

Scheme of work – Unit F180 – Fundamentals of science

About this Scheme of work

Our new AAQ Cambridge Advanced National in F180 Fundamentals of science is for first teaching from September 2025.

This resource:

- is **unit-specific** and has a **lesson by lesson** approach by area of study and allocated guided learning hours (GLH)
- has a **simple** and **editable** Word format
- highlights each lesson's **key words/terms** and **learning outcomes**
- contains **ideas** for teaching and learning with useful **links**
- provides additional **subject knowledge support by area of study**.

Assumptions for teachers

- You will adapt the SOW and lesson content to match your own timetabling arrangements
- You are aware that this SOW is just one approach to how the specification could be taught and the use of any resources highlighted is optional
- Students can access some resources outside of lessons for any online homework or extension tasks
- You will refer to the [Cambridge Advanced National Applied Science specification](#) as the key document for detailed insight into the qualification's content and assessment requirements.

In this scheme of work we have made suggestions for useful resources both for in class activities and for teacher subject knowledge enhancement. Where we have included a reference to endorsed products such as the Cambridge Advanced National textbook, this indicates that a resource is suitable to support delivery of an OCR specification, but it does not mean that the endorsed resource is the *only* suitable resource to support delivery, or that it is required or necessary to achieve the qualification. Unlike endorsed resources, the other listed resources have not been subject to review and so we cannot offer recommendations or guarantee the quality. We leave this to your professional judgment. These resources are suggestions and are not the only ones suitable to support delivery, neither are they required or necessary to achieve the qualification.

Performance objectives

Here is a reminder of the performance objectives in Unit F180

Performance Objectives	
PO1	Show knowledge and understanding
PO2	Apply knowledge and understanding

Further personal development support

For further training and professional development support, find out about our [upcoming training events](#). You'll be able to choose and book on to live online and face-to-face professional development.

Biology

Topic Area B1: Cell structure and microscopy

Area of study: 1.1 Cell structure and function

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
1	1.1.1 Ultrastructure and function of cells and their components - Features common to all cells - Eukaryotic cells - Plant and animal cells - Prokaryotic cells	2	By the end of the lesson students should: - understand why it is essential for living cells to have a cell surface membrane, cytoplasm and nucleic acid - know the 'cell theory' - know why viruses are not living cells - understand the features of a photomicrograph to	Start by asking students to draw and label a plant, animal and prokaryotic cell - assess recall of information from Key Stage 4 GCSE Biology. Address any misconceptions and show students labelled diagrams to amend / complete their diagrams with missing information. Structures to include which the students may not be familiar with (because they are not included in the GCSE specification) are: nucleolus centriole smooth endoplasmic reticulum (SER)	Cell structure - biology quiz (bbc.co.uk/bitesize) Interactive GCSE level quizzes for recapping content previously covered (can use with whiteboards).	Cognito (cognitoedu.org) Free access, sign up to the A Level Biology course to find detailed notes, quizzes and exam practice questions. Further ideas for consolidation include developing a visual glossary of key terms or matching/gap-fill activities for students to complete.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			draw and label a eukaryotic cell • know the differences between plant and animal cells • understand why a fungal cell could be identified as both a plant cell and an animal cell • understand how prokaryotic cells differ from eukaryotic cells • understand the difference between gram-positive and gram-negative bacteria.	• rough endoplasmic reticulum (RER) • 70s and 80s ribosomes • lysosomes and vesicles Discussion / teacher-led section explaining the roles of each of the organelles found in the cells and introducing Cell theory. • All living organisms are composed of one or more cells. • The cell is the basic unit of life. • All cells arise from pre-existing cells. The discussion could be supported by showing the Biology: Cell Structure I Nucleus Medical Media video. Photomicrograph interpretation Display a photomicrograph of a plant and an animal cell. Discuss how to identify key structures: cell membrane, nucleus, cytoplasm,	Science Photo Library (sciencephoto.com) Can be used to generate various images of different tissue types. Biology: Cell Structure I Nucleus Medical Media (youtube.com) A detailed video on the structure and function of cell organelles.	

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				mitochondria, and (for plant cells) chloroplasts and cell wall. Provide students with a photomicrograph. Instruct them to: • Draw the cell as accurately as possible. • Label the nucleus, cell membrane, mitochondria, cytoplasm, and (if a plant cell) chloroplasts and cell wall. • Add a title and magnification. Assess understanding of the role of organelles by giving students a short quiz on names, roles and appearance in photomicrographs. Discussion / teacher-led section describing the fluid mosaic model. Relate the model to movement of substances by: • Diffusion: Passive movement of small molecules.	STEM Learning (stem.org.uk) Many resources available for download. Fluid mosaic model (youtube.com) Video to support the teacher-led section.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• Facilitated diffusion: Through channel proteins. • Active transport: Using carrier proteins and ATP • Osmosis: The net movement of water molecules from a region of high water potential (low solute concentration) to a region of low water potential (high solute concentration) across a partially permeable membrane The discussion could be supported by showing the Fluid mosaic model video. In groups, students create a physical model of the fluid mosaic model using sweets or craft materials. Assess understanding by giving students a variety of molecules and ask students to explain how molecules would move through their model, indicating diffusion, facilitated diffusion, and active transport. Describe the role of the Golgi apparatus in modifying, sorting, and packaging proteins. Explain how vesicles transport	DIY Fluid mosaic model (edb.gov.hk) alternative with ping-pong balls floating in oil / water What Is A Virus? (youtube.com)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				proteins from the Golgi to other parts of the cell or for secretion. Get students to create a flow diagram showing the journey of a protein: Ribosome → Endoplasmic reticulum → Golgi apparatus → Vesicle → Cell membrane → Secretion (exocytosis) Students should complete a comparison table of the key differences in a plant and animal cell. Show students a fungal cell, encourage them to identify the features which mean it can be classified as a plant and animal cell. Show students a virus cell, and discuss that virus cells need a host cell to survive. This activity can be supported by showing the What Is A Virus? video. Discuss how prokaryotic cells differ from eukaryotic cells. Independent research task: Get students to research the difference between gram-positive and gram-negative bacteria, including how the differential response to antibiotics can be used to identify bacteria.	Video to show a virus requiring a host and the life cycle within a cell. Differences of gram-positive and gram-negative bacteria (antibioticresearch.org.uk) Gram staining video from Khan Academy (youtube.com) Investigating antimicrobial properties practical (practicalbiology.org) Resources to support students with the independent research task.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
2	1.1.2 Cell specialisation - Significance of cell specialisation in living organisms - Structure and function of specialised animal - Importance of retaining undifferentiated stem cells within the adult animal or plant - Structure and function of specialised cells found in a plant leaf	2	By the end of the lesson students should: - know how to interpret micrographs to identify cells in blood - understand the key features of squamous, ciliated and columnar epithelial cells - understand the key features of sperm and egg cells - understand differences between cardiac, smooth and skeletal muscle cells - know how to identify key cells found in a leaf - understand the transpiration stream and transport of	Start by getting students to complete the types of cell quiz on BBC Bitesize. Ask students why multi-cellular organisms need specialised cells. (Expected answers: efficiency, division of labour, adaptation to specific functions.) Introduce cell specialisation: Show an image of undifferentiated stem cells alongside various specialised cells (e.g. muscle, nerve, and epithelial cells). Ask students to predict the function of each specialised cell based on its structure. Activity: Leukocyte types using photomicrographs Briefly introduce the five types of leukocytes: neutrophils, lymphocytes, basophils, eosinophils, monocytes. Display photomicrographs of stained blood smears, guide students on how	Types of cell - biology quiz (bbc.co.uk/bitesize) Quiz to assess understanding at the start of the lesson. Science Photo Library (sciencephoto.com) Can be used to generate various images of different tissue types. Video of transport in plants (stem.org.uk)	ExamBuilder (ocr.org.uk) ExamBuilder can be used to source appropriate exam questions and provide to students.

