 \times \text{mass} \times \text{speed}^2$

$E_k = \frac{1}{2} m (v)^2$

- kinetic energy, E_k , in joules, J
- mass, m , in kilograms, kg
- speed, v , in metres per second, m/s

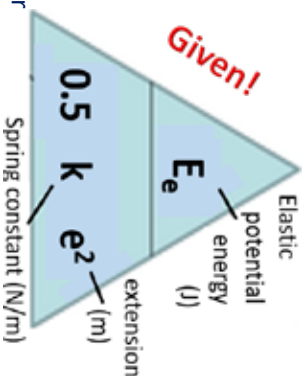


Elastic potential energy stored in a stretched spring can be calculated using the equation (assuming the limit of proportionality has not been exceeded):

elastic potential energy = $0.5 \times \text{spring constant} \times \text{extension}^2$

$E_e = \frac{1}{2} k e^2$

- elastic potential energy, E_e , in joules, J
- spring constant, k , in newtons per metre, N/m
- extension, e , in metres, m

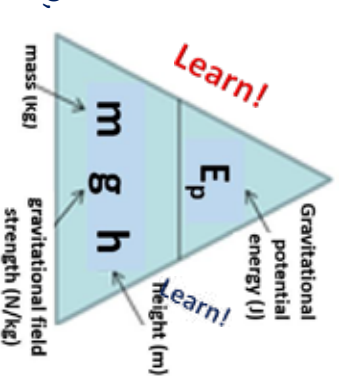


Gravitational potential energy gained by an object raised above ground level can be calculated using the equation:

g.p.e. = mass $\times$ gravitational field strength $\times$ height

$E_p = mgh$

- gravitational potential energy, E_p , in joules, J
- mass, m , in kilograms, kg
- gravitational field strength, g , in newtons per kilogram, N/kg
- height, h , in metres, m



Gravitational field strength is 9.8N/kg on Earth.
(g will be given in the exam).

Knowledge Organiser – 6.1 Energy

6.1.1.3 Energy changes in systems

The amount of energy stored in or released from a system as its temperature changes can be calculated using the equation:

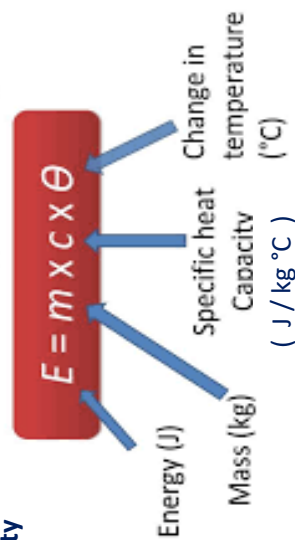
change in thermal energy = mass × specific heat capacity × temperature change

$$\Delta E = m c \Delta \theta \quad \text{Given!}$$

- change in thermal energy, ΔE , in joules, J
- mass, m , in kilograms, kg
- specific heat capacity, c , in joules per kilogram per degree Celsius, J/kg °C
- temperature change, $\Delta \theta$, in degrees Celsius, °C

Specific heat capacity

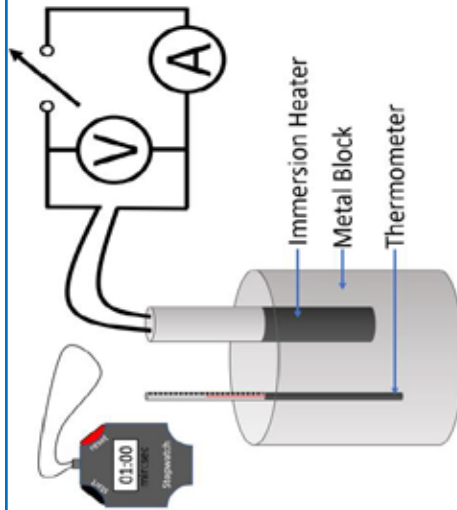
- This is the amount of energy needed to raise the temperature of 1kg of a material by 1°C



RPA: an investigation to determine the specific heat capacity of one or more materials. The investigation involve linking the decrease of one energy store (or work done) to the increase in temperature and subsequent increase in thermal energy stored

Method:

1. Place the immersion heater into central hole at top of block.
2. Place the thermometer into smaller hole and add drops of oil into the hole to ensure thermometer is surrounded by hot material.
3. Fully insulate the block by wrapping it loosely with cotton wool.
4. Record the temperature of the block.
5. Connect the heater to the power supply and turn it off after ten minutes. After ten minutes the temperature will still rise even though the heater has been turned off and then it will begin to cool.
6. Record the highest temperature that it reaches and calculate the temperature rise during the experiment.



Improving accuracy:

- Place the metal block on a heatproof mat to reduce the thermal energy lost to the table surface by conduction.
- Wrap the metal block in a thermal insulator to reduce the thermal energy lost to the air.
- Place the electronic balance on a flat, level surface to get an accurate reading of the mass.

Improving precision:

- Use a data logger rather than a thermometer to reduce the random error & add more decimal places.
- Ensure the immersion heater and block begin at room temperature to reduce the error in repeat readings.
- Ensure the same thickness and type of insulator is used for every repeat measurement reduce anomalies.

6.1.1.4 Power

Power is defined as the rate at which energy is transferred or the rate at which work is done.

- power, P , in watts, W
- energy transferred, E , in joules, J
- time, t , in seconds, s
- work done, W , in joules, J

An energy transfer of 1 joule per second is equal to a power of 1 watt

$$\text{power (W)} = \frac{\text{work done (J)}}{\text{time taken (s)}}$$

$$\text{power (W)} = \frac{\text{energy transferred (J)}}{\text{time taken (s)}}$$

Example

Two electric motors are used to lift a 5 N weight through a vertical height of 6 m. Motor A does this in 5 seconds. Motor B does this in 10 seconds.

For both motors the work done is:

$$W = F \times d = 5\text{N} \times 6\text{m} = 30\text{J}$$

For motor A: $P = \frac{W}{t} = \frac{30\text{J}}{5\text{s}} = 6\text{W}$ For motor B: $P = \frac{W}{t} = \frac{30\text{J}}{10\text{s}} = 3\text{W}$

Motor B is twice as powerful as motor A.

Learn!

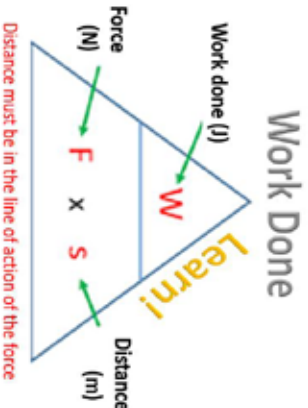
Knowledge Organiser – 6.1 Energy

joule (J) = unit of energy

6.1.1.1 Energy stores and systems

Energy store	Description	Examples
Magnetic	The energy stored when repelling poles have been pushed closer together or when attracting poles have been pulled further apart.	Fridge magnets, compasses, maglev trains which use magnetic levitation.
Internal (thermal)	Total kinetic and potential energy of the particles in an object, eg the vibrations - also known as the kinetic energy - of particles. In hotter objects, the particles have more internal energy & vibrate faster.	Human bodies, hot coffees, stoves or hobs. Ice particles vibrate slower, but still have energy.
Chemical	The energy stored in chemical bonds , such as those between molecules.	Foods, muscles, electrical cells.
Kinetic	Energy of a moving object.	Runners, buses, comets.
Electrostatic	The energy stored when repelling charges have been moved closer together or when attracting charges have been pulled further apart.	Thunderclouds, Van De Graaff generators.
Elastic potential	The energy stored when an object is stretched or squashed.	Drawn catapults, compressed springs, inflated balloons.
Gravitational potential	The energy of an object at height.	Aeroplanes, kites, mugs on a table.
Nuclear	The energy stored in the nucleus of an atom.	Uranium nuclear power, nuclear reactors.

- When a **force** causes a body to move, work is being done on the object by the force.
- Work is the measure of energy transfer when a force (F) moves an object through a distance (d).
- When work is done, **energy** has been transferred from one energy store to another.
- Therefore Energy transferred = work done



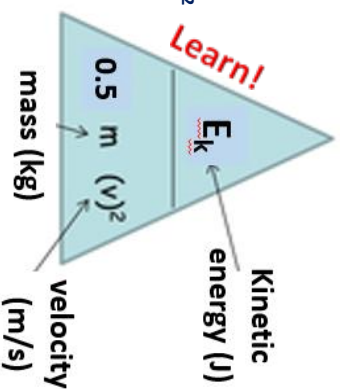
Quantity	Unit
Current	A
Energy	J
Mass	kg
Power	W
Time	s
Temp	°C
Height	m
Velocity	m/s
Extension	m
Spring constant	N/m
Force	N
Gravitational field strength	N/kg
Specific heat capacity	J/kg°C

6.1.1.2 Changes in energy

Kinetic energy of a moving object can be calculated using the equation:

kinetic energy = $0.5 \times \text{mass} \times \text{speed}^2$

- $E_k = \frac{1}{2} m (v)^2$
- kinetic energy, E_k , in joules, J
- mass, m , in kilograms, kg
- speed, v , in metres per second, m/s

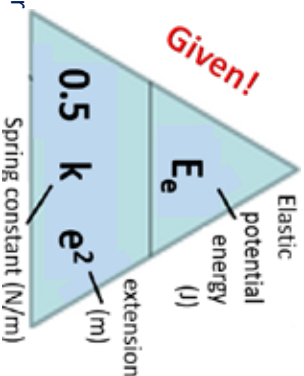


Elastic potential energy stored in a stretched spring can be calculated using the equation (assuming the limit of proportionality has not been exceeded):

elastic potential energy = $0.5 \times \text{spring constant} \times \text{extension}^2$

$E_e = \frac{1}{2} k e^2$

- elastic potential energy, E_e , in joules, J
- spring constant, k , in newtons per metre, N/m
- extension, e , in metres, m



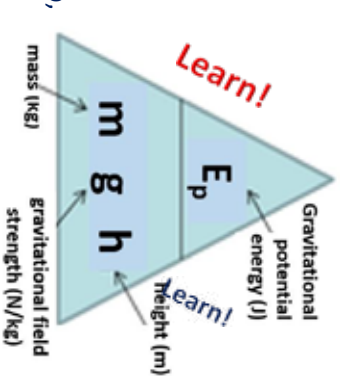
Gravitational potential energy

gained by an object raised above ground level can be calculated using the equation:

$g \cdot p \cdot e$ = mass $\times$ gravitational field strength $\times$ height

$E_p = mgh$

- gravitational potential energy, E_p , in joules, J
- mass, m , in kilograms, kg
- gravitational field strength, g , in newtons per kilogram, N/kg
- height, h , in metres, m



Gravitational field strength is 9.8 N/kg on Earth.

(g will be given in the exam).

Knowledge Organiser – 6.1 Energy

6.1.1.3 Energy changes in systems

The amount of energy stored in or released from a system as its temperature changes can be calculated using the equation:

change in thermal energy = mass $\times$ specific heat capacity $\times$ temperature change

$$\Delta E = m c \Delta \theta \quad \text{Given!}$$

- change in thermal energy, ΔE , in joules, J
- mass, m , in kilograms, kg
- specific heat capacity, c , in joules per kilogram per degree Celsius, J/kg $^{\circ}\text{C}$
- temperature change, $\Delta \theta$, in degrees Celsius, $^{\circ}\text{C}$

Specific heat capacity

- This is the amount of energy needed to raise the temperature of 1kg of a material by 1°C

$$E = m \times c \times \theta$$

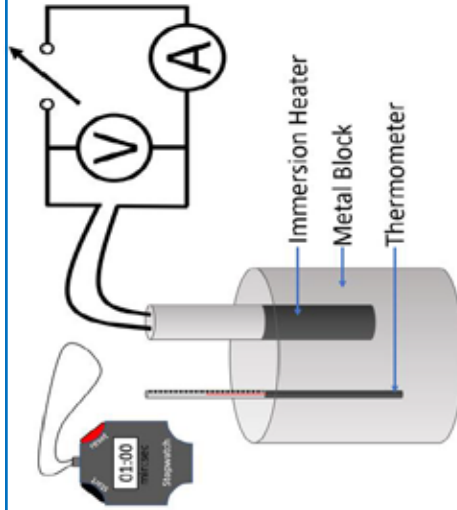
Energy (J) Specific heat Capacity (J / kg $^{\circ}\text{C}$) Change in temperature ($^{\circ}\text{C}$)

Mass (kg)

RPA: an investigation to determine the specific heat capacity of one or more materials. The investigation involve linking the decrease of one energy store (or work done) to the increase in temperature and subsequent increase in thermal energy stored

Method:

1. Place the immersion heater into central hole at top of block.
2. Place the thermometer into smaller hole and add drops of oil into the hole to ensure thermometer is surrounded by hot material.
3. Fully insulate the block by wrapping it loosely with cotton wool.
4. Record the temperature of the block.
5. Connect the heater to the power supply and turn it off after ten minutes. After ten minutes the temperature will still rise even though the heater has been turned off and then it will begin to cool.
6. Record the highest temperature that it reaches and calculate the temperature rise during the experiment.



Improving accuracy:

- Place the metal block on a heatproof mat to reduce the thermal energy lost to the table surface by conduction.
- Wrap the metal block in a thermal insulator to reduce the thermal energy lost to the air.
- Place the electronic balance on a flat, level surface to get an accurate reading of the mass.

Improving precision:

- Use a data logger rather than a thermometer to reduce the random error & add more decimal places.
- Ensure the immersion heater and block begin at room temperature to reduce the error in repeat readings.
- Ensure the same thickness and type of insulator is used for every repeat measurement reduce anomalies.

6.1.1.4 Power

Power is defined as the rate at which energy is transferred or the rate at which work is done.

- power, P , in watts, W
- energy transferred, E , in joules, J
- time, t , in seconds, s
- work done, W , in joules, J

An energy transfer of 1 joule per second is equal to a power of 1 watt

$$\text{power (W)} = \frac{\text{work done (J)}}{\text{time taken (s)}}$$

$$\text{power (W)} = \frac{\text{energy transferred (J)}}{\text{time taken (s)}}$$

Example

Two electric motors are used to lift a 5 N weight through a vertical height of 6 m. Motor A does this in 5 seconds. Motor B does this in 10 seconds.

For both motors the work done is:

$$W = F \times d = 5\text{N} \times 6\text{m} = 30\text{J}$$

For motor A: $P = \frac{W}{t} = \frac{30\text{J}}{5\text{s}} = 6\text{W}$ For motor B: $P = \frac{W}{t} = \frac{30\text{J}}{10\text{s}} = 3\text{W}$

Motor B is twice as powerful as motor A.

Learn!

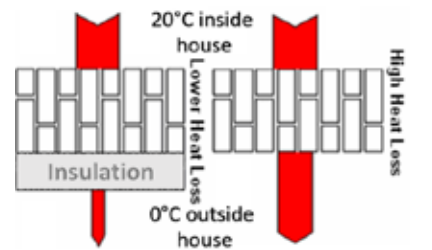
Knowledge Organiser – 6.1 Energy

6.1.2.1 Energy transfers in a system

Energy cannot be created or destroyed, only transformed from one form to another (**Law of conservation of energy**).

“**Work done**” is another way of describing energy transfer.

- where there are energy transfers in a **closed system**, there is **no net change to the total energy**.
- In all system changes energy is dissipated, so that it is stored in less useful ways. This energy is often described as being ‘wasted’.
- Unwanted energy transfers can be reduced, eg. through lubrication and the use of thermal insulation.
- The higher the thermal conductivity of a material the higher the rate of energy transfer by conduction across the material.



The rate of cooling of a building is affected by the **thickness and thermal conductivity of its walls**. Higher thermal conductivity = higher rate of energy transfer = house cools down quicker.

6.1.2.2 Efficiency

Useful energy output
total energy input x 100% **Learn!**

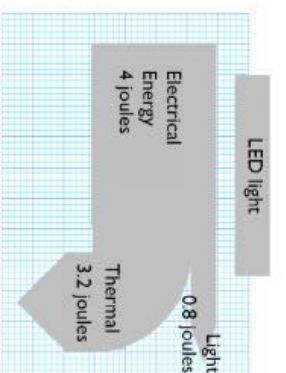
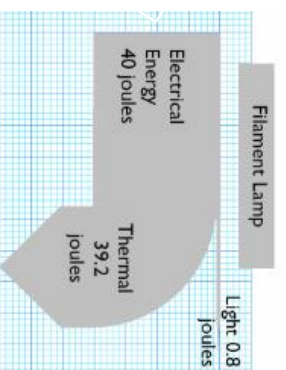
OR
Useful power output
total power input x 100%

Efficiency can be represented as a decimal or percentage. It has to be <100% (or <1.0) as all energy transfers involve wasted energy.

In a **closed system** there is **no net change** to the total energy

Total IN
=
total OUT

Increase efficiency by
insulating or streamlining/
lubricating to reduce
friction.



$$\frac{0.8}{40} \times 100 = 2\%$$

$$\frac{0.8}{4} \times 100 = 20\%$$

The LED is 10 x more efficient than the filament lamp

Investigate thermal conductivity using rods of different materials (NOT RPA)

Whichever rod gets hottest first at the other end is the best

conductor. The material that **heats the quickest** is said to have a **higher thermal conductivity**



6.1.3 National and Global energy resources

- Main energy resources available for use on Earth include: fossil fuels (coal, oil and gas), nuclear fuel, biofuel, wind, hydro-electricity, geothermal, the tides, the Sun and water waves.
- A **renewable energy** resource is one that is **being** (or can be) **replenished** as it is used.
- A **Non-renewable energy** source **cannot be replaced** after it has been used. It is **finite**
- The uses of energy resources include: transport, electricity generation and heating.