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			nutrients in the phloem.	to identify the cell types based on: nucleus shape, granule staining, cell size. Provide students with mixed photomicrographs. Ask them to: - identify the leukocyte type - draw and label key features - write a brief description of the cell's function. <i>Independent research task:</i> Get students to compare the structure and function of squamous, ciliated, and columnar epithelial cells. Students should: - draw and label each epithelial cell type - annotate their role in the body. <i>Activity:</i> Egg and sperm cells - Provide students with diagrams of egg and sperm cells. Ask them to label and explain how each feature supports reproduction. Discuss the different types of muscle found in the body. Ask students:	Animation on transport systems in plant (saps.org.uk) Resources to support the discussion on plant tissues and transpiration. Types of epithelial cells (rsscience.com) Resource to support students with the independent research task. Investigating transport systems in a flowering plant (practicalbiology.org) Optional practical activity	

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				- What are the different types of muscle in the body? - How are their roles different? - How would you expect their cellular structure to be different? Activity: Muscle cell comparison Give student photomicrographs of cardiac, smooth and skeletal muscle. Ask students to complete a table comparing the three muscle types: - structure (nucleus, shape, striations) - location in the body - function. Discussion / teacher-led section describing specialised plant cells involved in the transpiration stream and nutrient flow. Key points in the discussion: xylem phloem stomata (and significance of guard cells) transpiration stream.	investigating plant transport. Types of muscle cells (kenhub.com) Resource to support students with the muscle tissue activity.	

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				An optional practical activity can be carried out to investigate the transport systems in a flowering plant. (practicalbiology.org) Get students to create an annotated diagram showing the transport systems within a plant with annotations including: - the control of stomata opening and closing by stomata (based on water potential and the turgidity of guard cells) - movement of water through the xylem (consider role of adhesion, cohesion and transpiration pull) - key tissues found in the leaf - nutrient flow in the phloem and the importance of companion cells (include how active transport, diffusion and osmosis relate to this process, as well as sources and sinks)		
3	1.1.3 Tissue structure and function	2	By the end of the lesson students should: understand how to extrapolate the	Ask students to define a tissue on a whiteboard (expected answer: a group of similar cells working together to perform a function).	Science Photo Library (sciencephoto.com) Can be used to	Consolidate learning so far with a glossary of terms. Students to complete the glossary

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	- Definition of a tissue in animals and plants - Tissues found in animals - Tissues found in plants		function of a tissue based on its structural features - understand the movement across membranes in lung and gastrointestinal epithelial tissues - understand the function and features of root hairs - understand why retention of roots is essential for successful transplantation - know the differences between the transport of substances in xylem and phloem.	Tissue identification from photomicrographs Display photomicrographs of different tissues: muscle tissue → elongated cells, striations in skeletal muscle epithelial tissue → tightly packed cells, protective layers connective tissue → scattered cells with extracellular matrix xylem tissue → thick lignified walls for water transport phloem tissue → sieve plates and companion cells. Teach students how to identify: - cell shape (elongated, flat, cuboidal) - cell arrangement (layers, clusters, scattered) - presence of specialised structures (e.g. cilia, striations, thickened cell walls).	generate various images of different tissue types. Histology of the digestive system (kenhub.com) Respiratory epithelium (biologyinsights.com) Resources to support the teacher-led section of the lesson. Root hair (sciencefacts.net) Xylem and Phloem (sciencenotes.org) Resources to support students	and select five terms to create a Frayer model exemplar.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Provide students with photomicrographs of several tissues. Ask them to: • identify the tissue type • draw and label key features • predict the tissue's function based on its structural features. Discussion / teacher-led section comparing lung and gastrointestinal epithelial tissues and relate their structure to membrane transport. Students complete a table comparing lung and gastrointestinal epithelial tissues: • cell shape • specialised structures (cilia vs. microvilli) • function in membrane transport. Independent research task: ask students to research the roles of different plant tissues. Split the class into groups and assign research tasks: • function of root hairs • role of roots retention in transplantation	with the independent research task.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• differences between transport of substances in xylem and phloem. Each group can then present their information to the rest of the class for them to take notes.		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	To effectively engage with the lessons on cell specialisation, students should already have a foundational understanding of several key concepts in biology. Here are the required underlying knowledge and understanding for this area of study: Basic cell biology: Students should be familiar with the structure and function of a typical plant cell and a particular animal cell, including the roles of the nucleus, cytoplasm, cell membrane, ribosome, cell wall, chloroplast and mitochondria. Microscopy: Familiarity with the use of microscopes to observe cells and tissues, including the ability to interpret photomicrographs. Stem cells: Types of stem cells in plants and animals: meristems, embryonic stem cells and adult stem cells. Students should know the difference between totipotency and multipotency. Movement in and out of cells: Students should be familiar with osmosis, diffusion and active transport definitions. Tissues: Students should be familiar with the concept that tissues are made up of cells which have a similar function. Plant structures: Students should be familiar with the role of the xylem and phloem in plants, as well as the function of the root hair cells. They will also be familiar with the structure and function of stomata.
Common misconceptions	Misunderstanding the concept of specialisation: Students might think that all cells in an organism are the same and perform the same functions. They may not grasp that different cells have specific roles and structures tailored to those roles. Confusion between cell types: Students may struggle to differentiate between various specialised cells, such as erythrocytes, leukocytes, and epithelial cells. They might also find it challenging to understand the differences between plant and animal cells. Interpreting photomicrographs: Students may find it difficult to interpret photomicrographs and identify different cell types accurately. This can be particularly challenging when cells look similar under a microscope.

Subject knowledge enhancement	Details
	Adult stem cells: Students think that these are found in very limited places in the body and have very limited roles and uses. Embryonic vs adult stem cells: Students can confuse when each type of stem cell is present (adult stem cells are found in children and infants) and can confuse which type of cell is which. Animal stem cells vs meristems (plant stem cells): Students can confuse that meristems are undifferentiated and can develop into any plant cell, whereas adult stem cells can only develop into particular cells. Viruses: Students think that viruses are living cells (and there is some conflicting information that they are able to find). They are classed as non-living as they cannot replicate or produce their own energy outside of a host cell. Fungal cells: Students can think fungal cells are prokaryotes. They can be an animal or a plant cell, depending on the structures seen in the specific cell looked at. Osmosis: Students may refer to osmosis as being the diffusion of water. Students are familiar with referring to osmosis as the movement of water from an area of high concentration to a low concentration. However, they need to be referring to water potential: Osmosis is the movement of water molecules through a semipermeable membrane from a region of higher water potential to a region of lower water potential. Xylem and phloem: Students may confuse transpiration (movement of water) and translocation (movement of glucose). They may also confuse that the xylem only moves up the plant, and the phloem can move up and down the plant.
Key concepts	Living cells: Students should understand why living cells need to have a cell surface membrane, cytoplasm and nucleic acid. They also should understand viruses are not living cells. Cell surface membrane: Students should know the features of the fluid mosaic model, and how it relates to movement of substances in and out of cells. Movement of substances in and out of cells: Students should understand the definitions of osmosis, simple diffusion, facilitated diffusion and active transport.

Subject knowledge enhancement	Details
	Structures in cells: Students should understand the role of the following structures in the Eukaryotic cells: Cell surface membrane • Cytoplasm • Nucleus and nucleolus • Mitochondrion • Centriole • Smooth endoplasmic reticulum (SER) • Rough endoplasmic reticulum (RER) • 70s and 80s ribosomes • Golgi apparatus / body • Vesicles and lysosomes • Flagellum and cilium • Chloroplast • Cell wall. Bacteria: Students should know the difference between gram-positive and gram-negative bacteria, as well as how the differential response to antibiotics can be used to identify bacteria. These key concepts link to 2.3 in Unit F185. Significance of cell specialisation: Students should understand why cell specialisation is crucial in multi-cellular organisms and how it contributes to the overall functioning of the organism. Structure and function of specialised animal cells: This includes knowledge about erythrocytes, leukocytes, epithelial cells, sperm and egg cells, and muscle cells. Students should be able to describe the structure and function of these cells and understand their roles in the body. Importance of undifferentiated stem cells: Students should grasp the significance of retaining undifferentiated stem cells within adult animals or plants and how these cells can differentiate into various specialised cells. Specialised plant cells: Students should understand the structure and function of specialised cells found in a plant leaf, including epithelial cells, mesophyll cells, guard cells, xylem, and phloem. Interpreting photomicrographs: Students should be able to interpret photomicrographs to identify different cell types, particularly those found in blood. They should also be able to draw and label a low-power plan of a eukaryotic cell. They also need to be able to identify structural features of tissues shown in a photomicrograph. These key concepts link to 1.2 in Unit F180 and 2.2 in Unit F185. Differences between cell types: This includes understanding the differences in appearance, dimensions, and function of various cell types, such as the five types of leukocytes and different types of epithelial cells. Specialisation of sperm and egg cells: Students should know why sperm and egg cells are highly specialised and the key structural features that enable them to carry out their roles.

Subject knowledge enhancement	Details
	Transpiration and nutrient flow in plants: Students should understand why water flows along the transpiration stream in a plant leaf and why nutrients flow along phloem sieve elements. They also need to know the function of root hairs and why these are usually non-photosynthetic. These key concepts link to Unit F184, such as 1.1.2. Tissues: Students should know that a tissue is a collection of similar cells sharing a common function. They should also be able to identify the function of a tissue based on its structural features.
Subject knowledge enhancement for teachers	Watch: Crash Course Biology (youtube.com) Read: Cognito (cognitoedu.org) Human cells and tissues (bio.libretexts.org) Difference between cells and tissues (pw.live) <u>Support:</u> Some conversations about the use of embryonic stem cells may be triggering for some students, or introduce wider conversations about ethical use and religious viewpoints. Do consider the potential range of viewpoints when introducing these concepts and plan for a sensitive discussion of the topic area. For further information on facilitating discussions about potentially sensitive topics, you can: Read: Facilitating critical conversations with students (learningforjustice.org). The guidance here can be adapted to suit a variety of topics in the classroom, such as race, gender, disease and death. For further information on facilitating discussions about ethics, you can:

Subject knowledge enhancement	Details
	Read: How to have an ethical discussion in your classroom (journals.asm.org), Managing classroom discussions (sciencelearn.org.nz)

Area of study: 1.2 Microscopy

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
4	1.2.1 Light and electron microscopy - Key features of light (LM) and electron (EM) microscopes - Temporary microscope slides - Resolving power and magnification - Estimating the number of cells in a sample	1	By the end of the lesson students should: - know how to calculate and use the units - understand the stages of producing a stained mount of a LM specimen - know the advantages and disadvantages of LM and EM - understand the differences between, and advantages and disadvantages of, transmission and scanning EM - understand how to draw a low-power	Start by providing a worksheet to convert the units between cm, mm, μm and nm. Demonstrate the actual size of a mm, μm and nm using the scale of the universe animation. You will need to create this worksheet before the lesson. Recap (from GCSE Biology) how to use a light microscope (LM) and how to calculate the magnification. This should be accompanied by a demonstration of how to use an LM and completion of the microscopes recap quiz Using a light microscope Have various microscopes set up around the room with slides, ask students to draw the cells / tissues and label the structures that can be seen.	Scale of the universe animation (scaleofuniverse.com) Resource to support the starter activity. OCR A Level Biology M.01 Tutorial Microscopes recap quiz (footprints-science.co.uk) Quiz to give students to assess recall of GCSE Biology microscopy.	Making slides and observations (bbc.co.uk) This GCSE resource can be used to recap prior learning. There are also notes to support students writing a guide for how to use an LM.

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			plan of an EM image understand the advantages and disadvantages of using a haemocytometer vs a Coulter counter.	Students write a guide for a primary aged student on how to use a light microscope and how to prepare a sample of a cheek / onion cell. Use ExamBuilder to find past paper questions on applying the magnification questions. Independent research task: Half the students research how to use a haemocytometer and its advantages and disadvantages, the other half research a Coulter counter and its advantages and disadvantages, then they find their matching pair and create a complete overview of both practices for counting cells. Watch the Understanding microscopy video on light microscopes, transmission electron microscopes (TEM) and	ExamBuilder (ocr.org.uk) ExamBuilder can be used to source appropriate exam questions to assess understanding. How to use a haemocytometer (youtube.com) The guide to cell counters in the life sciences (chemometec.com)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				scanning electron microscopes (SEM). Students should make a comparison of the features, advantages and disadvantages of TEM and SEM.	Resources to support students with the independent research task. Understanding microscopy Biology – Bitesize Science (youtube.com) Students should watch the video in order to complete the comparison table.	
5	1.2.2 Practical 1: Light microscopy	2	By the end of the lesson students should: understand how to prepare and examine microscope slides for use in light microscopy,	Start by asking students to list the key features for making a good microscope slide. Students should be steered towards: - enhanced visibility - identification of cellular structures - enhanced contrast by using a stain.	Light Microscopy (bbc.co.uk/bitesize) How to count cells with a haemocytometer (chemometec.com)	Microscope drawings (youtube.com) Videos to support students with carrying out the practical activity.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			including the use of an eyepiece graticule and stage micrometer - understand how to use and interpret commonly used stains - understand how to use the equation linking magnification, observed size and actual size.	Slide preparation - Place a small biological sample e.g. onion epidermis on a clean microscope slide. - Add one drop of stain, e.g. iodine for plant cells or methylene blue for animal cells. - Gently place a coverslip over the sample at a 45° angle to avoid air bubbles. Viewing under the microscope - Start with the low-power objective lens ×10 magnification. - Adjust the coarse focus until the image is clear, then refine it with the fine focus, then repeat ×40. - Ask students to draw the sample in detail at low power, labelling visible features, e.g. cell wall, nucleus, cytoplasm.	) Resources to support teachers with the delivery of the practical activity. OCR A Level Biology Biological Drawing guide (ocr.org.uk) has appropriate guidance that can be used for Applied Science too. How to use a microscope (youtube.com)	Flipped learning: Using guidance for teachers available from How I Teach: Biological Drawing, students make appropriate biological drawings of biological drawing photos (pedagoggles.wordpress.com)