	Positives	Negatives
Fossil fuel (coal/oil/gas)	Reliable, cheap to run and mine	Finite, atmospheric pollution (CO ₂ , SO ₂ , NO _x)
Nuclear	Reliable, No CO ₂ , lots of energy released	Long lasting toxic waste, finite
Wind	Infinite, free, no atmospheric pollution	Unreliable (not always windy), visual pollution, costly to build, sometime noisy
Sun	Infinite, free, put on buildings/ in fields	Costly to set up, pollution from batteries
Geothermal	Infinite, free, no atmospheric pollution	Products from ground may contain toxic elements
Tidal	Barrages reduce flooding eg Thames, free, no pollution, reliable(2 tides/day)	Disturb ecology and shipping lanes, costly to build
Biofuel	Can be regrown, cheap, carbon neutral	Use up land that could grow food/ livestock
Hydroelectricity	No atmospheric pollution, free	High rainfall needed, floods valleys therefore habitats/ villages destroyed
Water Waves	No atmospheric pollution, free	Disturb ecology and shipping lanes, costly to build, unreliable (sea does not always have waves)

Knowledge Organiser – 6.2 Electricity (Separate Physics)

Static electricity is all about charges which are not free to move. This causes them to build up in one place which leads to sparks or shocks when they finally do move.	Van de Graaff generator Opposite charges attract. Like charges repel. Earthed metal dome Polystyrene box Protons are positively charged. Electrons are negatively charged.	Examples of static electricity: • Attracting dust: many objects around a house are insulating materials and get easily charged. Dust particles are attracted to anything that's charged (TV screen, glass, plastic etc.) • Clinging clothes and crackles: When synthetic clothes are dragged over each other (in tumble drier or over your head) electrons get scraped off leaving static electricity. • Bad hair days: Static builds up on hair, each strand having the same charge, so they repel each other.
• Build up of static is caused by friction ➢ When two insulating materials are rubbed together, electrons are scraped off one and dumped on the other. This leaves a positive static charge on one, and a negative static charge on the other. • Only electrons move ➢ When electrons (negatively charged particles) move, ions form. Both positive and negative electrostatic charges form as a result. • Positive charges don't move ➢ A positive charge is always caused by electrons being removed (so the positive charges don't move!) • Like charges repel ➢ Two things with the same charge will repel each other	Dangers: Lightning → Lightning is a sudden electrostatic discharge that usually occurs during a thunderstorm. This occurs between electrically charged regions of a cloud, between two clouds, or between a cloud and the ground. Synthetic clothes → Static charge can build up on synthetic materials if they are rubbed against each other. The charge can eventually build up large enough to cause a spark, dangerous if close to flammable gases or fuel fumes. Grain chutes, paper rollers, fuel pipes → Static can build up when grain shoots out of pipes/paper drags over rollers/fuel flows out of filler pipes. Can lead to a spark which might cause an explosion in dusty or fume-y places (like petrol station) The solution to the problem → Earthing of objects prevents build up of static charge. Earthing cables can be attached to prevent sparks. Conducting soles in shoes prevent static electricity from building up hence preventing you getting a shock.	Static Uses: Defibrillator A shock from a defibrillator can restore normal heart rhythm. Consists of two paddles connected to a power supply which are placed on the patient's chest. The charge passes through the paddles to the patient which makes the heart contract
Key Terms: Static electricity → It's the movement of electrons from one insulator to another. The insulator that loses electrons becomes positively charged and the insulator that gains the electrons becomes negatively charged Insulator → An electrical insulator does not easily allow electricity to pass through it. Earthing → Connecting a charged object to the ground using a conductor (e.g. copper wire) prevents build up of charge.	When a polythene rod is rubbed with a duster, the friction causes electrons to gain energy. Electrons gain enough energy to leave the atom and 'rub off' onto the polythene rod. The polythene rod has gained electrons, giving it a negative charge the duster has lost electrons, giving it a positive charge	A radial field around a positive charge
Van de Graaff Generator: When the Van de Graff generator is switched on, each hair gains the same negative charge. Similar charges repel so the student's hair stands on end.	Uniform electric field Field lines point away from + and towards -	If the field is strong enough, charges can be forced through insulators such as air and a spark will occur → lightning strike. It may also happen if a charged person touches a conductor. e.g. A person dragging their feet across the carpet may become charged, so if they reach out to touch a door handle there is a spark and they feel a small shock.
Static Uses: Paint Sprayer: Electrostatic paint sprayers Used to paint bikes and cars providing a fine even coat.		

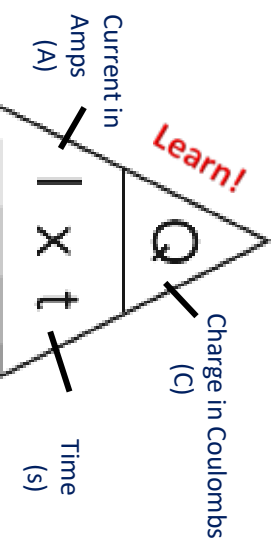
Knowledge Organiser – 6.2 Electricity

6.2.1.2 Electrical charge and current

Electric current is a flow of electrical charge.
Size of current is **rate of flow of electrical charge**.

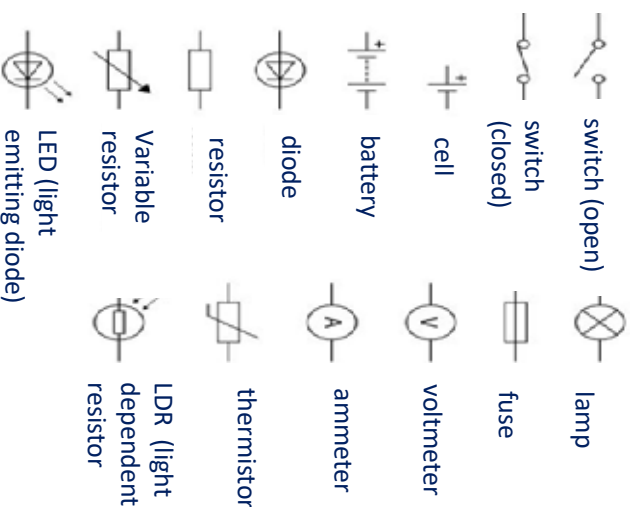
Charge flow, current and time are linked by the equation:

$$\text{charge flow} = \text{current} \times \text{time}$$



- Current has same value at any point in a single closed loop.
- Measured with **Ammeter**

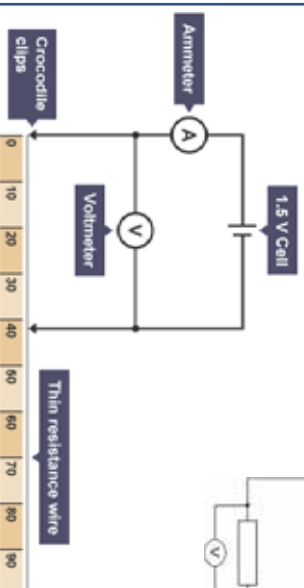
6.2.1.1 Standard circuit diagram symbols



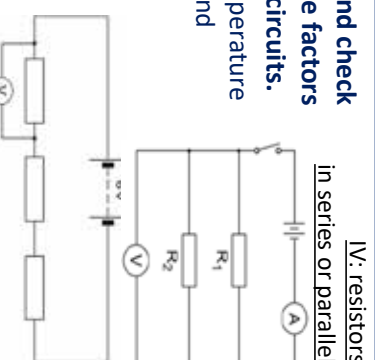
RPA: use circuit diagrams to set up and check appropriate circuits to investigate the factors affecting the resistance of electrical circuits.

- the length of a wire at constant temperature
- combinations of resistors in series and parallel.

IV: Length of a wire



Hazard **Consequences** **Control measures**
Heating Minor burns Set up circuit before closing the switch



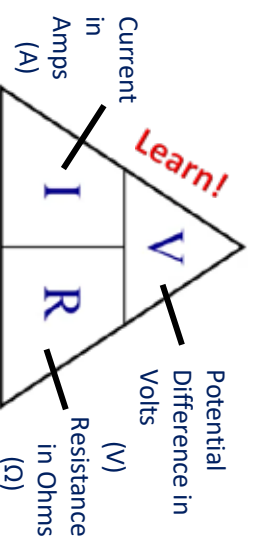
- In series, the resistance of the network is equal to the **sum of the other resistances**.
- In parallel, the resistance of the network is **less than** either of the other resistances.

6.2.1.3 Current, resistance and potential difference

- Potential difference** is the amount of work energy required to move an electric charge (Coulomb) from one point to another
- Current (I) through a component depends on the **resistance (R)** of the component and the **potential difference (V) across the component**.
- The **greater the resistance** of the component the **smaller the current** for a given **potential difference (pd)** across the component.
- Measured with **Voltmeter**
- Voltmeter must be connected in parallel**

Current, potential difference and resistance can be calculated using the equation:

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



- Metal atoms (ions)** in a wire have **delocalised electrons** which are free to move and **carry the charge**.
- Electrons moving** around the circuit **collide with the ions**.
- This is called **resistance**.
- Units of resistance = ohms, Ω**
- Components with high resistance** often get **hot** (e.g. filament lamp).
- Electrons colliding** with the ions **transfer energy** as **heat and light**.
- Causes the ions to vibrate more, increasing the resistance** even more.
- This makes it harder for the electrons to pass through without collisions.

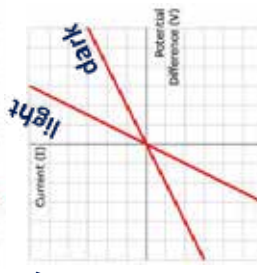
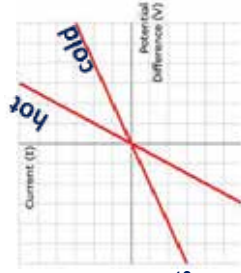
E.g. What is the resistance of a component if 12 V causes a current of 2 A through it?

$$R = V / I = 12V / 2A = 6\Omega$$

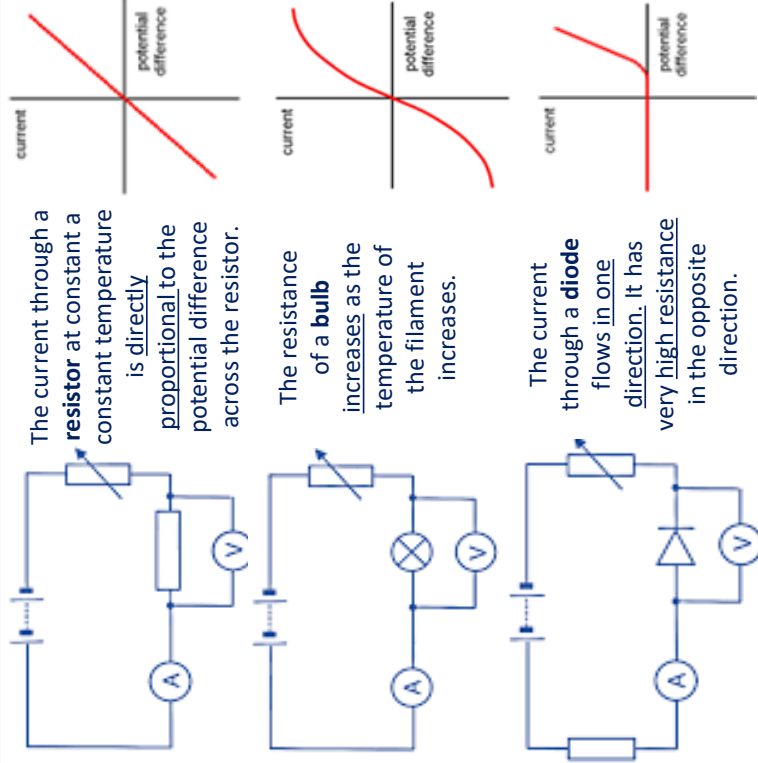
Knowledge Organiser – 6.2 Electricity

6.2.1.4 Resistors

- **Current through an ohmic conductor** (at a constant temperature) is **directly proportional to the potential difference** across the resistor.
- Resistance remains constant as the current changes.
- Resistance of components such as lamps, diodes, thermistors and LDRs is **not** constant; it changes with the current through the component.
- SEE RPA
- Resistance of a thermistor decreases as the temperature increases.
- Low temperature = High resistance
- Used in heat activate fire alarms and thermostats
- Resistance of an LDR decreases as light intensity increases
- Low light levels = high resistance.
- An LDR can be used in lights that come on when it's dark.



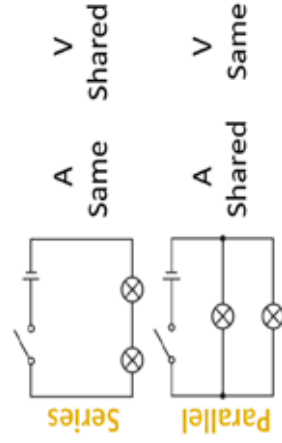
RPA: use circuit diagrams to construct appropriate circuits to investigate the I-V characteristics of a variety of circuit elements, including a filament lamp, a diode and a resistor at constant temperature



6.2.2 Series and Parallel circuits

For components connected in series:

- same **current (A)** through each component
- total **potential difference (V)** of the power supply is **shared between components**
- total resistance of two components is the sum of the resistance of each component.
 $R_{\text{total}} = R_1 + R_2$ resistance, R , in ohms, Ω



For components connected in parallel:

- **potential difference** across each component is the **same**
- **total current** through the whole circuit is **sum of the currents** through the separate components
- **total resistance of two resistors is less** than the resistance of the **smallest individual resistor**.

Charge is a property of a body which experiences a force in an electric field.

Charge is measured in **coulombs (C)**.

Since electrons are so small and one electron will not have much of an effect anywhere, it is more useful to refer to packages of electrons.

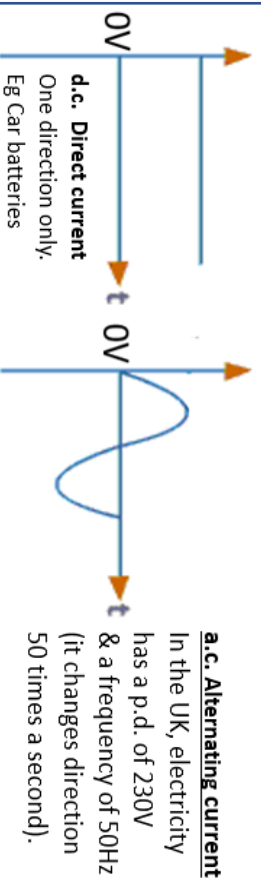
One **coulomb of charge** is a package equivalent to 6,250,000,000,000,000,000 electrons.

Unit	symbol
Potential difference	V
Current	A
Energy	J
Work done	J
Charge	C
Time	s
Power	W
Resistance	Ω

One **volt** is the **potential difference** when **one coulomb** of **charge** transfers one **joule** of energy.

Knowledge Organiser – 6.2 Electricity

6.2.3.1 Direct and alternating potential difference



6.2.3.2 Mains electricity

A= neutral wire, close to 0V.
B= earth wire, 0V, only carries current if there's a fault, stops appliance becoming live.

C= live wire, 230V between earth and live.

D= Fuse, internal wire melts when current is too big so breaks the circuit.

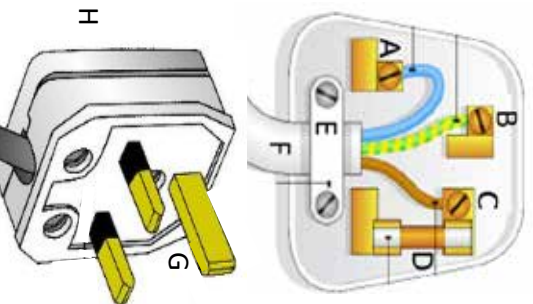
E= cable grip

F= three-core cable, copper wire = flexible and good conductor, plastic coating.

G= brass pins, hard wearing, good conductor

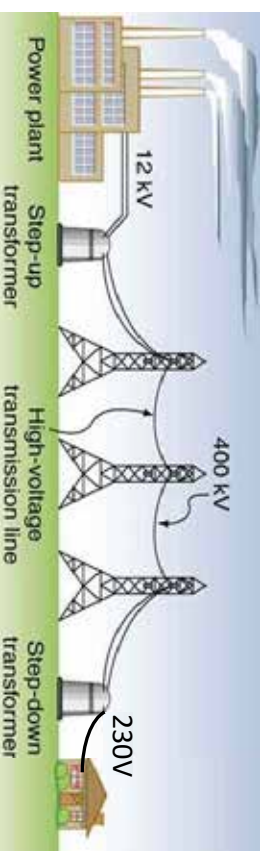
H= plastic casing is an insulator

- a live wire may be dangerous even when a switch in the mains circuit is open
- It is dangerous to provide any connection between the live wire and earth.



6.2.4 Energy Transfers

6.2.4.3 The National Grid



- Network of cables and transformers linking power stations to consumers
- Step-up transformers = higher potential difference
- Reduced energy loss because resistance is lower in cables (high volts = fewer amps for same power)
- Step-down transformers = decrease potential difference to safe level for domestic use (about 230V in UK)
- Underground cables protected from bad weather but get damaged by diggers in building projects

E.g. What is the potential difference between two points if 5 C of charge shifts 10 J?

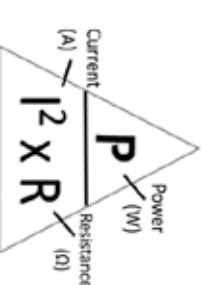
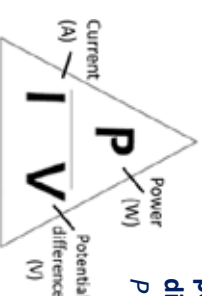
$$V = E/Q$$

$$= 10\text{ J} / 5\text{ C}$$

$$= \underline{2\text{ volts}}$$

6.2.4.1 Power

power = potential difference × current
 $P = V I$

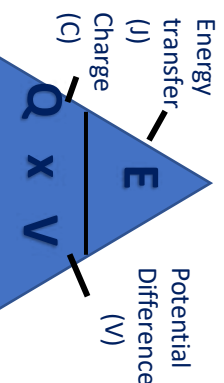
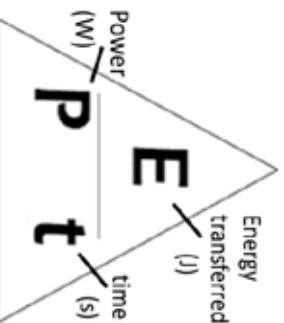


power = current² × resistance
 $P = I^2 R$

- power, P , in watts, W
- potential difference, V , in volts, V
- current, I , in amps, A
- resistance, R , in ohms, Ω

6.2.4.2 Energy transfers in everyday appliances

- The rate at which energy is transferred by an appliance is called the **power**.
- Also known as "**work done**" by the components in the circuit when charge flows.
- The energy transferred by an appliance depends on how long it is switched on for and the power of the appliance.



- energy transferred, E , in joules, J
- power, P , in watts, W
- time, t , in seconds, s
- charge flow, Q , in coulombs, C
- potential difference, V , in volts, V

Knowledge Organiser – 6.3 Particle model of matter (Sep Physics 4.3)

6.3.2.3 Changes of heat and specific latent heat

If a **change of state** happens:

- The energy needed for a substance to change state is called **latent heat**.
- When a change of state occurs, the energy supplied **changes the energy stored** (internal energy) but **does not change the temperature**.
- specific latent heat** of a substance is the amount of energy required to **change the state of one kilogram of the substance** with no change in temperature.

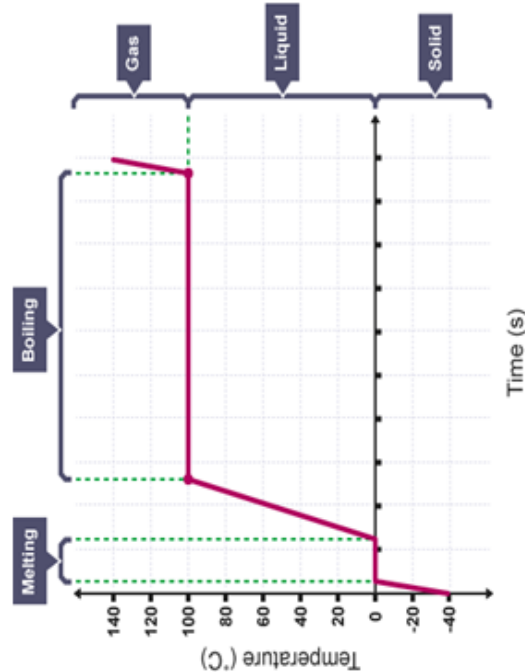
energy for a change of state = mass x specific latent heat

$$E = mL$$

- energy, E , in joules, J
- mass, m , in kilograms, kg
- specific latent heat, L , in joules per kilogram, J/kg
- specific latent heat, L** , in joules per kilogram, J/kg

Specific latent heat of fusion – change of state from solid to liquid

Specific latent heat of vaporisation – change of state from liquid to vapour



6.3.3.1 Particle motion in gases

- Molecules of gas in **constant random motion**
- Temperature** of gas related to average **kinetic energy** of the molecules
- Changing the **temperature** of a gas, held at constant volume, changes the **pressure** exerted by the gas

The pressure in the atmosphere (atmospheric pressure) at sea level is about **100,000 N/m²**.

The **pressure** caused by a gas can be calculated using the equation:

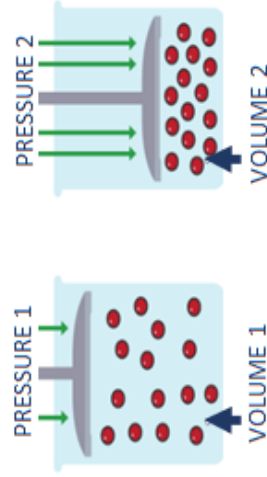
$$\text{Pressure} = \frac{\text{force} \times \text{area}}{\text{N/m}^2}$$

(HT) Mechanical work transfers energy from the person or machine's store of chemical energy to the internal energy store of the gas.

When a person presses a piston down on a column of gas, they apply a force that moves the piston a certain distance. They have done work on the gas by compressing it.

$$\text{work done} = \text{force} \times \text{distance}$$

Real-life context → a bicycle pump gets warm when it is used to inflate a tyre as thermal energy is transferred (work is done) when the air is compressed.



4.3.3.3 Pressure in gases

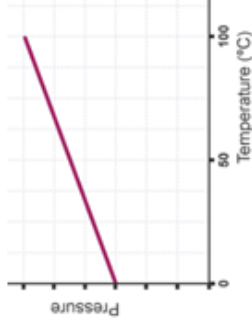
Gas Pressure → Caused by the force exerted when particles collide with their container

Increasing temperature → increases the gas pressure. Gas molecules move faster and hit the surfaces with more force. The number of impacts between the gas molecules and the surface of the container increases, so the total force of impact increases

As the **temperature increases**, the **pressure increases** showing that pressure is **proportional** to temperature.

Motion of gases →

The unpredictable motion of smoke particles is evidence of the random motion of gas molecules – called Brownian motion

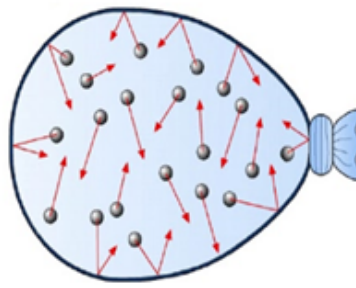


4.3.3.3 Pressure in gases

The force acting on the container due to these collisions is at right angles to the container.

For example, the collisions caused by a gas trapped inside a balloon cause forces to act outwards in all directions, giving the balloon its shape.

A person standing in a room full of air is constantly being hit by the particles of the gases that make up the air.



Gas pressure and Volume → If a balloon is squeezed it will get smaller. If the pressure is increased, the volume will decrease.

Boyle's Law → Pressure (p) x Volume (V) = constant
Pa (Pascal) m³

This is also shown as:-

$$p_1 V_1 = p_2 V_2$$

Knowledge Organiser – 6.3 Particle model of matter

6.3.1.1 Density of materials

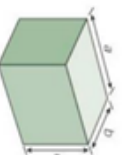
The particle model can be used to explain the different states of matter differences in density.

Calculation	Equation	Symbol equation	Units
Density	$\text{Density} = \frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{v}$	Density = kg/m ³ Mass = kg Volume = m ³

RPA: Measuring volume of irregular objects and calculating density

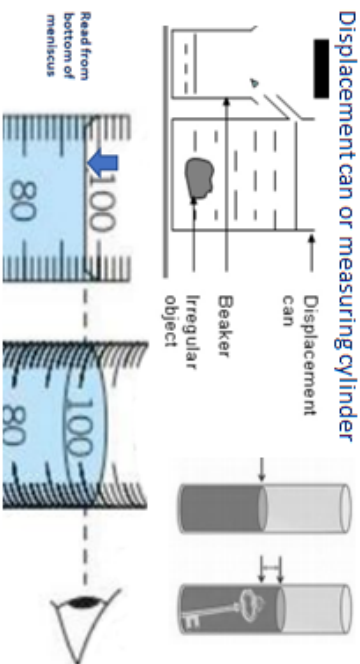
Method 1: Regular solid volume
Length x width x height

Sphere: $\frac{4}{3}\pi(\frac{d}{2})^3$



Method 2: Stone or other irregular shaped object volume

Displacement can or measuring cylinder



Measure mass of object and then use density equation.

6.3.1.3 Internal Energy

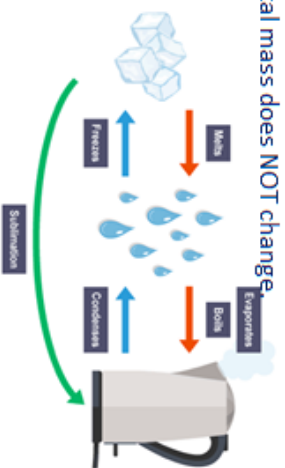
- Internal Energy:** Energy is stored inside a system by the particles that make up the system. Internal energy is the **total kinetic energy** and **potential energy** of **all the particles** that make up a system.
- Heating **increases** the energy of the particles
- Either **raises the temperature** of the system or **produces a change of state**.

Solid	Liquid	Gas
Particles closely packed - vibrate - Little energy - Very strong forces of attraction	Particles touching, move past each other - Some energy - Relatively strong forces of attraction	Particles very far apart - Move very fast - Lots of energy - Weak forces of attraction

6.3.1.2 Changes of State

Conservation of mass

- The number of particles does not change during a change of state, only their spacing and arrangement.
- Total mass does **NOT** change
- Change of state is **physical**.
- The material **recovers its original properties** if the change is reversed.



6.3.2.2 Temperature changes in a system and specific heat capacity

- The change in temperature of a system depends on:
 - the amount of **thermal energy** transferred to the system
 - the mass of the substance
 - the nature of the substance itself
- change in** = mass x specific heat capacity x **temperature change**

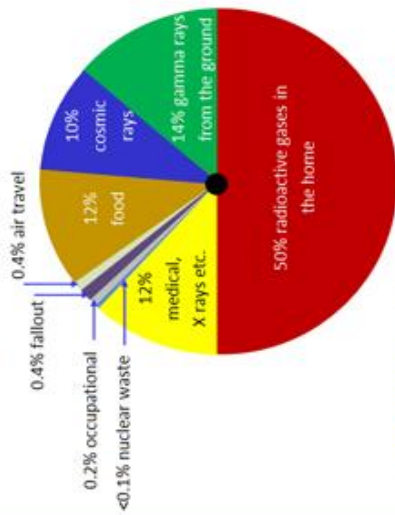
$$\Delta E = mc\Delta\theta$$

Key Terms	Particle Model of Matter	Definitions
condensation	A change of state in which gas becomes liquid by cooling.	
energy	The capacity for doing work	
evaporation	The process in which a liquid changes state and turns into a gas.	
freeze	A change of state in which liquid becomes solid by cooling.	
Internal energy	The total kinetic energy and potential energy of the particles in an object. Heating changes the energy stored within the object by increasing the energy of the particles that make up the system.	
Kinetic energy	Energy which an object possesses by being in motion	
Melting	The process that occurs when a solid turns into a liquid when it is heated	
Specific heat capacity	The amount of energy needed to raise the temperature of 1 kg of substance by 1°C	
Specific latent heat	The amount of energy needed to melt or vaporise 1 kg at its melting or boiling point	
Sublimation	When a solid turns straight into a gas on heating, without becoming a liquid first, or when a gas turns straight into a solid, without becoming a liquid.	
Temperature	How warm or cold something is	
Thermal energy	Scientific term for heat energy	

- Units Used:-
- change in thermal energy, ΔE , in joules, J
 - mass, m , in kilograms, kg
 - specific heat capacity, c , in joules per kilogram per degree Celsius, J/kg °C
 - temperature change, $\Delta\theta$, in degrees Celsius, °C.

Knowledge Organiser – 6.4 Atomic Structure (Sep Physics 4.4)

4.4.3.1 Background Radiation



Radiation dose is measured in Sv (sieverts)
You will be provided with this unit in your exam.

You must know 1 Sv = 1000 mSv

Note → 1 Sv = 1 J/kg (absorbed dose per kg as opposed to exposed dose per kg)

1 Sv will cause illness if absorbed all at once, and 8 Sv will result in death, even with treatment.

Background radiation falls into 2 categories:

- ❖ **Natural** e.g. rocks, cosmic rays from space.
- ❖ **Man-made** e.g. fallout from nuclear weapons testing and nuclear accidents

Some people may be exposed to more radiation because of their occupation e.g. radiographer or their location e.g. Dartmoor

Did you know? A banana produces approximately 98.2 nanosieverts!



4.4.3.2 Radioactive isotopes

Isotopes used in medicine for **medical imaging**, treatment of **cancer** and as **tracers** to monitor organs. How useful the radioactive isotope is, depends on its half life and the type of radiation given out.

4.4.3.3 Uses of Radiation

Radioactive Tracers:

- e.g. radioactive **iodine** is used because:
 - Half life of **8 days** (lasts long enough for test but decays completely after a few weeks).
 - Emits **gamma** so can be detected outside the body.
 - Decays into a **stable product**.

Gamma Cameras:

Take images of internal body organs.

- ✓ Before image is taken, patient is injected with solution containing a gamma-emitting radioactive isotope.
- ✓ The solution is absorbed by the organ and the camera detects the gamma radiation.
- ✓ The half life of the radioactive isotope should not be too long (to avoid unnecessary risks) or too short (so a useful image produced).

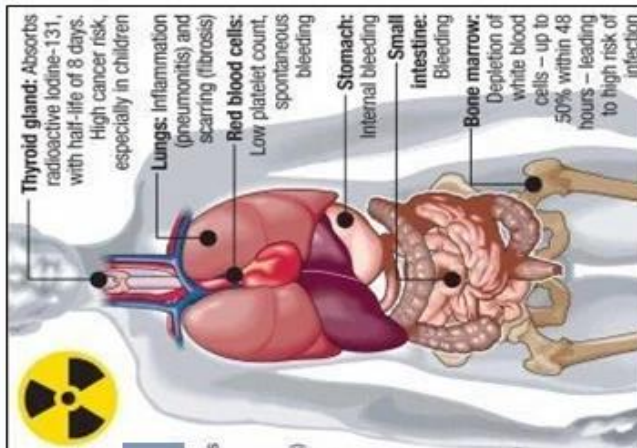
Gamma beams:

- o Gamma beams (or radioactive implants) can destroy cancer cells in a **tumour**.

Maximum level detected at Fukushima so far: 1.5 Sieverts

Timing of Symptoms

Timing of Symptoms	0.05	0.5	0.70	0.75	0.90	1.0	4.0	10.0	20.0
Blood cell changes									
Nausea (hours)									
Vomiting (hours)									
Hair loss (2 weeks)									
Diarrhoea (hours)									
Haemorrhage (weeks)									
Possible death (2 months)									
Destruction of intestinal lining, internal bleeding, death (1-2 weeks)									
Cognitive impairment, convulsions, death (hours)									



4.4.4.1 Nuclear Fission	
Nuclear fission is the splitting of a large and unstable atom's nucleus (e.g. uranium or plutonium) into two smaller nuclei and the release of neutrons and energy.	
Induced fission	Energy is released in a nuclear reactor because of nuclear fission. In induced fission, the nucleus of an atom is struck by a neutron, causing the nucleus to split into two smaller fragment nuclei. Energy is also released.
	Induced fission
	- Unstable nuclei are bombarded with neutrons. - The nuclei undergo fission and split. Two smaller nuclei are formed plus neutrons. Energy is released. - Released neutrons cause more nuclei to split which produces a chain reaction. - The reaction is controlled using control rods which absorb the neutrons (slowing down the chain reaction). - A coolant removes the heat energy, usually to produce steam.
Nuclear fission in Power Stations	Chain reaction (extremely dangerous if not controlled). The explosion caused by a nuclear weapon is caused by an uncontrolled chain reaction.

4.4.4.2 Nuclear fusion

- ❑ Forcing the nuclei of two atoms close together forming a single larger nucleus.
- ❑ The two nuclei collide at high speed.
- ❑ Energy is released when the nuclei fuse together.
- ❑ The sun's core releases energy from nuclear fusion of H nuclei into He nuclei.

Nuclear fission

Been used for over 50 years.

Uses uranium (only found in some parts of world)

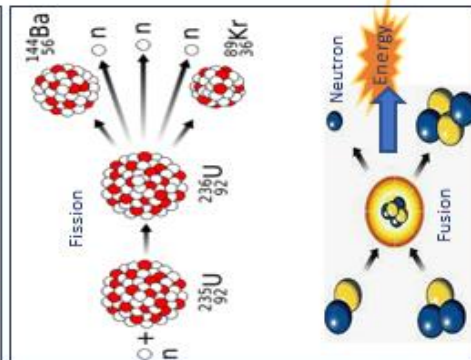
Produces radioactive waste which has to be stored safely and securely.