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				• Include the magnification used and scale bar on their drawing. • Calculate the actual size of the image using the formula: $\text{Magnification} = \frac{\text{observed size}}{\text{actual size}}$ Discuss why staining improves contrast and allows better visualisation of internal structures. Cell counting activity • Use a pipette to place a small volume of the cell suspension onto the haemocytometer grid. • Focus on the gridlines of the haemocytometer. • Count the cells in several squares and calculate the average number of cells per square. • Use the volume factor of the haemocytometer to calculate the number of cells using the formula:		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				$\text{cell concentration (cells / mL)} = \frac{\text{total cell count} \times \text{dilution factor} \times 10^4}{\text{number of cells counted}}$		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	Students should have familiarity with the use of microscopes to observe cells and tissues, including the ability to interpret photomicrographs. Students will probably have some familiarity with this and the parts of a microscope from required practicals at GCSE level. Students need to be familiar with the organelles within cells and how these can be identified. They should also have the mathematical skills to be able to convert from mm to μm and vice versa and be able to rearrange the equation linking magnification, image size and actual size in order to calculate any of the quantities.
Common misconceptions	Students may find it difficult to interpret photomicrographs and identify different cell types accurately. This can be particularly challenging when cells look similar under a microscope.
Key concepts	Students should understand the stages involved in the production of a temporary, stained mount of a LM specimen. They should be able to compare the advantages and disadvantages of LM and EM and also know the differences between transmission electron microscopes and scanning electron microscopes (along with the advantages and disadvantages of these techniques). Students should know how to draw a low-power plan of an EM image and understand the advantages and disadvantages of using a haemocytometer vs a Coulter counter. These key concepts link to 1.2 in Unit F180 and 2.2 in Unit F185.
Subject knowledge enhancement for teachers	Read: What is microscopy? (clinical-sciences.ed.ac.uk) Watch: Microscopes and how to use a light microscope (youtube.com) The future of microscopy (youtube.com) Microscopy UK (microscopy-uk.org.uk)

Topic Area B2: Bioenergetics

Area of study: 2.1 Photosynthesis and 2.2 Cellular respiration

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
6	2.1.1 Site of photosynthesis - Structure and function of chloroplast components - Location of chloroplasts	2	By the end of the lesson students should: - understand how to interpret biological drawings and photomicrographs of chloroplasts - know the function of the components of a chloroplast - understand the benefit of the large surface area to volume ratio of the stacked thylakoids.	Start by showing students biological drawings and photomicrographs of chloroplasts, in pairs the student should describe the key components that they can see. Alternatively, the students could be given a list of the key components (with descriptions) to identify within the images. Discussion / teacher-led section addressing misconceptions from the starter activity and outlining the function of the key features of the chloroplast: Outer membrane Stroma Granal and intergranal thylakoids. Explain how the outer membrane: - maintains the internal environment of the chloroplast - increases the local concentration of enzymes and substrates, increasing the frequency of collisions.	Science Photo Library (sciencephoto.com) Image library to generate various images of chloroplasts. The Chloroplast (youtube.com) Video to support the teacher-led section of the lesson.	ExamBuilder (ocr.org.uk) KS4 and KS5 past paper questions from OCR.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				The discussion could be supported by showing the video of The Chloroplast. Give students a diagram of a chloroplast to label the key structures along with their functions. Show students images of biological examples of an increased surface area, e.g. villi and microvilli in the small intestine, alveoli, and ask them to identify the common feature. Explain the benefits of the large surface area of stacked thylakoids: • maximise light absorption • efficient electron transport. Investigating the distribution of chloroplasts • View pre-prepared microscope slides of the cross section of a leaf under low power initially to locate the cells. • Switch to high power and compare the distribution of chloroplasts in the upper epidermis, palisade layer and lower epidermis. If pre-prepared slides are not available images could be used from the Science Photo Library. Discuss with students: • Where are the majority of chloroplasts located? Why?	Science Photo Library (sciencephoto.com) Image library to generate various images of chloroplasts.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Why are there fewer chloroplasts in the lower epidermis? - Why do guard cells contain chloroplasts, unlike other epidermal cells?		
7	2.1.2 Biochemistry of photosynthesis - Equations for photosynthesis - Photosynthetic pigments in photosynthesis - Importance of CO₂ absorption on climate change	2	By the end of the lesson students should: - understand why water is not combined with carbon dioxide to form glucose - understand how light absorption is affected by the type of photosynthetic pigment found and the concentration of chloroplasts - understand how to interpret the light absorption spectrum for different photosynthetic pigments - understand how to interpret graphs	Assess recall of information from GCSE Biology; ask students to write the word and balanced symbol equation for photosynthesis on a whiteboard. Address any gaps in knowledge and discuss why water and carbon dioxide cannot directly form glucose (thermodynamically impossible). Investigating pigment absorption Provide students with absorption spectra graphs of chlorophyll a, b, and carotenoids . Ask students to: - Identify which wavelengths each pigment absorbs. - Explain how multiple pigments increase photosynthetic efficiency. Investigating photosynthesis rate with pondweed - Place the pondweed in the beaker with sodium bicarbonate. - Vary the distance from the light source. - Count the oxygen bubbles released over 1 minute at each distance.	Absorption of light (bio.libretexts.org) Article to support the absorption spectra task. A-Level set practicals: TLC of plant photosynthetic pigments (stem.org.uk) Additional practical activities investigating photosynthetic pigments by thin layer chromatography.	Using How Climate Change Will Affect Plants (news.climate.columbia.edu) and the video resources, students could <i>analyse</i> the impact of increasing atmospheric carbon dioxide levels on plants.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			showing the impact of light intensity on the rate of photosynthesis in pondweed understand why CO₂ absorption can reduce the predicted increase of greenhouse gas levels in the context of climate change.	Plot the rate of photosynthesis vs. light intensity and discuss how light intensity impacts the rate of photosynthesis. Alternatively, the Investigating rate of photosynthesis video could be shown. <i>Independent research task:</i> Get students to research the link between CO₂ absorption during photosynthesis and the increase in greenhouse gases in the context of climate change. Students could create presentations in groups to present to the rest of the class.	Investigating rate of photosynthesis (youtube.com) Video to show as an alternative to the practical activity. Wavelengths of light and photosynthetic pigments (khanacademy.org) Resource to support students with the absorption spectra task. Photosynthesis and climate change (ugc.berkley.edu) Resource for students to use for the independent research task.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