Nuclear fusion

A developing technology. Needs to be at a **high temperature and pressure** for reaction take place and generate energy.

Hydrogen fuel easily available as present in sea water

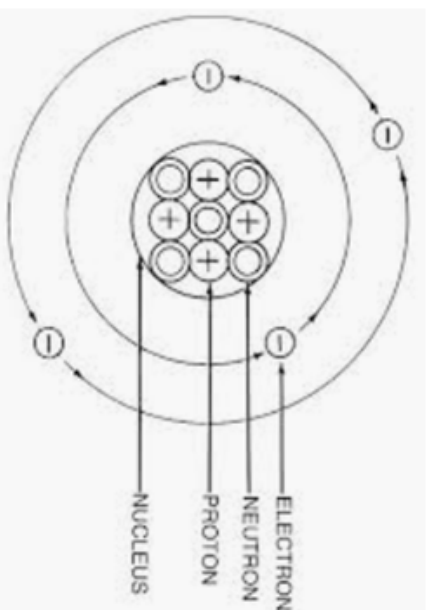
Reaction product helium is stable.



Knowledge Organiser – 6.4 Atomic Structure

6.4.1.1 The structure of an atom

Atoms are very small, having a radius of about 1×10^{-10} metres. They make up all of the matter around us. The basic structure of an atom consists of a **positively charged nucleus** composed of **protons** and **neutrons** surrounded by **negatively charged electrons**.



The electrons are arranged at different distances from the nucleus known both as **shells** and **energy levels**. They are the represented by the circles around the nucleus on the diagram.

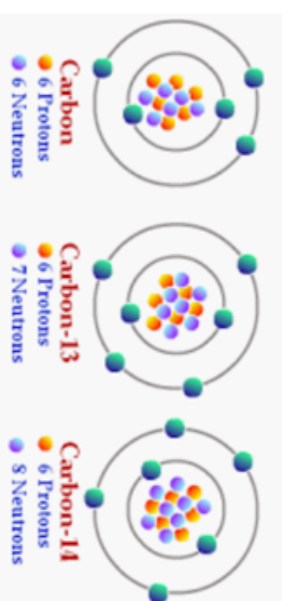
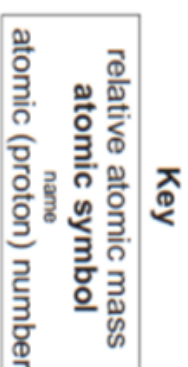
Electron arrangements can change with **absorption** of electromagnetic radiation or **emission** of electromagnetic radiation.

6.4.1.2 Mass number, atomic number and isotopes

The numbers on the periodic table are called the **mass number** and the **atomic number**.

The atomic number (proton number): Smaller number, tells you the number of protons are in an atom of that element. There will be the same number of electrons as protons.

Mass number: larger number, tells you how many neutrons and protons combined are in that atom. Calculate neutrons by taking away the atomic number from the mass number.



Isotopes: Versions of same element (same number of protons) with **different numbers of neutrons** in their nuclei.

Atoms turn into **positive ions**, if they lose one or more outer electron(s)

6.4.1.3 The development of the model of the atom

Experimental evidence may lead to a scientific model changing over time. Atoms were originally thought to have been **solid spheres of matter**.

The **discovery of the electron** led to the **plum pudding model** which suggested a **positive ball of charge** containing negative particles.



Rutherford's **alpha particle scattering** experiment (using gold leaf) led to the conclusion that the **mass of an atom was concentrated with a positively charged nucleus**.

This **nuclear model replaced** the previous one.



Niels Bohr adapted the nuclear model by suggesting that **electrons orbit the nucleus at specific distances**.

Later experiments identified positive particles which were called **protons**. The experimental work of James Chadwick provided the evidence to show the existence of **neutrons within the nucleus**.

Sub-atomic particle	Mass	Charge	Position in Atom
Proton	1	+1	Nucleus
Neutron	1	0	Nucleus
Electron	$\frac{1}{2000}$	-1	Orbiting in shells

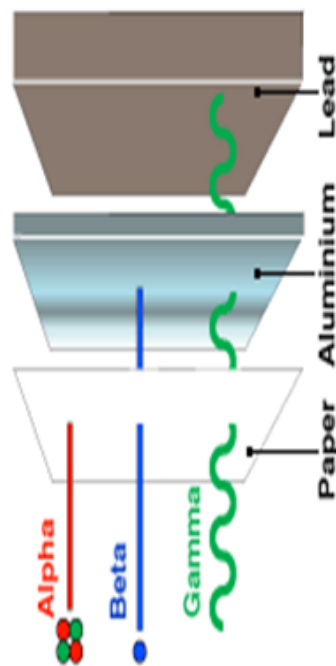
Knowledge Organiser – 6.4 Atomic Structure

6.4.2.1 Radioactive decay and nuclear radiation

Some atomic **nuclei** are **unstable**, radiation is given out and the nucleus becomes more stable. This is a **random process** called **radioactive decay**.

- **Alpha particles** consist of two neutrons and two protons (same as a helium nucleus)
- **Beta particles** consist of a high speed electron ejected from the nucleus as a neutron turned into a proton.
- **Gamma rays** are electromagnetic radiation from the nucleus.
- **Neutron emission** is a decay process where one or more neutrons are ejected from a nucleus. It can occur in nuclei that are neutron rich/proton poor. As only one or more neutrons are lost, the atom becomes a different isotope of the original element.

Each type of radiation has a **different range** and **penetration power**, Alpha has the **highest ionising power** although having the shortest range and is least penetrating.



- **Activity** is the rate at which a source of unstable nuclei decays.
- Activity is measured in **becquerel (Bq)**
- **Count-rate** is the number of decays recorded each second by a detector (e.g. Geiger-Muller tube).

6.4.2.2 Nuclear equations

Are used to represent radioactive decay.

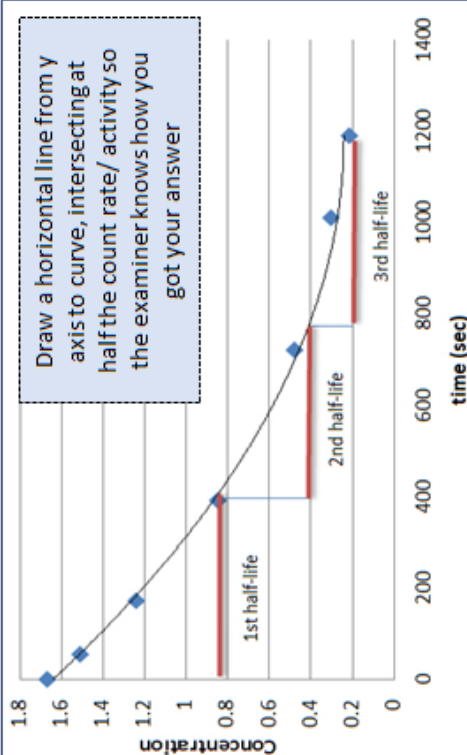
Alpha decay causes both the mass and charge of a nucleus to decrease.

Beta decay causes the charge to increase but does not change the mass of the nucleus

Gamma ray emission does not cause a change in the mass or charge of a nucleus.



6.4.2.3 Half-lives and the random nature of radioactive decay



(HT Only) Calculating half life.

Question:

The half-life of cobalt-60 is 5 years. If there are 100 g of cobalt-60 in a sample, how much will be left after 15 years?

15 years is three half-lives so the fraction remaining will be $(\frac{1}{2})^3 = \frac{1}{8} = 12.5\text{g}$

As a ratio of what was present originally compared to what was left, this would be 100:12.5 or 1:0.125

A **half-life** is either:-

- ☒ the time it takes for the number of nuclei of a radioactive isotope in a sample to **halve**
- or
- ☐ the time it takes for the count rate from that sample to fall to **half of its initial level**.

6.4.2.4 Radioactive contamination

Irradiation: Exposing an object to nuclear radiation, the object **does not** become radioactive but it can still **damage cells**.

Contamination: Occurs when an object is exposed to a source of radiation outside the object. Doesn't cause the object to become radioactive. Can be blocked from the object with suitable shielding. Stops as soon as the source is removed.

Radioactive Contamination: **Unwanted** presence of **materials** containing **radioactive atoms** on other materials.

Knowledge Organiser – 6.5 Forces (Sep Physics 4.5)

6.5.4.1.5 Acceleration

Average acceleration can also be calculated using:

Acceleration (m/s^2) = change in velocity (m/s) $\div$ time (s)

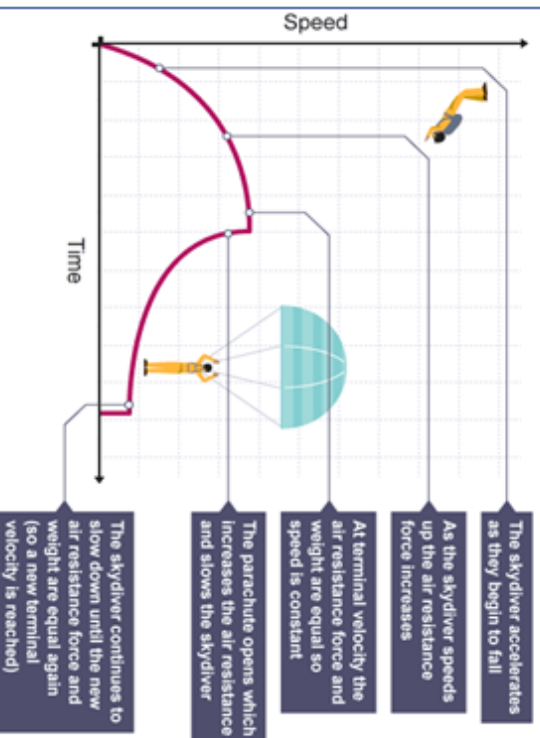
$$a = \Delta v \div t$$

- acceleration, a , in metres per second squared, m/s^2
- change in velocity, Δv , in metres per second, m/s
- time, t , in seconds, s
- An object that slows down is **decelerating**.
- The acceleration of an object can be calculated from the **gradient of a velocity–time graph**.

Uniform acceleration can also be calculated using:

$$(final\ velocity)^2 - (initial\ velocity)^2 = 2 \times acceleration \times distance$$

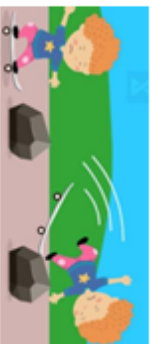
- final velocity, v , in metres per second, m/s
- initial velocity, u , in metres per second, m/s
- acceleration, a , in metres per second squared, m/s^2
- distance, s , in metres, m



6.5.4.2.1 Newton's first law

An object will not move or change speed unless a force acts on it.

- A stationary object will stay **stationary**.
- A moving object will continue at a **constant speed**.



(HT) The tendency of an object to stay still or stay at a constant speed is **inertia**.

6.5.4.2.2 Newton's second law

Force (N) = mass (kg) $\times$ acceleration

$$F = m \times a$$

The acceleration of an object depends on mass and force.

- If the mass **increases** and the force **stays the same**, the acceleration **decreases**.
- If the mass **stays the same** and the force **increases**, the acceleration **increases**.



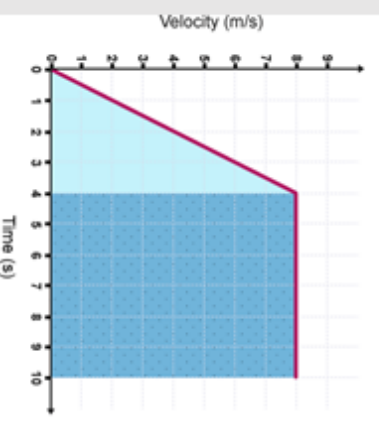
(HT) **inertial mass:**

- measure of how **difficult** it is to **change the velocity** of an object
- the **ratio of force over acceleration**.



6.5.4.1.5 Acceleration (HT)

The distance travelled by an object (or displacement of an object) can be calculated from the **area** under a velocity–time graph.



e.g. for graph above...

Area of triangle = $4 \times 8 = 32\text{m}$

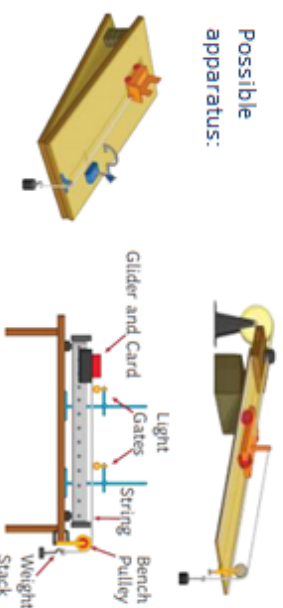
Area of rectangle = $6 \times 8 = 48\text{m}$

Total distance travelled = $32 + 48 = 80\text{m}$

RPA

Version 1- Investigate the **effect of varying the force** on the acceleration of an object of constant mass, AND
Version 2- the effect of **varying the mass** of an object on the acceleration produced by a constant force.

Possible apparatus:



Something is a **fair test** when only the independent variable has been allowed to affect the dependent variable.

e.g. for version 1- The IV was force. The DV was acceleration.

The CV were:

- same **total mass**
- same surface/glider/string/pulley (**friction**)
- same **gradient** if you used a ramp

Knowledge Organiser – 6.5 Forces (Sep Physics 4.5)

6.5.4.3.1 Stopping distance

The stopping distance of a vehicle is the sum of the drivers **reaction time (thinking distance)** and the **braking distance**.
Greater speed = greater stopping distance

6.5.4.3.2 Reaction time

Reaction times vary from person to person but are usually in the range of **0.2 s to 0.9 s**.
A driver's reaction time is affected by **tiredness, distractions, drugs** and **alcohol**.

There are different ways to measure reaction times.

- One simple method involves **dropping a ruler** between someone's open thumb and forefinger.
- The **higher the reaction time** needed to grasp the falling ruler, the **further the ruler falls** before being stopped.

6.5.4.3.3 Factors affecting braking distance 1

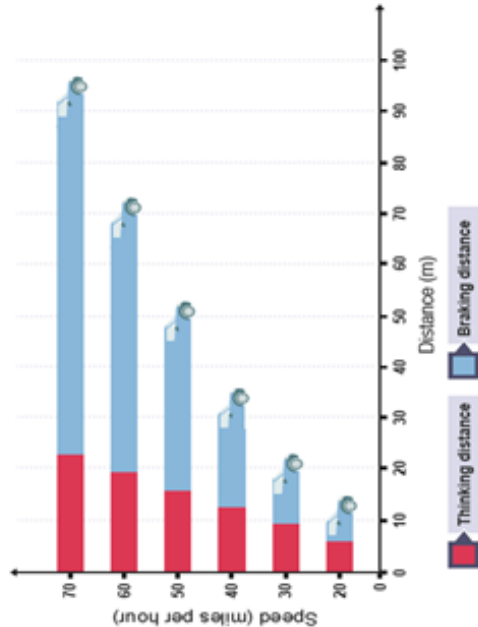
The braking distance of a car can be affected by:

- **wet or icy road conditions**
- **faulty tires or brakes**.

6.5.4.3.4 Factors affecting braking distance 2

When a force is applied to the brakes of a vehicle, work done between the **brakes** and the **wheel** reduces the **kinetic energy** of the vehicle.

- This would increase the **temperature** of the brakes.
- **Large decelerations** may lead to **brakes overheating** and maybe the **loss of control**.



4.5.7.1. Momentum (HT)

Momentum is a property of moving objects. Momentum can be calculated by the equation:

$$\text{Momentum} = \text{mass} \times \text{velocity}$$

$$(\text{kg m/s}) \quad (\text{kg}) \quad (\text{m/s})$$

$$p = m \times v$$

- momentum, p , in kilograms metre per second,
- kg m/s mass, m , in kilograms, kg
- velocity, v , in metres per second, m/s

Calculate the momentum of a 85kg cyclist travelling at 7m/s

$$p = m \times v$$

$$p = 85\text{kg} \times 7\text{m/s}$$

$$p = 595\text{kg m/s}$$



4.5.7.2 Conservation of Momentum

In a closed system, the total momentum before an event is **equal** to the total momentum after the event; this is called **conservation of momentum**.

- Conservation of momentum explains why a gun or cannon **recoils backwards** when it is fired.

- When a cannon is fired, the cannon ball gains **forward momentum** and the cannon gains **backward momentum**.

- Before the cannon is fired (the 'event'), the total momentum is zero. This is because **neither object is moving**.

- The **total momentum** of the cannon and the cannon ball after being fired is also zero, with the cannon and ball moving in **opposite directions**.

4.5.7.3 Changes in Momentum

When a force acts on a moving or moveable object there is a change of momentum.

The equations for calculating force and acceleration can be combined:

$$F = m \times a$$

$$a = (v - u) \div t$$

$$F = \frac{m \Delta v}{\Delta t}$$

This equation tells you that the **force is equal to the rate of change of momentum** in the object.

A lorry with a mass of **12 000kg**, travelling at **20m/s**, collides with a **stationary** car with a mass of **1500kg**. After the collision, the vehicles move off together.



Calculate their velocity.

Step 1: find the momentum of each vehicle before the collision.

Calculate the **momentum** of the lorry: $p = m \times v$

$$\text{Lorry} \rightarrow p = 12\,000 \times 20 = 240\,000 \text{ kg m/s}$$

Calculate the momentum of the car: $p = m \times v$

$$\text{Car} \rightarrow p = 1500 \times 0 = 0 \text{ kg m/s}$$

Step 2: find the total momentum (lorry + car) **before** the collision.

$$\text{total momentum before} = 240\,000 + 0 = 240\,000 \text{ kg m/s}$$

Step 3: use the law of conservation of momentum and rearrange the equation.

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

total momentum before collision = total momentum after collision

$$V = p/m = 240\,000 \text{ kg m/s} \div (12\,000 + 1500) = 17.78 \text{ m/s.}$$

Units of momentum are **kg m/s**

Knowledge Organiser – 6.5 Forces (Sep Physics 4.5)

4.5.4 Moments

A moment is the turning effect produced by a force. To find the size of a moment, use the equation:

$$\text{moment (Nm)} = \text{force (N)} \times \text{distance (m)}$$

Remember that the distance is the perpendicular distance from the pivot to the line of action of the force.

4.5.4 Worked example

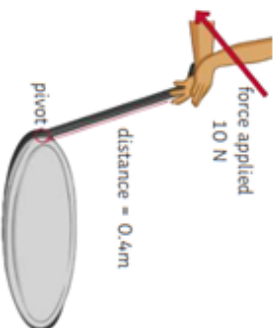
A crowbar is being used to lift a manhole cover.

Calculate the moment produced.

$$M = F \times d$$

$$M = 10\text{ N} \times 0.4\text{ m}$$

$$M = \underline{40\text{ Nm}}$$



To increase the turning effect achieved without increasing the amount of force applied, you would need to increase the distance between the force and the pivot.

For example, if the crowbar in the example above was 0.5m, then the moment would be:

$$M = F \times d$$

$$M = 10\text{ N} \times 0.5\text{ m}$$

$$M = \underline{50\text{ Nm}}$$

4.5.4 Levers

Levers can be used to increase the effect of a force applied, acting as a force multiplier. Some everyday examples include:

spanner



wheelbarrow

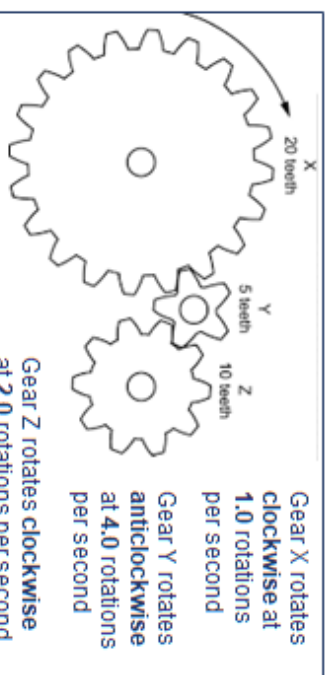
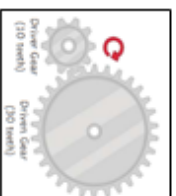


pair of scissors



4.5.4 Gears

- A force multiplier makes it easier to do work because the same force applied at a greater distance from the pivot increases the moment produced.
- A gear is a wheel which has 'teeth' around the circumference.
- The teeth of different gears lock together and the gear can turn on an axle, turning the other gears it is connected to. Where the teeth meet, they must move in the same direction.
- This means that the gears rotate in opposite directions. If one gear is turning clockwise, it will turn the connected gear anticlockwise.
- When gears are connected, the same force is applied to each; however, if they are different sizes, they will produce different moments.
- This is because the moment is calculated using the distance from the pivot (the radius of the gear) and if the gear is smaller, it will move a shorter distance.
- If the gear is larger, it will move a greater distance.



4.5.4 Balancing Moments

When the anticlockwise moment on an object is equal to the clockwise moment, the resultant moment is zero and the object does not move or turn.

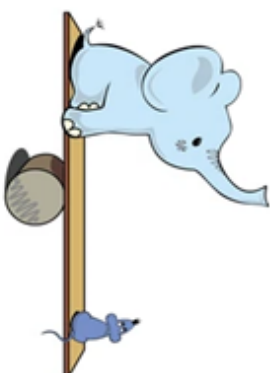
To balance moments:

$$\text{total anticlockwise moments} = \text{total clockwise moments}$$

Worked example:

An elephant sits on a seesaw. It has a weight of 750N and is sat 2.5m from the pivot. A mouse with a weight of 60N is sitting on the other side of the seesaw. The seesaw is balanced.

What distance is the mouse from the pivot?



Step 1:	Step 2:	Step 3:
Calculate the anticlockwise moment.	total anticlockwise moments = total clockwise moments	Use the value calculated for the moment to find the distance on the clockwise side.
$M = F \times d$	$1875\text{ Nm} = 1875\text{ Nm}$	rearrange: $d = M \div F$
$= 750\text{ N} \times 2.5\text{ m}$		$d = 1875 \div 60$
$= 1875\text{ Nm}$		$d = 31.25\text{ m}$

4.5.4 Worked example

A gear has a radius of 0.25m. It turns a second gear with a radius of 1.5m. The moment of the smallest gear is 30Nm.

Calculate the moment of the largest gear.

Step 1: calculate the force using

$$M = F \times d$$

$$\text{Rearrange to } F = M \div d$$

$$F = 30 \div 0.25$$

Step 2: use the force to calculate the moment of the larger gear.

$$M = F \times d$$

$$M = 120 \times 1.5$$

$$M = \underline{180\text{ Nm}}$$

Knowledge Organiser – 6.5 Forces (Sep Physics 4.5)

4.5.5 Pressure and Pressure Difference in Fluids

4.5.5.1 Pressure in a fluid

A fluid is any material that flows - liquid or gas.
The pressure in a fluid causes a force at a right angle (normal) to the surface.

The pressure is calculated using the equation:

pressure (Pa) = force (N) surface area (m²)

Worked example 1:

Find the pressure exerted by an elephant on a frozen pond. The force exerted by the elephant is 4500N and the area of the pond is 30m².

$$p = 4500 \div 30$$

$$p = 150\text{Pa}$$

4.5.5.2 Atmospheric Pressure

- ☐ Surrounding the earth is a layer of air called the atmosphere.
- ☐ Compared to the size of the planet, this layer is relatively thin.
- ☐ The air becomes less dense the farther from the planet's surface you are (with increasing altitude).
- ☐ When the air molecules collide with the surface of the earth, pressure is exerted and this is called atmospheric pressure.
- ☐ The amount of air molecules above a surface decreases with altitude and so the pressure exerted also decreases with increasing height.

Worked example 2

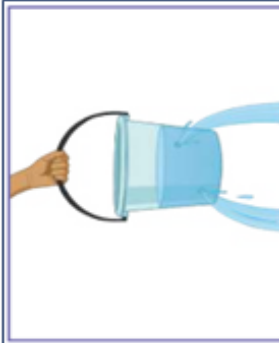
The density of water is 1,000 kg/m³. Calculate the pressure exerted by the water on the bottom of a 2.0 m deep swimming pool. (g = 9.8 N/kg).

4.5.5.2 – Pressure in a fluid (HT)

You can find the pressure produced by a column of liquid using the equation:

pressure = height of column × density of liquid × gravitational field strength
(Pa) (m) (kg/m³) (N/kg)

The more water above an object, the greater the force applied and the greater the pressure exerted.



Demo 1

Water leaking from the hole higher up the bucket will be at a lower pressure than water leaking from the hole lower in the bucket.



Demo 2

When an object is submerged partially, it will have a greater pressure on the bottom surface than on the top surface (there is more water behind the force acting upwards). This creates an upwards resultant force called upthrust and this is what causes an object to float.

Worked example 3

A stone is dropped into a lake. Calculate the increase in pressure on the stone caused by the water when it sinks from 1m deep to 6m deep. (The density of water is 1,000 kg/m³ and gravitational field strength is 9.8 N/kg).

$$\text{change in depth} = 6 - 1 = 5 \text{ m}$$

$$p = h \rho g$$

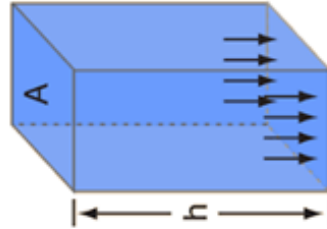
$$p = 5 \times 1,000 \times 9.8$$

$$p = 49,000 \text{ Pa}$$

$$p = h \rho g$$

$$p = 2.0 \times 1,000 \times 9.8$$

$$p = 19,600 \text{ Pa}$$



Pressure at depth h:
 $p = \rho gh$

Lower case p is **ALSO** the symbol for **momentum**

Not to be confused with...

Symbol for

density is the

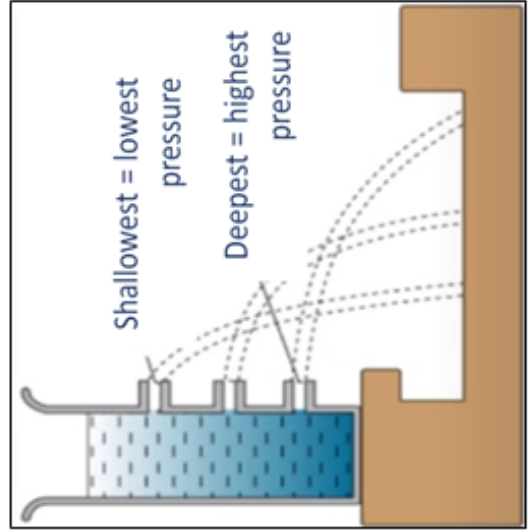
lower case

Greek letter rho.

Pronounced like "row".

It looks like a fancy "p".

Not to be confused with...



Knowledge Organiser – 6.5 Forces

6.5.1.1 Scalar and vector quantities

Scalar quantities have **magnitude (size) only**.

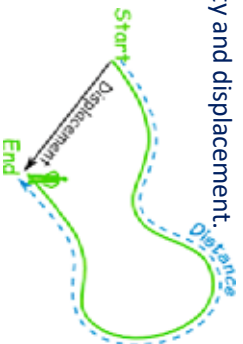
- Represented by a **number**.

Example: speed and distance.

Vector quantities have **magnitude and direction**.

- Represented by a **number and an arrow**.

Example: velocity and displacement.



6.5.1.2 Contact and non-contact forces

A **force** is a **push or pull** that acts on an object when it interacts with another object.

A **force** is a **vector quantity**.

- Contact forces** – the objects are **touching** each other.
Example: friction, air resistance, and tension.
- Non-contact forces** – the objects are **separated**.
Example: magnetic and gravitational force.

6.5.1.3 Gravity

Weight is the force acting on an object due to gravity.

This can be calculated by:

$$\text{Weight (N)} = \text{mass (kg)} \times \text{gravitational field strength (N/kg)}$$

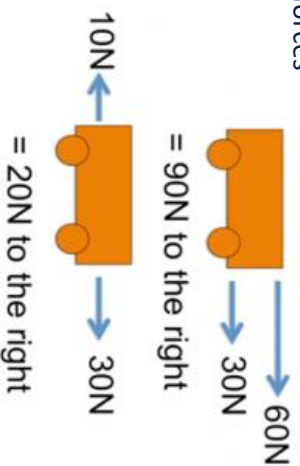
$$W = m \times g$$

The weight of an object acts at an object's '**centre of mass**'.

The weight and mass of an object are **directly proportional**.

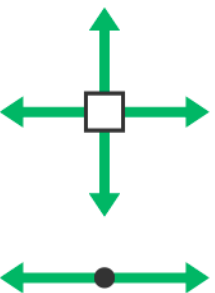
Weight is measured using a **newtonmeter**.

6.5.1.4 Resultant forces

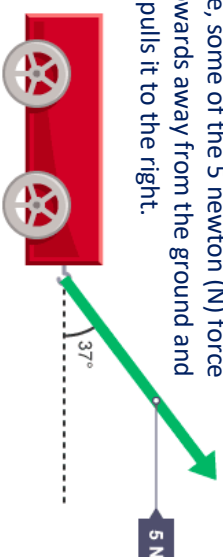


6.5.1.4 HT only

Free body diagram: models the forces acting on an object. The object or 'body' is usually shown as a box or a dot. The forces are shown as thin arrows pointing away from the centre of the box or dot.



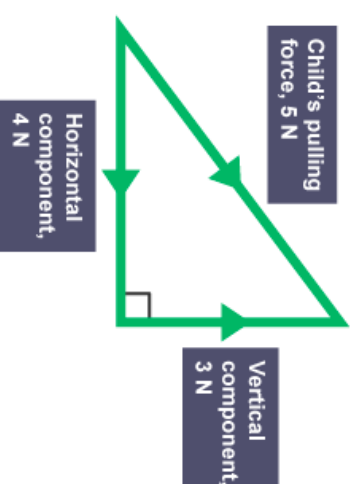
Resolving forces: Two forces can be added together to find a resultant force. A single force can be resolved (broken down) into two component forces at right angles to each other. In the diagram of a toy trailer below, when a child pulls on the handle, some of the 5 newton (N) force pulls the trailer upwards away from the ground and some of the force pulls it to the right.



Vector diagrams: can be used to resolve the pulling force into a horizontal component acting to the **right** and a vertical component acting **upwards**.

Draw a right-angled triangle to scale, in which each side represents a force.

- For the toy trailer example above, draw:
- a line representing the 5 N force at 37°
 - a horizontal line ending directly below the end of the first line
 - a vertical line between the ends of the two lines
 - arrow heads to show the direction in which each force acts
- Measure the lengths of the horizontal and vertical lines. Use the scale for the first line to convert these lengths to the corresponding forces.



Knowledge Organiser – 6.5 Forces

6.5.2 Work Done and Energy Transfer

When a **force** causes an object to move a **distance**, **work** is done on that object.

$$\text{Work done (J)} = \text{Force (N)} \times \text{distance (m)}$$

$$W = F \times s$$

- work done, W , in joules, J
- force, F , in newtons, N
- distance, s , in metres, m
- One joule of work is done when a force of one newton causes a displacement of one metre.
- 1 joule = 1 newton-metre

6.5.3 Forces and elasticity

- To change the shape of a stationary object (by stretching, bending or compressing), **more than one force has to be applied**
- The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.

$$\text{Force (N)} = \text{spring constant (N/m)} \times \text{extension (m)}$$

$$F = k \times e$$

- Force, F , in newtons, N
- spring constant, k , in newtons per metre, N/m
- extension, e , in metres, m
- Also applies to the **compression** of an elastic object, where 'e' would be the compression of the object.
- A force that stretches (or compresses) a spring does work and **elastic potential energy is stored in the spring**. Provided the spring is not inelastically deformed, the **work done on the spring and the elastic potential energy stored are equal**.

$$\text{elastic potential energy} = 0.5 \times \text{spring constant} \times \text{extension}^2$$

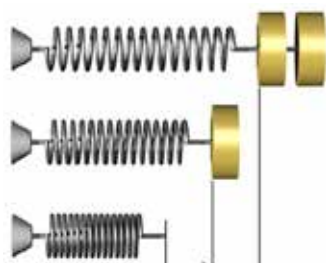
$$E_e = \frac{1}{2} k e^2$$

RPA: Investigate the relationship between force and extension for a spring

When a force acts on an **elastic** object, the object will extend a proportional amount until it is **permanently deformed** (won't return to original shape).

By **adding more weight** to a spring and measuring its **extension**; the extension of a spring can be found.

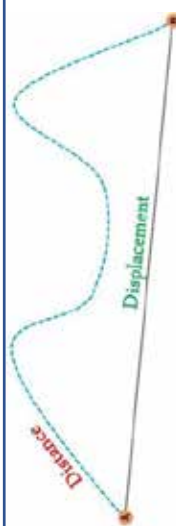
You may also have to use the equation in the equation sheet to find the elastic potential energy.



6.5.4.1.1 Distance and displacement

Displacement is how far an object moves in a straight line from start to finish. It is **vector**.

Distance is how far an object moves. It is **scalar**.



6.5.4.1.2 Speed

- Speed is a **scalar** quantity. The speed of moving objects often varies greatly.
- The typical speed of sound is 330 m/s.
- The speed at which a person can walk, run or cycle depends on many factors including: age, terrain, fitness and distance travelled.

- Typical values may be taken as:

walking- 1.5 m/s

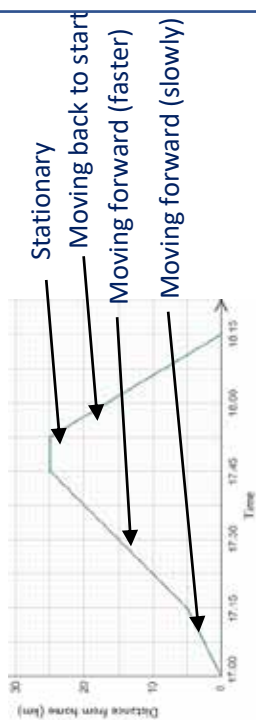
running- 3 m/s

cycling- 6 m/s.

For an object travelling at a constant speed:

$$\text{Speed (m/s)} = \text{distance (m)} \div \text{time (s)}$$

$$v = s \div t$$



6.5.4.1.4 Distance-time relationship

- If an object moves along a straight line, the distance travelled can be represented by a distance–time graph.
- The speed of an object can be calculated from the gradient of its distance–time graph

(HT only) If an object is accelerating, its **speed at any particular time** can be determined by **drawing a tangent** and **measuring the gradient** of the distance–time graph at that time

6.5.4.1.3 Velocity

Velocity is the **speed** in a **direction**. It is a **vector**.