8	2.2.1 Site of cellular respiration Structure of mitochondria	2	By the end of the lesson students should: - know how to interpret biological drawings and photomicrographs of mitochondria - understand how the mitochondria is adapted to carry out cellular respiration - understand why active animal and plant cells have an abundance of mitochondria - understand why water-logged soils can reduce the active uptake of mineral ions.	Start by showing students biological drawings and photomicrographs of mitochondria and a list of key components. The students should try to identify the features in the biological drawings and micrographs. Discussion / teacher-led section describing the mitochondrial adaptations for respiration. Key points for the discussion: outer membrane controls entry and exit of molecules - folded inner membrane (cristae) to increase surface area for electron transport chain - watery matrix provides environment for enzyme-substrate collision. Students can add details of the role of each component to the electron micrographs and biological drawings from the starter activity. Give students images of sperm cell, muscle cell / fibre, renal tubule cell, synaptic knob of neuron, root hair cell and phloem companion cells. Discuss why each of these cells have a high number of mitochondria. Give students a short quiz on transport in and out of cells (diffusion, osmosis and active transport GCSE Biology content).	Science Photo Library (sciencephoto.com) Resource to generate various images of mitochondria and various cells. Structure of the Mitochondrion (savemyexams.com) Notes to support the teacher-led section of the lesson.	Transport quiz (bbc.co.uk/bitesize) BBC Bitesize quizzes can be used to assess understanding of osmosis, diffusion and active transport. Using Appendix B of the specification and Understanding the Assessment (ocr.org.uk), students should try to write 10-15 marks of exam-style questions (with mark scheme) to challenge their peers. Remind them that the maximum number of marks on F180 is 4 marks.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Address any gaps in knowledge and recap the active uptake of mineral ions from soil into root hair cells. Discuss student ideas as to why this process could be compromised in water-logged soils. Steer students towards the fact that water-logged soils lack oxygen therefore the production of ATP is compromised and therefore reduce active transport.		
9	2.2.2 Biochemistry of cellular respiration - Equations for aerobic and anaerobic respiration - Net production of ATP	2	By the end of the lesson students should: - understand the similarities and differences between aerobic and anaerobic respiration - understand why ATP synthesis is not 100% efficient - understand when anaerobic respiration can be applied to industrial and agricultural processes.	Give students sets of cards with both words and chemicals for students to rearrange into equations for photosynthesis, aerobic and anaerobic respiration. Show the video showing the differences between aerobic and anaerobic respiration. Recap similarities and differences in aerobic and anaerobic respiration, e.g. via a Venn diagram or comparative table. Get students to complete a table for comparison of the two types of respiration. For scaffolding they could be asked to compare: - oxygen requirement - ATP production - location in cell - end products - efficiency and speed.	Aerobic and anaerobic respiration (youtube.com) Video to show students to explain differences between aerobic and anaerobic respiration.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Discussion / teacher-led section explaining why ATP synthesis is not 100% efficient: - ATP is produced during respiration, but not all energy is captured as ATP. - Some energy is lost as heat due to inefficiencies in the biochemical pathway. - The electron transport chain in mitochondria is not perfect—some energy is dissipated. The concepts covered in lesson 3 and 4 can be challenging. Select from the suggested recap / review activities to consolidate learning: - ExamBuilder questions / peer marking - Create whole class mindmap using Post-its or use an app like Miro - Create flashcards and students challenge each other in a whole class quiz <i>Independent research task:</i> Get students to research industrial and agricultural applications of anaerobic respiration. If students need direction the class could be split into groups and each group research a different application from: - alcohol production - biogas production - silage production. Each group can then present their information to the rest of the class to watch and take notes.	Useful resource: Aerobic and anaerobic respiration lesson element. (ocr.org.uk) Or Aerobic & Anaerobic Respiration Lesson (cognitoedu.org) Respiration (thesciencehive.co.uk) Lesson: Anaerobic cellular respiration in humans and other organisms (thenational.academy) Resources to support students with the independent research task.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Note: The specification indicates not to include details of the biochemical reactions along the phases of glycolysis, link reaction, Krebs cycle and electron transfer chains. Ensure students realise that A Level Biology content will go beyond what is required for Applied Science and to carefully follow the guidance in the specification.		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	In order to fully understand topic area B2 students need to have an understanding of: Cell structure: the structure of plant and animal cells and the function of cellular organelles. Cell transport: the three methods of cell transport: diffusion, osmosis and active transport. Enzyme reactions: the structure of enzymes (in terms of protein folding and the active site) and the 'lock and key' hypothesis of enzyme specificity. Students should also be familiar with the effect of pH and temperature on the rate of reactions involving enzymes.
Common misconceptions	Students often mistakenly think that plants carry out photosynthesis but not respiration because students often associate plants only with oxygen production and not with glucose breakdown for energy. In reality during the day, photosynthesis occurs at a higher rate, producing more glucose and oxygen and at night (or in darkness), plants continue to respire but cannot photosynthesise. This is coupled with the misconception that plants do not release carbon dioxide but at night, only respiration occurs, and plants release carbon dioxide into the environment. Students often also assume that photosynthesis only happens in the leaves of plants and while most photosynthesis does occur in the leaves, other green plant parts (e.g. stems) with chlorophyll can also carry out photosynthesis. Students commonly confuse respiration with the process of breathing; the term 'respiration' is often incorrectly used interchangeably with 'breathing' in everyday language. There is also a misconception that respiration only happens in animals, because this is often the focus in textbooks whereas all living organisms (including plants, fungi, and bacteria) carry out cellular respiration to produce ATP.
Key concepts	The structure and function of chloroplasts should be understood, including how the outer membrane of the chloroplast provides an enclosed site for the different stages of photosynthesis and the benefit of the large surface area:volume ratio provided by the stacked thylakoids bathed in watery stroma. Students should understand why water is not combined with carbon dioxide to produce glucose and how light absorption is affected by the type of photosynthetic pigment. Students should be able to interpret graphs showing the impact of light intensity on the rate of photosynthesis in pondweed and explain why carbon dioxide absorption can reduce the predicted increase of greenhouse gas levels in the context of climate change. Students should be able to interpret biological drawings and photomicrographs of mitochondria and explain how the mitochondria provides an enclosed site for different stages of cellular respiration and a large surface area : volume ratio for reactions. The benefits of the folded cristae and watery matrix to the aerobic phase should be understood

Subject knowledge enhancement	Details
	along with why active animal and plant cells, including sperm cells and root hair cells, have an abundance of mitochondria. Students should understand why water-logged soils can reduce the active uptake of mineral ions. The similarities and differences between aerobic and anaerobic respiration should be understood along with why ATP synthesis is not 100% efficient. Students should be able to describe situations where anaerobic respiration can be applied to industrial and agricultural processes.
Subject knowledge enhancement for teachers	Read: Photosynthesis (rsb.org.uk) Respiration (rsb.org.uk) Photosynthesis (education.nationalgeographic.com) Watch: Photosynthesis (youtube.com) Support: Climate anxiety among young people is increasing. There are some resources available from the Royal College of Psychiatrists (rcpsych.ac.uk) and from Mental Health UK (mentalhealth-uk.org).

Topic Area B3: Structure and function of biological molecules

Area of study: 3.1 Biological molecules

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
10	3.1.1 Structure and function of carbohydrates - Monomers / monosaccharides - Disaccharides - Polysaccharides	1	By the end of the lesson students should: - know how to interpret molecular diagrams of mono-, di- and polysaccharides - understand how to compare C1-4 and C1-6 glycosidic bonds - understand the advantages and disadvantages of starch and glycogen as carbohydrate stores - know the key features of the iodine test, reducing sugar test and non-reducing sugar test.	Get students to brainstorm what they already know about carbohydrates on whiteboards. Structure of carbohydrates Using Molymod kits, assign groups and ask each group to create either two glucose molecules, a glucose and a fructose molecule or a glucose and a galactose molecule, making sure to number the carbon atoms on the desk. Students then move around the room with a table to compare the three different sugar monomers and draw the relevant molecular diagrams. Students then return to their Molymod molecules and have to remove a water molecule (H₂O) from the C4 and C6 to make	Biochemical tests (savemyexams.com) Free sign up is required to access the site. Resource to support the delivery of the practical activity.	Testing for carbohydrates (bbc.co.uk/bitesize) BBC Bitesize can be used for students to recap GCSE food tests. Students can write up their results from this food testing practical for their independent work using the above BBC Bitesize link to support them.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				maltose (glucose and glucose), sucrose (glucose and fructose) or lactose (glucose and galactose). The Condensation and hydrolysis animation can be shown to support this activity. Students again visit other molecules to see the different disaccharides. They return to their disaccharides and then add in the water molecule onto the correct C4 and C6 atoms, this is the hydrolysis reaction and they should have two separate monosaccharides. <i>Independent research task:</i> Students should research the advantages and disadvantages of starch and glycogen as carbohydrate stores. The Carbohydrates: Starch and glycogen video can be shown to start the students on the task	Condensation and hydrolysis animation (youtube.com) Optional animation which explains the condensation and hydrolysis reactions. This OCR A Level Biology Jelly Mods (ocr.org.uk) activity could be useful to reinforce mono and disaccharides. Carbohydrates: Starch and glycogen (youtube.com) Video to support students with the independent research task.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Activity: Food testing practical Recap on the iodine practical and benedict's reagent practical (reducing sugars). Discuss the non-reducing sugars (sucrose) and describe the process to break down sucrose into glucose and fructose before completing the Benedict's reagent test.	CLEAPSS GL018 Food Tests (cleapss.org.uk subscription required) https://polysaccharides/Starch and Glycogen (getrevising.co.uk) Notes to support students with the independent research task.	
11	3.1.2 Structure and function of lipids - Saturated and unsaturated fatty acids - Mono-, di- and triglycerides - Phospholipids - Condensation and	2	By the end of the lesson students should: - understand the key features of ester bond formation between glycerol and fatty acids - understand the relevance of phospholipids within the cell surface membrane - understand why triglycerides are an	Display images of lipid-rich foods, e.g. avocado, butter, fish, and oil and ask: - What do these foods have in common? - Why are lipids essential for our bodies? Discuss the role of lipids in the body: - energy-rich molecules - components of cell membranes - involved in nerve insulation (myelin sheath)	Lipids (alevelnotes.com) Notes to support the teacher-led section of the lesson.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	hydrolysis reactions		effective energy source - understand the role of lipids in the myelin sheath - know the key features of the emulsion and Sudan IV tests.	- essential for hormone production and vitamin absorption. Building a lipid model – ester bond formation Using Molymod kits students should: - Make one glycerol molecule with three hydroxyl groups. - Make three fatty acid chains with carboxyl groups. - Connect the hydroxyl group of glycerol to the carboxyl group of each fatty acid. - Remove H₂O molecules to simulate condensation reactions. Students should use their models to draw molecular diagrams of glycerol, fatty acids and lipid molecules and diagrams of the condensation and hydrolysis reactions that take place between them forming and breaking the ester bond. Independent research task: Split students into groups and assign each group a role of lipids from:	Testing for lipids (savemyexams.com) Notes to support the delivery of the practical activity. Lipids (savemyexams.com) Myelinated and unmyelinated axon (alevelbiology.co.uk) Phospholipid bilayer (study.com) Resources to support the independent research task.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• Triglycerides as an effective energy source in animals and plants. • Role of lipids in the myelin sheath providing insulation of the neuron axon. • Relevance of phospholipids within cell surface membrane, including effect of saturated and unsaturated fatty acids on membrane thickness and fluidity. Each group should present their work to the rest of the class to take notes. <i>Activity: Emulsion and Sudan IV tests for lipids</i> Test vegetable oil and butter using the emulsion and Sudan IV tests for lipids. Students should compare the results of the two tests as positive confirmation of the presence of lipids. Assess understanding with a short quiz on understanding of key terms, for example: ester bond, condensation, hydrolysis, phospholipids.		
12	3.1.3 Structure and function of proteins	2	By the end of the lesson students should:	Display images of different protein types, for example: • keratin (structural – hair / nails)		Graphing homework: students draw appropriate graph(s) from the enzyme activity

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	- Amino acid structure - Dipeptides and polypeptides - Levels of protein organisation - Enzyme structure and function		- understand how to interpret molecular diagrams of amino acids - understand how to carry out thin layer chromatography and interpret chromatograms - understand the levels of protein organisation - understand the key features of the enzyme as a protein.	actin and myosin (contractile – muscle movement) insulin (hormonal – regulates blood sugar) haemoglobin (transport – carries oxygen) catalase (enzymatic – speeds up reactions). Ask students what these proteins have in common and why do proteins have such a range of functions? Modelling protein structure Use Molymod kits to build individual amino acids, students should be instructed to build different amino acids: - Discuss the similarities (carboxyl group and amine group). - Discuss the differences (R- side chain).	Levels of protein structure (khanacademy.org) A resource to support the teacher-led section of the lesson. Thin Layer Chromatography instructions (edu.rsc.org)	practical or simulation. Could be marked next lesson with prepared marking rubric as starter. <i>Flipped learning task:</i> Get students to research the functions of different categories of enzymes, for example lipases, proteases and carbohydrases. Enzymes (byjus.com) A resource to support students with the flipped learning activity.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Students should then join the amino acids into dipeptides with the formation of peptide bonds. Students should draw the structures of the amino acids and write equations to show the condensation and hydrolysis reactions involved in the formation and breakdown on the dipeptides. Discussion / teacher-led section: Following on from the modelling activity explain the levels of protein structure. Students could complete a partially completed summary table or a match up activity to consolidate their knowledge. You would need to prepare this resource before the lesson. • Primary structure → Linear chain. • Secondary structure → Helices and sheets. • Tertiary structure → Folded 3D structure. • Quaternary structure → Multiple chains linked. Thin layer chromatography	Instructions for the thin layer chromatography of amino acids.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Students should separate and identify amino acids using TLC, visualised with ninhydrin spray. Measure distances and calculate R_f values for each amino acid. Explain how to identify individual amino acids from the R_f values by comparison to literature values. Give students a short quiz to assess their understanding of enzyme structure and function from GCSE Biology. Address gaps in understanding and recap the 'lock and key' hypothesis of enzyme action. The Lock and key hypothesis video can be shown to support the discussion. Compare with the induced fit model. Investigating enzyme activity: Investigate how temperature, pH, and concentration affect enzyme activity (breakdown of starch by amylase would be a suitable enzyme to use). • temperature → Use water baths. • pH → Use different buffer solutions. • concentration → Use different enzyme dilutions.	Lock and key hypothesis (youtube.com) Video to remind students of the lock and key hypothesis. Lock and key vs induced fit model (biologyonline.com) Supporting notes and videos. Enzyme practical instructions (practicalbiology.org) Instructions for the enzyme practicals to support students.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Measure the reaction rate by measuring the colour change of iodine. Discuss the results of the experiment and get students to summarise the effect of each variable on the activity of the enzyme in terms of the frequency of the collisions between the enzyme and substrate. A WAGOLL model can be provided to support students as well as to make sure that their answers contain sufficient detail.	Otherwise this simulation (biologysimulations.com) may allow for a recap of the practical students likely did at GCSE.	
13	3.1.4 Structure and function of nucleic acids - Key features of a nucleotide - ATP and ADP as mononucleotides - Significance of base pairing	3	By the end of the lesson students should: - understand how to interpret molecular diagrams of mono- and poly nucleotides - understand the purpose and function of DNA and RNA in inheritance and protein synthesis - understand the similarities and differences between DNA and RNA - know how base pairing is fundamental	Either: Provide rubric to students and peer mark graphs of enzyme activity. Or: Flipped learning task - start by asking students to share their answers to the flipped learning task on functions of enzymes. Extend the task by introducing the nuclease enzyme and describing its role in phosphodiester bond cleavage. Discussion / teacher-led section describing the structure of nucleotides.	Nucleotides and Phosphodiester bonds (savemyexams.com) Notes to support the teacher-led sections of the lesson.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			to the integrity of DNA and the formation of RNA know why alterations in the sequence of bases can lead to mutations.	Nucleotide structure: phosphate group (PO_4^{3-}) pentose sugar (deoxyribose in DNA, ribose in RNA) nitrogenous base: purines: adenine (A) and guanine (G) pyrimidines: cytosine (C), thymine (T), and uracil (U) (RNA only). Describe nucleotide formation via phosphodiester bonds between the phosphate group of one nucleotide and the sugar of another. Give students molecular diagrams of: - a single nucleotide - a polynucleotide chain - DNA double helix and RNA single strand. Get students to label the diagrams with the key features of each structure. <i>Independent research task:</i> Get students to research the structures of ADP and ATP.	ATP-ADP (study.com) Phosphorylated nucleotides (savemyexams.com)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Students should draw the molecules, labelling the key features and showing how ATP becomes ADP through the removal of one phosphate group. Discussion / teacher-led section explaining the functions of DNA and RNA in inheritance and protein synthesis. Key points: • DNA's role in inheritance: • DNA carries genetic information • encodes genes → Passed to offspring during reproduction. RNA in protein synthesis: • mRNA (messenger RNA): Carries the genetic code from DNA to the ribosome • tRNA (transfer RNA): Transfers amino acids to the ribosome during translation • rRNA (ribosomal RNA): Component of the ribosome, catalyses peptide bond formation. • mtDNA (mitochondrial DNA): Circular DNA found in mitochondria.	Resources to support students with the independent research task. Students should draw the molecules, labelling the key features and showing how ATP becomes ADP through the removal of one phosphate group.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				DNA base pairing model Get students to build a DNA model with base pairs: • A → T and C → G pairs • antiparallel strands. Discuss why complementary base pairing ensures accurate replication. Get students to Introduce mutations to their base pair model: • Substitution → Change one base. • Insertion → Add an extra base. • Deletion → Remove one base. Using their model, students should describe the impact of each mutation on the sequence of bases in the model. Discuss how these alterations in the sequence of bases can lead to mutations. Assess students' understanding using questions taken from OCR ExamBuilder.	DNA base pairing worksheet (davidswart.com) A base pairing worksheet for independent practice. ExamBuilder (ocr.org.uk) KS4 and KS5 past paper questions from OCR to assess understanding.	