(HT only) **Motion in a circle involves constant speed but changing velocity**.

Knowledge Organiser – 6.5 Forces

6.5.4.1.5 Acceleration

Average acceleration can also be calculated using:

$$\text{Acceleration (m/s}^2\text{)} = \text{change in velocity (m/s)} \div \text{time (s)}$$

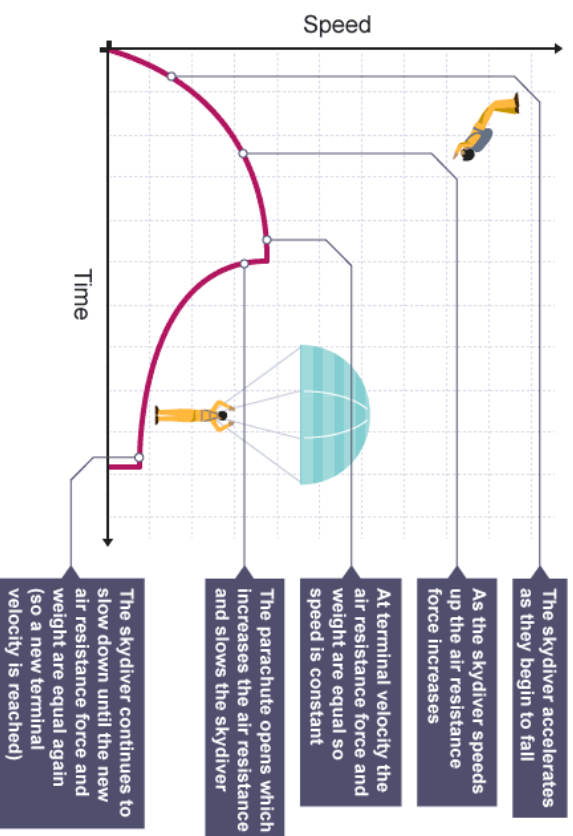
$$a = \Delta v \div t$$

- acceleration, a , in **metres per second squared**, m/s^2
- change in velocity, Δv , in **metres per second**, m/s
- time, t , in **seconds**, s
- An object that **slows down** is **decelerating**.
- The **acceleration** of an object can be calculated from the **gradient of a velocity–time** graph.

Uniform acceleration can also be calculated using:

$$(final\ velocity)^2 - (initial\ velocity)^2 = 2 \times acceleration \times distance$$

- final velocity, v , in **metres per second**, m/s
- initial velocity, u , in **metres per second**, m/s
- acceleration, a , in **metres per second squared**, m/s^2
- distance, s , in **metres**, m



6.5.4.2.1 Newton's first law

An object will not move or change speed unless a force acts on it.

- A stationary object will stay **stationary**.
- A moving object will continue at a **constant speed**.

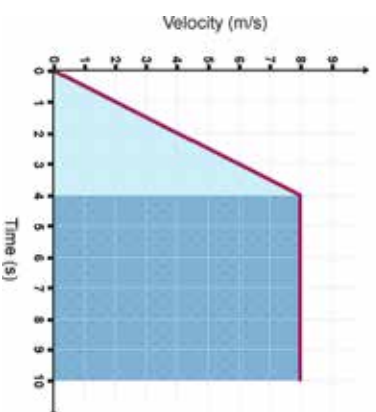
(HT only) The **tendency of an object to stay still or stay at a constant speed is inertia**.

6.5.4.2.3 Newton's third law

When two objects interact, the forces they exert on each other are **equal and opposite**.

6.5.4.1.5 Acceleration (HT Only)

HT only: The distance travelled by an object (or displacement of an object) can be calculated from the area under a velocity-time graph.



6.5.4.2.2 Newton's second law

The **acceleration** of an object depends on mass and force.

- If the mass **increases** and the force **stays the same**, the acceleration **decreases**.
- If the mass **stays the same** and the force **increases**, the acceleration **increases**.

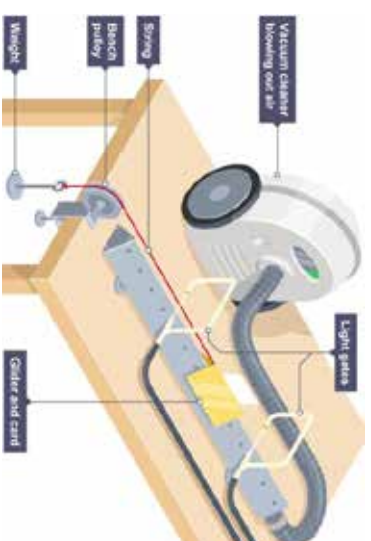
$$\text{Force (N)} = \text{mass (kg)} \times \text{acceleration}$$

$$F = m \times a$$

(HT only) **inertial mass**:

- measure of **how difficult it is to change the velocity** of an object
- the **ratio of force over acceleration**.

RPA investigate the effect of varying the force on the acceleration of an object of constant mass, and the effect of varying the mass of an object on the acceleration produced by a constant force.



Knowledge Organiser – 6.5 Forces

6.5.4.3.1 Stopping distance

The stopping distance of a vehicle is the sum of the drivers **reaction time (thinking distance)** and the **braking distance**.

Greater speed = greater stopping distance

6.5.4.3.2 Reaction time

Reaction times vary from person to person but are usually in the range of **0.2 s to 0.9 s**.

A drivers reaction time is affected by **tiredness, distractions, drugs and alcohol**.

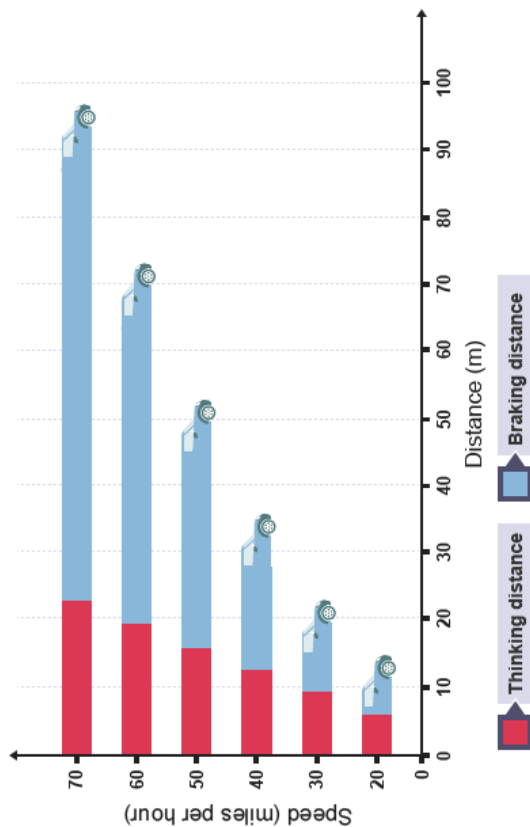
There are different ways to measure reaction times.

- One simple method involves dropping a ruler between someone's open thumb and forefinger.
- The higher the reaction time needed to grasp the falling ruler, the further the ruler falls before being stopped.

6.5.4.3.3 Factors affecting braking distance 1

The braking distance of a car can be affected by:

- **wet or icy road conditions**
- **faulty tires or brakes.**



6.5.4.3.4 Factors affecting braking distance 2

When a force is applied to the brakes of a vehicle, work done between the **brakes** and the **wheel** reduces the **kinetic energy** of the vehicle.

- This would increase the **temperature** of the brakes.
- **Large decelerations** may lead to brakes **overheating** and maybe the **loss control**.

6.5.5. Momentum (HT only)

Momentum is a property of moving objects.

Momentum can be calculated by the equation:

$$\text{Momentum (kg m/s)} = \text{mass (kg)} \times \text{velocity (m/s)}$$

$$p = m \times v$$

- momentum, p , in kilograms metre per second,
- kg m/s mass, m , in kilograms, kg
- velocity, v , in metres per second, m/s

In a closed system, the total momentum before an event is **equal** to the total momentum after the event; this is called **conservation of momentum**.

- Conservation of momentum explains why a gun or cannon recoils backwards when it is fired.
- When a cannon is fired, the cannon ball gains forward momentum and the cannon gains backward momentum.
- Before the cannon is fired (the 'event'), the total momentum is zero. This is because neither object is moving.
- The total momentum of the cannon and the cannon ball after being fired is also zero, with the cannon and cannon ball moving in opposite directions.

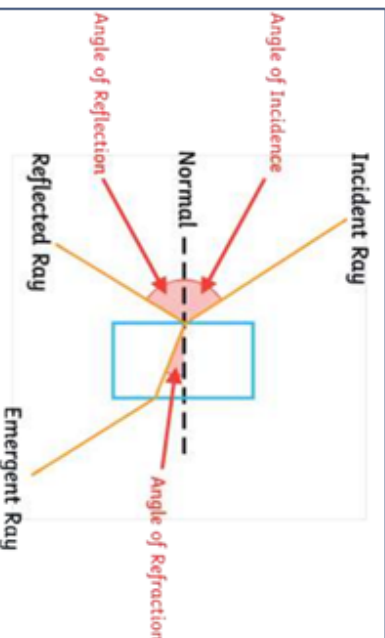
Knowledge Organiser – 6.6 Waves (4.6 Separate Physics)

RPA – Reflection of light

Aim: Investigate the reflection of light by different types of surface and the refraction of light by different substances. **Method:**

1. In a darkened room, set up the ray box on a flat surface and insert the filter to produce a single ray of light.
2. Place a glass block in the centre of a piece of plain A3 paper.
3. Draw a line around the glass block.
4. Draw a line at 90° to the glass block and label the line normal, as shown in the diagram.
5. Position the ray box so the ray of light hits the glass at an angle.
6. Using a pencil, draw the incidence, reflected and emergent rays as shown in the diagram.
7. Remove the glass block and draw the refracted ray going through the block
8. Using a protractor, measure the angles of incidence, reflection and refraction. Record your results.
9. Repeat the experiment by placing a clear acrylic block on the A3 paper in the same position as the glass block.
10. The incident ray must follow the same line as before. Draw the reflected and refracted rays and measure using a protractor.
11. Collect four sets of results from other members of the class.

The law of reflection states:
angle of incidence = angle of reflection

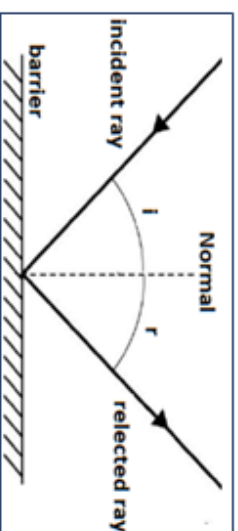
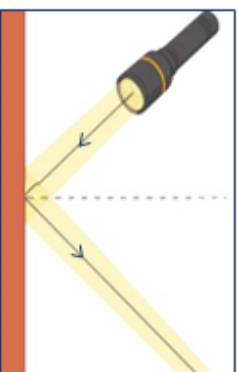


RPA Risk assessment:

- ☐ The ray box will become hot during use and may cause minor burns. To prevent this, you should not touch the lamp and ensure you allow time for the ray box to cool after use.
- ☐ You will be working in a semi-dark environment which means there is a higher risk of trips or falls. You should ensure your working space is clear of bags and coats, and that stools are tucked under desks before you start your investigation.

4.6.1.3 Reflection of Waves

- o When a wave comes into contact with a surface or a boundary between two media (different materials), it can be reflected or it can be absorbed.
- o What happens depends on the properties of the surface the wave hits.
- o Specular reflection occurs when a wave is reflected in a single direction from a perfectly smooth surface.



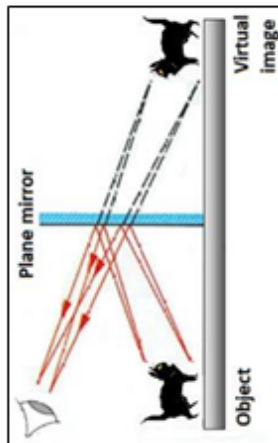
Key Terms 4.6.1.3

- Reflect** The wave bounces off a surface; the angle of incidence is equal to the angle of reflection.
- Refract** The wave changes direction when it enters a medium of different density where it has a different speed.
- Normal** The normal at a point on a mirror is a line drawn perpendicular to the mirror at the point of incidence.
- Law of reflection** The law of reflection states that the angle of incidence = the angle of reflection.
- Plane mirror** A mirror with a flat (planar) reflective surface.
- Real image** An image that can seen on a screen because it is formed by focussing light rays onto the screen.
- Virtual image** An image formed at a place where the light rays appear to come from after they've been reflected (or refracted)
- Specular** Reflection from a smooth surface, parallel rays are reflected in a single direction.
- Diffuse** Reflection from a rough surface, parallel rays are scattered in different directions.
- Transparent** A transparent object lets all light that enters it pass through (and doesn't scatter or refract the light.)
- Translucent** A translucent object lets light pass through but it scatters (or refracts) the light inside it

Knowledge Organiser – 6.6 Waves (4.6 Separate Physics)

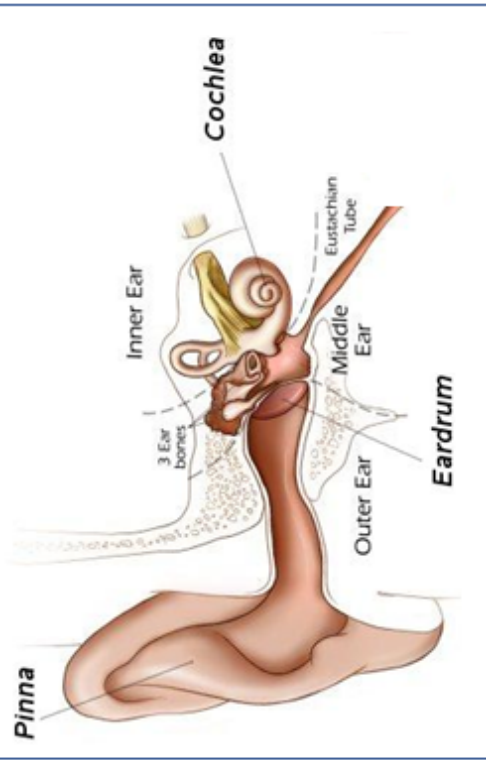
4.6.1.3 Image formed by a plane mirror

The image formed by a plane mirror is **virtual, upright and laterally inverted** (back to front but not upside down.)



4.6.1.4 Sound Waves (HT)

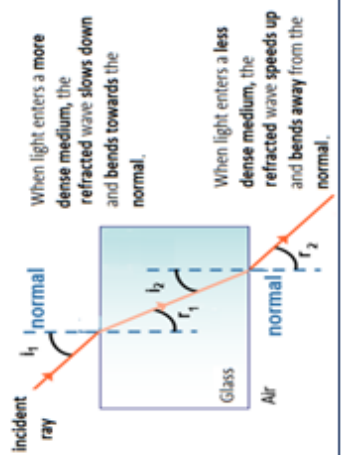
- A sound wave can travel through a **solid material**.
- This is because the **space** between the particles is so **small** (almost non-existent) and the vibrations are transmitted **more quickly** than in liquids or gases.
- The **speed of sound in air** is about **330m/s**. As the majority of space is a **vacuum** (no particles), sound waves do not travel in space.
- Sound waves within the range of **20Hz to 20kHz** can usually be detected by the **human ear**.
- **Vibrations** are passed along air particles down the ear canal and to the ear drum.
- The ear drum **vibrates and transmits** this to the **small ear bones** and then along the **cochlea**.
- The cochlea carries the vibrations to the **auditory nerve** which carries the sound wave as an **electrical impulse** to the brain.



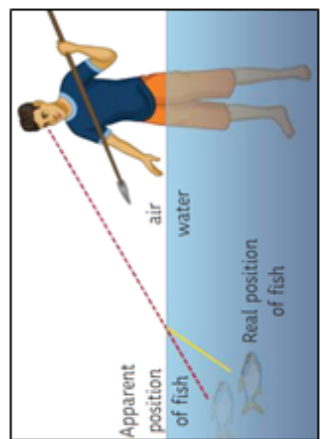
4.6.2.2 Refraction of light (HT)

Refraction is a change in direction of waves when they travel across a boundary from one medium to another.

- When a light enters a more dense medium (air into glass) the angle of refraction r_1 is less than the angle of incidence i_1 .
- When light enters a less dense medium (from glass into air,) the angle of refraction r_2 is more than the angle of incidence i_2 .

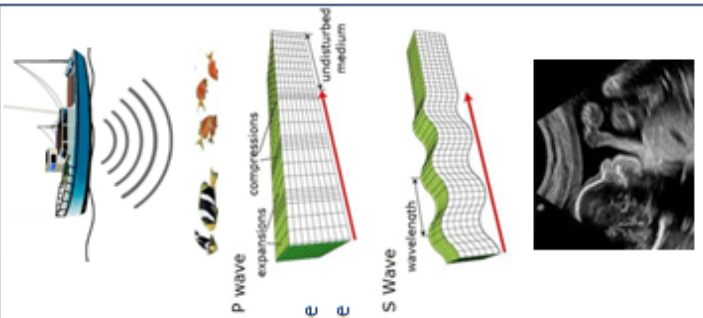


Refraction occurs when a wave changes direction, usually at the boundary of two different materials. The density of the material affects the speed at which the wave can travel through it. When a wave passes from a more dense material to a less dense material, it speeds up and so will bend. Imagine a car travelling across a muddy river at an angle. As it approaches the bank of the river, one of the wheels will be on the dry bank while the other is still in the mud. The wheel on the dry bank will move faster than the one still in the mud and it will change direction.