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	To effectively engage with the lessons on biological molecules, students should already have a foundational understanding of several key concepts in biology. Here are the required underlying knowledge and understanding for this area of study: Chemistry: Students need to have a basic understanding of chemical molecules, including how bonds can be formed and broken between atoms. A basic understanding of some organic functional groups such as amine and carboxyl would also support learning. Macronutrients: Students should have an understanding of carbohydrates, lipids and proteins being macronutrients which are needed in the diet for numerous roles. Genetics: From GCSE Biology students should have some knowledge of patterns of inheritance and how DNA is the genetic information responsible for passing from parents to offspring.
Common misconceptions	There are misconceptions around carbohydrates, namely that they are only sugars rather than recognising the structural and storage functions of carbohydrates such as starch and glycogen. Similarly, lipids are often assumed to be 'unhealthy' and lead to obesity and the importance of lipids in hormone formation and phospholipid integrity are not understood. There can be a misconception that mutations in DNA always cause harmful diseases, whereas some mutations are neutral or even beneficial, e.g. silent mutations where there is no change in the amino acid sequence and beneficial mutations which can drive evolution.
Key concepts	The interpretation of molecular diagrams of mono-, di- and polysaccharides should be known, along with the formation of glycosidic bonds and the advantages and disadvantages of starch and glycogen as carbohydrate stores. Students should know the key features of the iodine test, reducing sugar test and non-reducing sugar test. Similarly, students should be able to interpret diagrams of mono-, di- and triglycerides and know the features of ester bond formation between glycerol and fatty acids. The relevance of phospholipids within the cell surface membrane, including the effect of saturated and unsaturated fatty acids on membrane thickness and fluidity. Students should understand why triglycerides are an effective energy source in plants and animals and how lipids in the myelin sheath provide insulation of the neuron axon. The key features of the emulsion and Sudan IV tests should be known.

Subject knowledge enhancement	Details
	Students should understand the difference between primary, secondary, tertiary and quaternary levels of protein organisation and be able to interpret diagrams of amino acids. They should also be able to carry out and analyse thin layer chromatography of amino acids. The formation of a peptide bond between the carboxylic acid and amino groups of adjacent amino acids should be understood. Students should understand the key features of the enzyme as a protein and the functions of lipases, proteases and carbohydrases. They should be able to explain the lock and key and induced fit hypothesis. The effect of enzyme concentration, temperature, pressure and pH on reaction time should be understood. Students should be able to interpret molecular diagrams of mono- and polynucleotides including DNA and RNA. The function of nucleases and the relevance of the mononucleotide structure of ATP and ADP should be understood. The purpose and function of DNA and RNA in inheritance and protein synthesis should be known along with the similarities and differences between DNA and RNA, including mtDNA, rRNA, mRNA and tRNA. Students should know how base pairing is fundamental to the integrity of DNA and the formation of RNA and that alterations in the sequence of bases can lead to mutations.
Subject knowledge enhancement for teachers	Read: Carbohydrates (rsb.org.uk) Chemistry for Biologists (rsb.org.uk) Factors affecting enzyme activity (practicalbiology.org) Watch: The structure of DNA and its assembly from nucleotides (youtube.com)