4.6.1.5 Waves for detection and exploration (HT)

- **Deep sea:** A high-frequency sound wave is sent out through the water & the time taken for the pulse to reflect back is measured. distance from object (m) = speed (of sound) (m/s) $\times$ time (s)
 - **Earth structure:** Volcanoes, earthquakes and explosions cause seismic waves to travel through the earth.
 - P-waves = **longitudinal** = travel quickly through **solids and liquids**.
 - S-waves = **transverse** = travel slower and only in **solids**.
- Seismic waves can **change direction** when they are reflected or refracted at the boundary of **different media** (solid, liquid or gas). The **epicentre** of an earthquake can be found by calculating the difference in **time taken** for S- and P-waves to reach a **certain point**. Since the waves can change direction, at **least three points** are used to triangulate the data and pinpoint the **source** (where they all **intersect**). The study of seismic waves has given scientists **new evidence** about the structure of the earth in parts which are **not visible for direct observations**.
- **Inside the Body:** Ultrasound = higher frequency than the range which is detectable by the human ear. When the waves reach a different media, they are **partially reflected** and a detector is used to measure the **time taken** and calculate the **distance**. Ultrasound is used for **medical and industrial imaging**.



Knowledge Organiser – 6.6 Waves (4.6 Separate Physics)

4.6.2.5 Lenses

- Lenses use refraction in order to work.
- Projectors, microscopes and telescopes all use lenses to allow an object or image to be enlarged or viewed more easily.
- The human eye contains a lens which enables us to see objects at a range of distances.
- Depending on the type of lens, the light waves will be refracted differently to produce a different image.
- The two main lenses are convex lenses and concave lenses

The table below compares them briefly.

convex lens	Lens	concave lens
	Ray Diagram	
Causes parallel waves to converge at the principal focus.	Action	Causes parallel waves to diverge from the principal focus.
	Type of image	always virtual

- A real image is when light reflected from an object converges to form an image on a surface. For example, on the retina of the human eye.
- A virtual image occurs when the light waves are diverging and so appears to be coming from a different place. A virtual image cannot be projected onto a screen. For example, a mirror produces a virtual image.
- A magnifying glass uses a converging (convex) lens. It produces a virtual image which appears larger than the actual object.
- The magnification can be calculated using the equation:

$$\text{magnification} = \frac{\text{image height (mm)}}{\text{object height (mm)}}$$

4.6.2.5 Lenses – Key Terms

Convex lens → Focuses parallel rays to a point called the principal focus.

Principal focus → The point where parallel rays are focussed to.

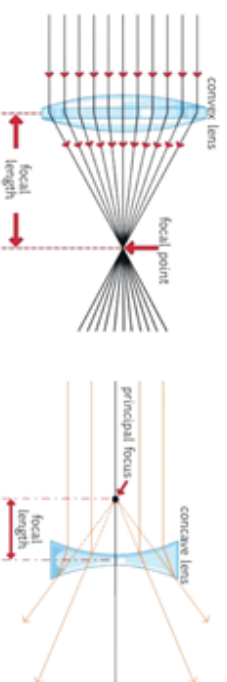
Concave lens → A concave lens (or diverging lens) makes parallel rays spread out as if they had come from a point called the principal focus.

Magnification → The image height ÷ the object height.

Focal length → Distance from the centre of a lens to the point where light rays parallel to the principal axis are focussed.

Magnifying lens → A convex lens used to form a virtual image of an object.

- An imaginary horizontal line through the middle of the lens is called the axis and this is where the principal focus forms.
- In a convex lens, the light rays enter the lens parallel to one another and then converge at the principal focus after the lens.
- In a concave lens, the light rays enter the lens parallel to one another and then diverge.
- The principal focus is the virtual source of the diverging rays before the lens



$$\text{power (D)} = \frac{1}{\text{focal length (m)}}$$

- D stands for dioptres which is the unit of measurement for lens power.
- In a converging lens the power is a positive value.
- In a diverging lens the power is a negative value.

$$\frac{1}{\text{focal length}} = \frac{1}{\text{distance between lens and object}} + \frac{1}{\text{distance between lens and image}}$$

➤ Focal length depends on two factors: the refractive index of a material and how curved the surfaces of the lenses are.

➤ A higher refractive index makes the lens flatter in shape.

➤ To make a powerful lens thinner, a material with a higher refractive index can be used.

➤ Objects which are a distance greater than one focal length away from a converging lens will produce a real image.

➤ Objects which are closer than one focal length from the converging lens will produce a virtual image.

➤ The lens equation can be used to show the relationship between focal length, position of the object and position of the image:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

4.6.2.6 Visible Light

The colours of the visible spectrum can be remembered with the rhyme:

Richard Of York Gave Battle In Vain

(red – orange – yellow – green – blue – indigo – violet)



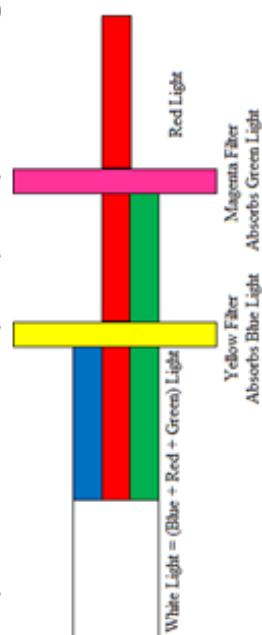
- ✓ These are all the wavelengths which are visible and detectable by the human eye.
- ✓ Each colour has a narrow range of wavelength and frequency within the spectrum.
- ✓ White light is the combination (full spectrum) of wavelengths in the visible light region of the electromagnetic spectrum.
- ✓ The Sun is a natural source for visible light waves and our eyes see the reflection of this sunlight off the objects around us.

Knowledge Organiser – 6.6 Waves (4.6 Separate Physics)

4.6.3 Black Body Radiation

4.6.3.1 Emission and absorption of infrared radiation

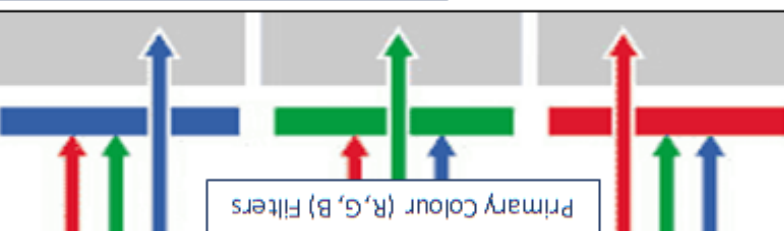
- A colour filter absorbs some wavelengths and only transmits certain wavelength(s).
- This means that a filter will absorb some colours and transmit others.
- E.g. red filter absorbs all other colours in the spectrum except red, which it transmits.
- Secondary colour filters allow only their primary colours through e.g.



- An object which is transparent (see-through) or translucent (partially see-through) can transmit light.
- Opaque objects reflect and absorb light.
- The wavelengths which are reflected or absorbed determine the colour which the object is perceived

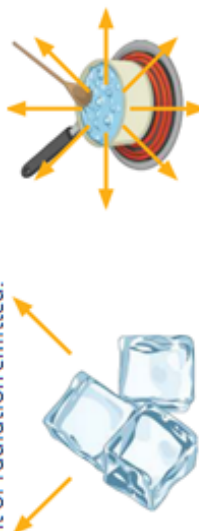


- An object which absorbs all wavelengths will appear black. An object which reflects all wavelengths will appear white.



4.6.3.2 Perfect Black Bodies and Radiation

All objects emit and absorb infrared radiation. The hotter an object is, the greater the amount of radiation emitted.



- An object which absorbs all the radiation it is exposed to is called a **perfect black body**. No radiation is **reflected from or transmitted through** it.
- A perfect black body would be the **most effective emitter**
- An object which is a **good absorber** is also a **good emitter**.

(HT) 		
An object absorbing and emitting infrared radiation at the same rate has a constant temperature.	An object emitting more than it is absorbing will decrease in temperature.	An object absorbing more than it is emitting will increase in temperature.

4.6.3.2 Temperature of the Earth (HT)

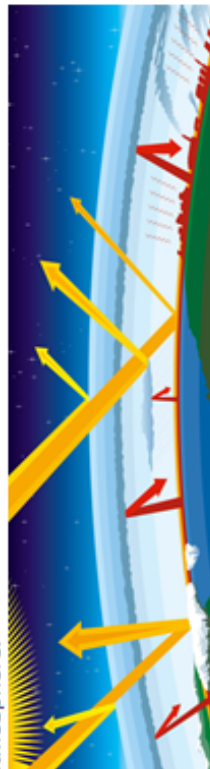
The temperature of the earth depends on:

- The rate at which light radiation and infrared radiation are absorbed by the earth's surface and atmosphere.
- The rate at which light radiation and infrared radiation are emitted by the earth's surface and atmosphere.

□ Light and infrared radiation absorbed by the earth cause the **internal energy** of the planet to **increase** and in turn, the **surface temperature** of the earth **increases**.

□ Energy from the surface of the earth can be transferred to the atmosphere by **conduction and convection**.

□ The infrared radiation emitted from the earth's surface will either travel through the atmosphere and back into space or it will be absorbed (and reflected) by the greenhouse gases in the earth's atmosphere.



Knowledge Organiser – 6.6 Waves

6.6.1.1 Transverse and longitudinal waves

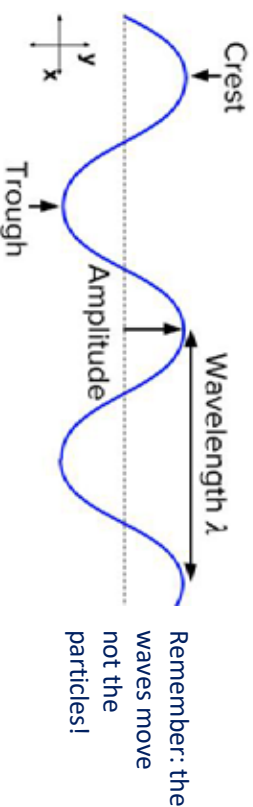
Waves can either be **transverse** or **longitudinal**.

1) Transverse waves

In **transverse** waves, the particles in the wave move **perpendicular** to the direction of the wave.

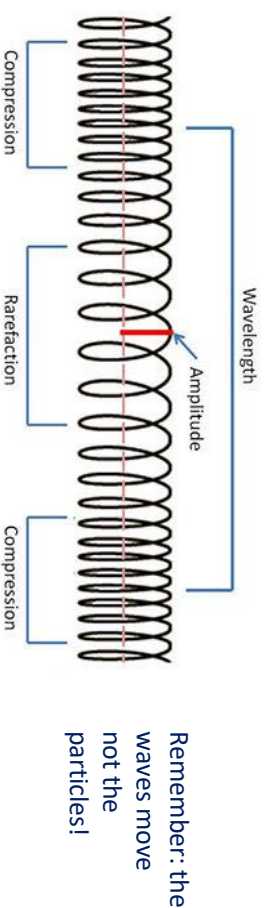
An example is a ripple on water or an electromagnetic wave.

It is the wave that travels NOT the water.



2) Longitudinal waves

In **longitudinal** waves, the particles in the wave move **parallel** to the direction of the wave. An example is a sound wave.



6.6.1.2 Properties of waves

Amplitude: the maximum displacement of a point on a wave from the undisturbed point.

Wavelength: the distance between a point on a wave and the same point on the next wave. Measured in metres (m).

Frequency: the number of waves passing a point each second. Measured in Hertz (Hz)

Period: time span of one wave in seconds

$$\text{Period } (T) = \frac{1}{\text{Frequency } (f)}$$

period, T , in seconds, s
frequency, f , in hertz, Hz

Wave speed is the speed at which the energy is transferred (or the wave moves) through the medium. Measured in m/s

$$\text{Wave speed } (v) = \text{frequency } (f) \times \text{wavelength } (\lambda)$$

RPA: Measuring frequency, wavelength and speed of waves in solid and a liquid



Wavelength: Measure the length of a number of waves then divide by the number of waves to calculate the wavelength. It may be more practical to take a photograph of the card.

Frequency: Count the number of waves passing a point in ten seconds then divide by ten to record frequency.

Wave speed: Calculate the speed of the waves using

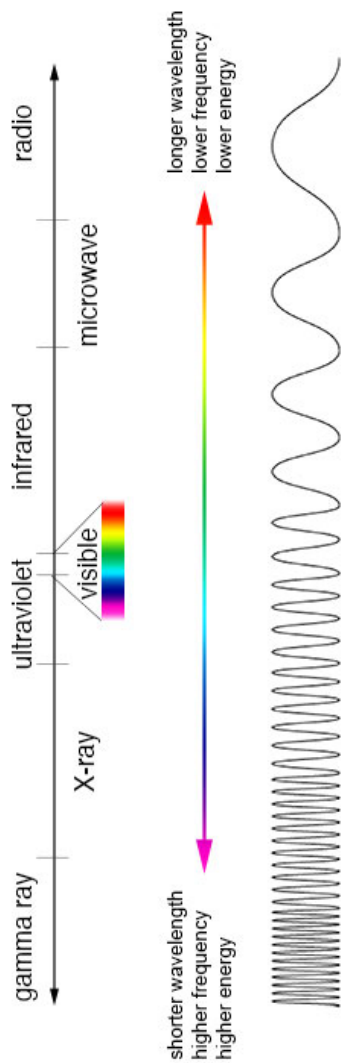
$$\text{Wave speed } (v) = \text{frequency } (f) \times \text{wavelength } (\lambda)$$

Knowledge Organiser – 6.6 Waves

6.6.2.1 Types of electromagnetic waves

Electromagnetic waves are **transverse** waves that transfer energy from a source to an absorber.

All electromagnetic waves travel at the same speed as each other through a vacuum or air.



6.6.2.3 Properties of electromagnetic radiation 2

Changes in **atoms and atomic nuclei** can generate or absorb electromagnetic radiation. Gamma rays, X-rays and ultraviolet waves are **ionising** and can have **hazardous effects** on human body tissues. The effect depends on the **dose and type** of radiation.

- UV rays can age skin prematurely and increase risk of skin cancer.
- Gamma rays and X-rays can mutate genes and cause cancer.

(HT only) **Radio waves** can be produced by **oscillations in electrical circuits**.

(HT only) 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**.

6.6.2.4 Uses and applications of electromagnetic waves

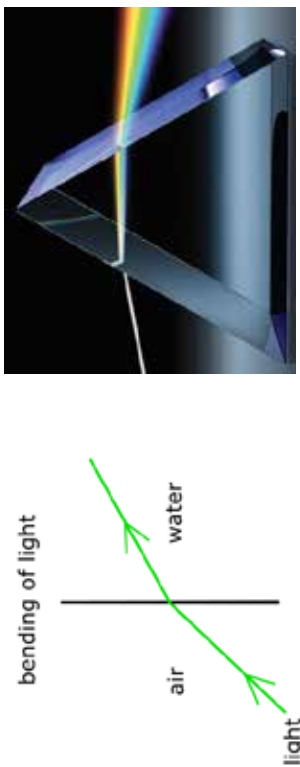
Different types of electromagnetic radiation have many uses:

- **Radio waves** – TV and radio
- **Microwaves** – Satellite communications and cooking food
- **Infrared** – Heating, cooking, and thermal cameras
- **Visible** – Fibre optic communication
- **Ultraviolet** – energy efficient lamps and sun tanning
- **X-ray and Gamma** – Medical imaging and treatment

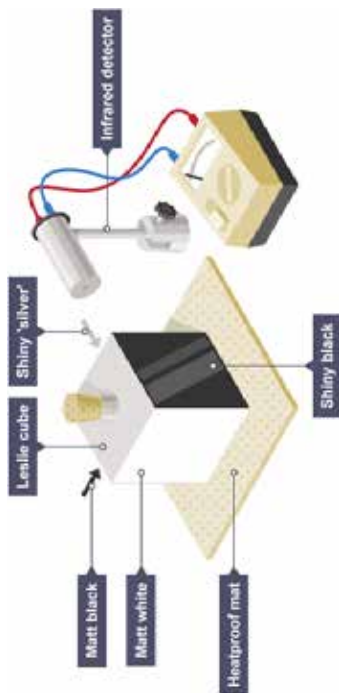
(If higher tier you need to explain why each type of wave is suitable)

6.6.2.2 Properties of electromagnetic waves 1

- (HT only) **Different substances may absorb, transmit, refract or reflect** electromagnetic waves in ways that **vary with wavelength**.
- (HT only) When electromagnetic waves meet a barrier of a **different density** they **change speed** and therefore direction. This is **refraction**..



RPA: Investigating the absorption or emission of IR radiation by nature of surfaces



1. Fill the **Leslie cube** with boiling water and replace the lid.
2. Leave for one minute to allow the surfaces to heat up.
3. Use the **infrared detector** to measure the intensity of infrared radiation emitted from each surface.

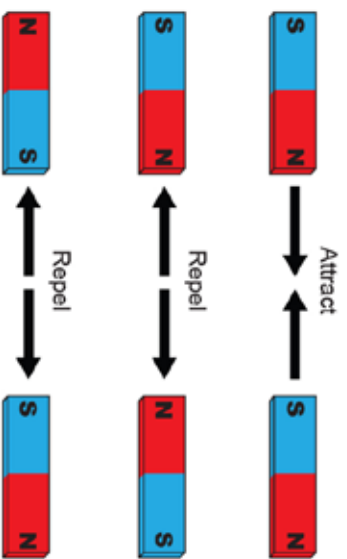
The **matte black** surfaces emit the **most** IR radiation.
The **shiny silver** emits the **least**.

Knowledge Organiser – 6.7 Magnetism and Electromagnetism

6.7.1.1 Poles of a magnet

The poles of magnet are where the magnetic forces are strongest. Two close together magnets will exert a non-contact force on each other.

- Two opposite poles will attract (north and south).
- Two similar poles will repel (north and north or south and south).

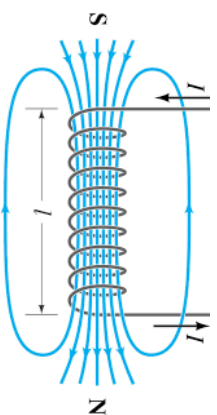


A **permanent magnet produces** its own magnetic field.

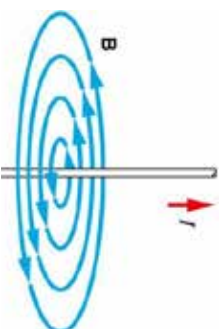
An **induced magnet** becomes a magnet when inside a magnetic field. Induced magnets lose their magnetism easily.

6.7.2.1 Electromagnetism

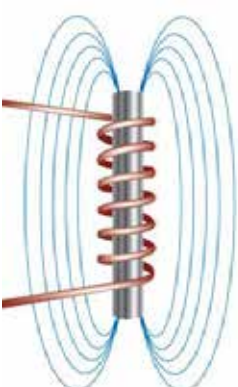
When a current flows through a wire a magnetic field is produced. The higher the current, the stronger the field.



If the wire is wrapped into a coil called a **solenoid** the magnetic field becomes **strong** and **uniform**. The magnetic field around a solenoid has a similar shape to that of a bar magnet.



Adding an iron core to a **solenoid** increases the strength of the magnetic field and turns it into an electromagnet.



How can we increase the strength of an electromagnet?

- **Increase the current**
- **Increase the size and number of coils.**



6.7.1.2 Magnetic field

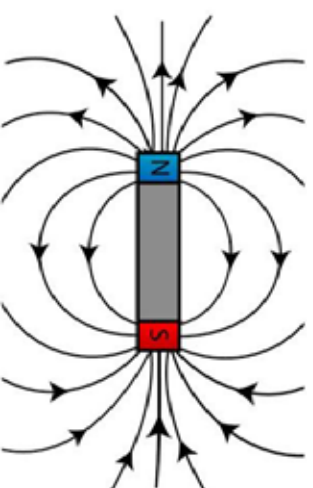
magnetic field : the region around a magnet where a force acts on another magnet or on a magnetic material (iron, steel, cobalt and nickel)

The **field of a magnet** always **flows from the north pole to the south pole**.

The **strength of the field** **increases as the distance from the magnet decreases**.

Magnetic materials **always attract** a magnet and include **iron, cobalt, nickel, and steel**.

A **compass** is a small bar magnet that is attracted to the **Earth's magnetic field**. A compass can be used to draw a magnets field.



Knowledge Organiser – 6.7 Magnetism and Electromagnetism

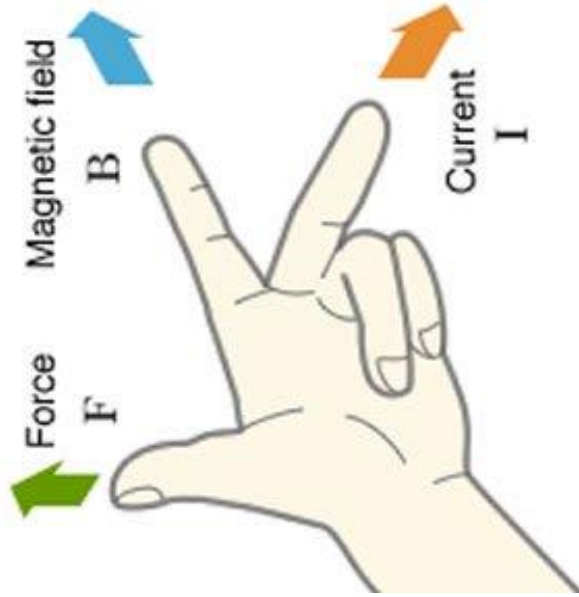
6.7.2.2. Fleming's left-hand rule (HT)

The **motor effect** when a conductor carrying a current is placed in a magnetic field the magnet producing the field and the conductor exert a force on each other.

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.



For a conductor at right angles to a magnetic field and carrying a current:

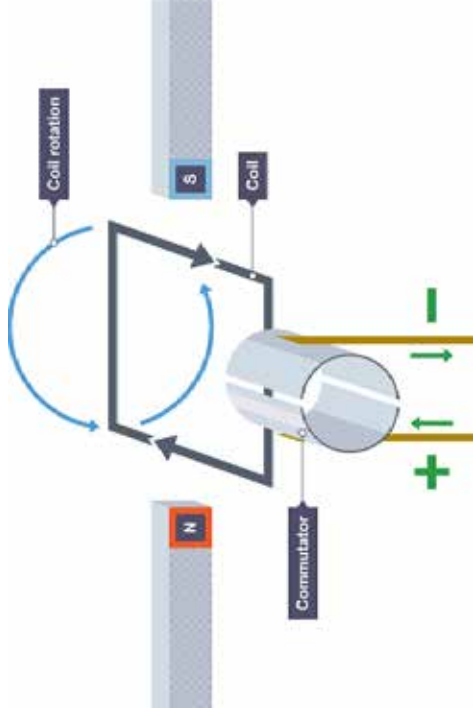
$$F = B \times I \times l$$

F = force measured in Newtons (N)
B = Magnetic flux density in tesla (T)

I = current in amperes (A)
l = Magnetic flux density in tesla (T)

6.7.2.3 Electric motors (HT)

A coil of wire carrying a current in a magnetic field tends to rotate. This is the basis of an electric motor.



Starting from the position shown in the diagram of the **dc motor**:

1. current in the left hand part of the coil causes a downward force, and current in the right hand part of the coil causes an upward force
2. the coil rotates anti-clockwise because of these forces
3. When the coil is vertical, it moves parallel to the magnetic field, producing no force. This would tend to make the motor come to a stop, but two features allow the coil to continue rotating:
 - the momentum of the motor carries it on round a little
 - a **split ring commutator** changes the current direction every half turn
4. Once the conducting brushes reconnect with the commutator after a half turn:
5. current flows in the opposite direction through the wire in the coil
6. each side of the coil is now near the opposite magnetic pole
7. This means that the motor effect forces continue to cause anti-clockwise rotation of the coil.

Knowledge Organiser 4.8 Space Physics (Sep Physics)

4.8.1.1 Our Solar System;

- Our Sun is the only star in our solar system.
- There are 8 planets in our solar system.
- Moons are natural satellites.
- Our solar system is part of a galaxy called the Milky Way.
- The Sun formed from a cloud of gas called a nebula.
- The gas particles were attracted to each other by gravitational attraction.
- The start of our Sun was with gravity and fusion reactions which made an equilibrium between gravitational collapse and expansion due to fusion.

4.8.1.2 Life cycle of a star

- **Gravity and nuclear fusion** reactions drive the formation and development of stars.
- **Nebula:** A star forms from massive clouds of dust and gas in space, mostly composed of hydrogen.
- **Gravity** begins to pull the dust and gas together.
- **Protostar:** As the mass falls together it gets hot enough for the hydrogen nuclei to fuse together to make helium. Fusion process releases energy, keeping the core of the star hot.
- **Main sequence star:** Gravity holding the star together is balanced by higher pressure due to the high temperatures. The Sun is at this stable phase in its life.
- **Red giant star:** When all the hydrogen has been used up in the fusion process, larger nuclei begin to form and the star may expand to become a red giant.
- **White dwarf:** When all the nuclear reactions are over, a small star like the Sun may begin to contract under the pull of gravity. In this instance, the star becomes a white dwarf which fades and changes colour as it cools.
- **Supernova:** A larger star with more mass will go on making nuclear reactions, getting hotter and expanding until it explodes as a supernova.
- **Neutron star or black hole:** Depending on the mass at the start of its life, a supernova will leave behind either a neutron star or a black hole.

Universe - about 13.8 billion years ago all the matter in the Universe was concentrated into a single incredibly tiny point.

Galaxy - cluster of billions of stars

Star - large ball of burning gas

Planet - a celestial body moving in an elliptical orbit round a star.

Moon - natural satellite of a planet

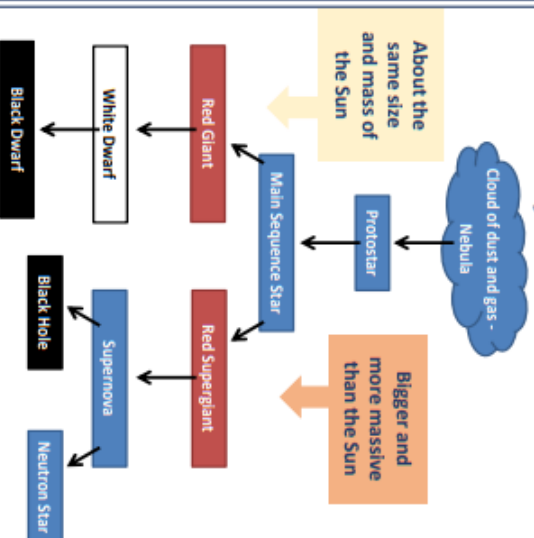
Dwarf planet - a planetary-mass object that does not dominate its region of space (as a planet does) and is not a satellite.

Asteroid - A rock in space. Asteroids orbit the Sun but some may cross the Earth's orbit, producing a risk of collision.

Comet - A ball of icy rock that follows an elliptical orbit around the Sun.



4.8.1.2 Life cycle of a star



- **Stars about the same size as our Sun:** follow the left hand path

main sequence star → red giant → white dwarf → black dwarf

- **Stars much bigger than our Sun:** follow the right hand path

main sequence star → red super giant → supernova → neutron star or black hole

Main sequence stars

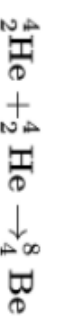
For most of its lifetime, a star is a **main sequence** star. It is stable, with balanced forces keeping it the same size all the time. During this period:

1. gravitational attraction tends to collapse the star
 2. radiation pressure from the fusion reactions tends to expand the star
 3. forces caused by gravitational attraction and fusion energy are balanced
- The Sun is expected to be a main sequence star for billions of years.

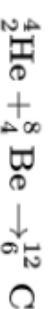
Supernova (pl. supernovae)

All the naturally occurring **elements** in the Universe are produced by nuclear fusion reactions in stars. The heavy elements found on Earth, such as gold, came from material thrown out in previous supernova explosions.

For example, beryllium and carbon nuclei can be produced from helium nuclei:



(two helium nuclei join to form a beryllium nucleus)



(a helium nucleus and a beryllium nucleus join to form a carbon nucleus)

Fusion reactions

In a main sequence star, hydrogen nuclei fuse together to form helium **nuclei**. This happens in several steps, but one way to simplify the overall change is:

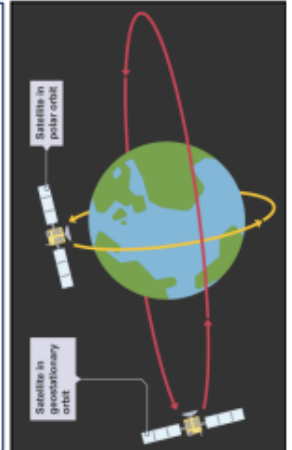
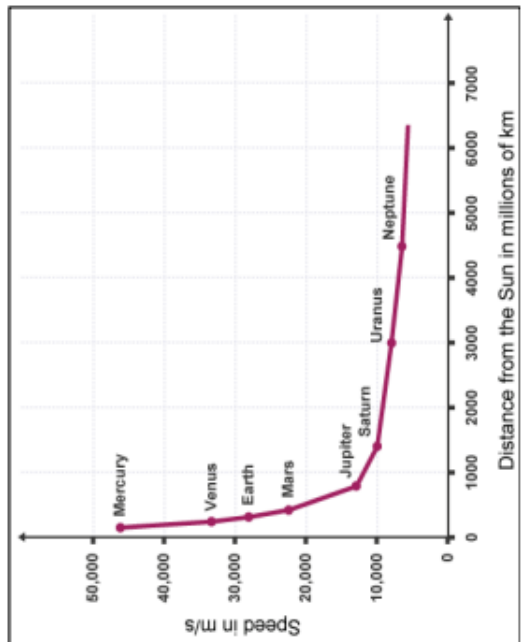
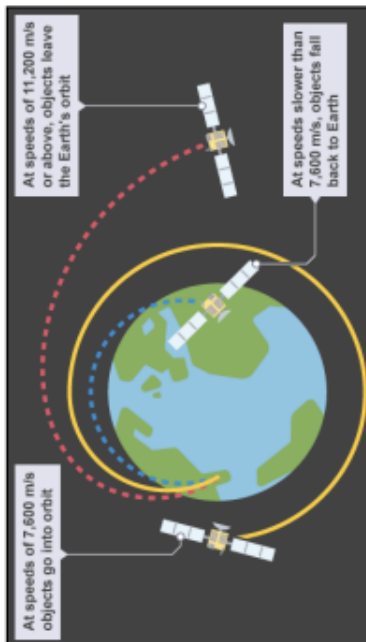


Two hydrogen nuclei fuse to produce a helium nucleus and a neutron. The Big Bang produced **hydrogen** and **helium**. All the **other elements** have been produced by nuclear fusion reactions in stars and supernova explosions.

Knowledge Organiser 4.8 Space Physics (Sep Physics)

4.8.1.3 Orbital motion, natural and artificial satellites;

- Moons are natural satellites
- Elliptical orbits, are oval or egg-shaped and may take millions of years to complete.
- For an object to remain in a steady, circular orbit it must be travelling at the right speed.
- Artificial satellites are put into orbits around a planet by humans.
- **HT** – must be able to explain why satellites move with acceleration at a constant speed
 - it is the changing direction that makes it acceleration
- In circular orbits the force of gravity can lead to changing velocity but unchanged speed.
- **HT** – the relationship between radius of orbit and the speed at which the satellite orbits –
 - and it is ... for a stable orbit of a satellite the.....
- **CLOSER TO THE PLANET A SATELLITE ORBITS, THE FASTER IT MUST MOVE.**
- Therefore, the further away from the planet the orbit is, the slower the satellite must move.



- There are three possible outcomes:
1. If the satellite is moving too quickly then the gravitational attraction between the Earth and the satellite is too weak to keep it in orbit. If this is the case, the satellite will move off into space. This occurs at speeds around or above 11,200 metres per second (m/s).
 2. If the satellite is moving too slowly then the gravitational attraction will be too strong, and the satellite will fall towards the Earth. This occurs at speeds below 7600 m/s.
 3. A stable orbit is one in which the satellite's speed is just right - it will not move off into space or spiral into the Earth, but will travel around a fixed path.

4.8.2 Red-Shift

The Universe of full of galaxies which are **moving away from us**.

- There are huge distances between the distance between each one and between each galaxy & Earth.
- On Earth we can see the light from distant stars and galaxies.
- Light has different wavelengths and colour.
- The faster the galaxies are moving, the further away from us they are.
- This makes the light from the distant galaxies appear red – the longest wavelength of the electromagnetic spectrum.



These are what you need to explain:

- Red-shift means that distant galaxies are receding and moving faster away from us
- Since 1998, observations tell us that the furthest galaxies are receding ever faster
- This receding and fast movement tells us that the Universe is expanding
- The red-shift helps us give evidence for the Big Bang model.
- We observe the night sky and beyond and from centuries of observations using telescopes – scientists have put the model of the Big Bang to explain how it all started!
- We do not know much really – especially dark matter and dark energy.

The Big Bang is how astronomers explain the way the universe began. It is the idea that the universe began as just a single point, then expanded and stretched to grow as large as it is right now (and it could still be stretching).

This 'stretching' is what we see as the **red-shift**. **This is very important 'the Universe began from a very small region that was extremely hot and dense' (exam words)**

Astronomers have also discovered a cosmic microwave background radiation (CMBR). This comes from all directions in space and has a temperature of about -270 °C. The CMBR is the remains of the thermal energy from the Big Bang, spread thinly across the whole Universe.

Prediction from Big Bang theory	Evidence observed	Does evidence support the Big Bang theory?
More distant galaxies should move away faster	More distant galaxies have greater red-shift	Yes
Initial Big Bang heat should now be thinly spread across the whole Universe	CMBR is everywhere at a temperature of about -270°C	Yes