Topic Area B4: Biodiversity and ecosystems

Area of study: 4.1 The distribution of organisms

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
14	4.1.1 Distribution of organisms - Location and interaction of organisms in the living world - Factors affecting the distribution of organisms in an ecosystem	2	By the end of the lesson students should: - understand the relationship between ecosystem, community, population, habitat and niche - understand how organisms participate in food chains and webs - know how percentage efficiency of energy limits trophic levels - understand the impact of abiotic	Start with an independent research task: students should research the definitions of the key terms: ecosystem community population habitat niche. Agree on the definitions together as review, and then continue to add to this glossary throughout this lesson. Building a food web - Give students cards with organism names. - Use string to connect predator-prey relationships. - Add decomposers and top-level consumers.	Ecological terms (studysmarter.co.uk) Resource to support students with the starter task. Food Web: concept and applications (nature.com) A resource with food web examples to support the web building activity.	Flipped learning task: For next lesson students should research how climate change influences the distribution and survival of organisms. Students could be split into groups and each group given a different factor to research from: - Rising temperatures. - Changing rainfall patterns. - Extreme weather events. - Shifts in food web stability. Limit word count / slides.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			and biotic factors on distribution and survival understand the effect of climate change on distribution and survival of organisms.	- Discuss how energy flows through the web. Give students further examples of food webs and ask students to describe the impact of increasing or decreasing different organisms within the food web on the numbers of other organisms. Explain how to calculate efficiency of energy transfer from one trophic level to the next using the formula: $\text{Percentage efficiency} = \frac{\text{useful energy transferred}}{\text{total energy transferred}} \times 100\%$ Explain how the percentage efficiency of energy transfer limits the number of trophic levels in a food web. Investigating population distribution Use quadrats to measure species distribution in a sample area. - Select an area of grass or school grounds.	Using quadrats in sampling (bbc.co.uk/bitesize) BBC Bitesize provides resources for the sampling activity.	Biodiversity climate change impacts (ukri.org) Climate change impacts on ecosystems (epa.gov) Resources to support students with the flipped learning task.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Place quadrats randomly and record the number of plant species. - Repeat across multiple areas. - Compare results to identify species distribution patterns. Get students to analyse what factors affected the distribution of species seen in the results. Use the results of the activity to lead on to a teacher-led section explaining how different factors affect distribution and survival of organisms: Biotic factors: living components of an organism, e.g. competition, predation, disease. Abiotic factors: non-living components, e.g. light, wind, soil, temperature, water. Get students to construct a Venn diagram to show how the biotic and abiotic factors interact.		
15	4.2.1 Sampling techniques	1	By the end of the lesson students should:	Flipped learning activity: students should present the results of the flipped learning activity from the previous lesson. If students	Field techniques for population sampling and	Sampling to determine biodiversity (savemyexams.com)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	- Influences on the choice of sampling technique - Features of random sampling - Measurement of abiotic factors		- understand why different sampling techniques are needed for different types of organisms - understand the benefits and limitations of random sampling, including bias - understand how to determine soil features of water, humus and particulate mass - understand the importance of sampling in agriculture.	were split into groups, ensure bullet point notes are capture by all. Discuss with students why different sampling techniques are needed for different types of organisms. Ask student what factors need to be considered when sampling: - plants - sedentary or mobile animals - algae and seaweed. Random sampling using quadrats and pooters - Select a grassy area. - Use random coordinates to place quadrats. - Record the number of plants or small animals. - Use pooters to capture and count invertebrates. Using pitfall traps and sweep nets Pitfall trap:	estimation (bio.libretexts.org) A resource for teachers to support the practical activities. Biotic and abiotic factors (byjus.com) Notes to support the recap on biotic and abiotic factors	Notes for students independent revision and consolidation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• Dig a small hole and place a cup flush with - the soil. • Leave overnight to catch invertebrates. Sweep net: • Sweep through vegetation in a figure-eight motion. • Record the species caught. Get students to produce a summary of the four sampling techniques, including which type of organism it is suitable for and where it is most effectively used. Students should complete a table summarising the benefits and limitations of random sampling, including the impact of bias. Discussion / teacher-led section recapping the biotic and abiotic factors covered in the previous lesson (4.1.1 Distribution of organisms). Determining soil features Water content: • Weigh soil sample.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Heat for 24 hours and reweigh to calculate water loss. Humus content: - Burn sample at 550°C for 2 hours. - Measure the mass loss. Particulate mass: - Weigh sample after removing water and humus. Review: quite a few techniques have been discussed this lesson. Consolidate by asking students to propose advantages and disadvantages of each technique, and suggest scenarios where each one would be recommended. <i>Independent research task</i> Get students to research the importance of sampling techniques in agriculture. For scaffolding the students could be assigned key areas: Monitoring crop health. Soil sampling. Biodiversity assessment.	Soil sampling (ams-samplers.com) Sampling methods in agriculture (researchgate.net) Resources to support students with the independent research task.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
16	4.2.2 Practical 2: Sampling - Use of simple and grid quadrats - Line and belt transects	2	By the end of the lesson students should: - understand how to choose the appropriate type of sampling technique for collecting random and non-random samples in the field - know how to use a quadrat for sampling in an area and along a transect - understand how to measure abiotic factors under field conditions.	Start with an explanation of the difference between random, e.g. random placing of a quadrat, and non-random, e.g. transect, sampling. Ask students to give an advantage and disadvantage of both random and non-random sampling. Quadrat sampling The students could be split into 2 groups, half carry out simple quadrat sampling, half carry out grid quadrat sampling. Simple quadrat sampling: - Students will use a simple square quadrat (e.g. 1m × 1m) to sample a small area in the field. - Place the quadrat randomly in the designated area. - Students will estimate the percentage of plant cover within the quadrat. Grid quadrat sampling: - Use a quadrat with a grid inside (e.g. 10 × 10 grid for a 1m × 1m quadrat).	Tools for measuring abiotic factors (sciencing.com) Transects (field-studies-council.org) Notes to support the delivery of the practical activities.	Abiotic factors (bbc.co.uk/bitesize) Sampling to determine biodiversity (savemyexams.com) Resources to support students with independent consolidation and revision.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Each student will count how many grid squares are occupied by plants and estimate the percentage cover for each species within the quadrat. Discuss with students the advantages and disadvantages of each method of sampling. Questions to answer: - How accurate was the percentage estimation using both methods? - Did the grid quadrat provide more detailed information than the simple quadrat? Transect sampling - Mark a 10-metre transect line in the field using measuring tape. - Every metre along the transect, place a quadrat (or use a point frame) to estimate plant cover. - Record data on the plant species and their cover along the line. If using a point frame, count how many points hit vegetation for each metre.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Repeat this process at 1-metre intervals, moving along the transect. Belt transect sampling - Set up a belt transect, which is a continuous strip, e.g. 1m wide, along the 10-metre line. - At regular intervals along the transect, record data on plant cover and species. Discuss results with students, key points for the discussion: - How did plant cover change along the transects? - How did a belt transect differ from a line transect in terms of data collection? - What might influence plant cover along the transects (e.g. light, moisture, soil type)? Measuring abiotic factors Temperature measurement: Use a thermometer to record the air temperature at different points along the transects.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• Light intensity: Using a light meter, measure light intensity at the same points along the transect. • Soil moisture: Use a soil moisture sensor or perform a hand test (pinch the soil to feel moisture) at the same intervals along the transects.		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	To effectively engage with the lessons on biodiversity and ecosystems, students should already have a foundational understanding of several key concepts in biology. Here are the required underlying knowledge and understanding for this area of study: Mathematical skills: Ecological sampling involves data collection and analysis, requiring mathematical proficiency. Students need to be able to calculate mean, median, and mode and percentages. Working scientifically: Students need to have an understanding of the basic principles of scientific methods such as hypothesis and prediction, control variables, reliability and accuracy of results.
Common misconceptions	Students can sometimes think all organisms in an ecosystem have equal importance whereas some species play a disproportionately large role in maintaining ecosystem stability (keystone species). Removing them can drastically alter the ecosystem, while other species have a smaller ecological impact. There is also a misconception that a larger sample size always leads to more accurate results, whereas whilst larger sample sizes reduce random error, sampling bias or poor technique (e.g. unrepresentative sites) can still lead to inaccurate data, regardless of the sample size. Additionally there is a misconception that all sampling methods are equally reliable however different methods have varying degrees of accuracy and reliability.
Key concepts	The relationship between ecosystem, community, population, habitat and niche should be understood, along with how organisms participate in food chains and food webs, including brown food chains. Students should know how the percentage efficiency of energy transfer limits the number of trophic levels in a food chain and be able to calculate percentage efficiency. The impact of biotic and abiotic factors on the distribution and survival of organisms within an organism should be understood along with why climate change has such a profound influence on the distribution and survival of organisms. Students should understand why different sampling techniques are needed for different types of organisms including plants, sedentary or mobile animals and algae and seaweed. The characteristic features of pitfall traps, sweep nets, quadrats and pooters should be known, and also the limitations of random sampling, including bias. Students should know the abiotic factors including light intensity, air, water, substrate or soil, temperature and pH and should know how to determine soil features of water, humus and particulate mass. The importance of sampling techniques in agriculture should be known.

Subject knowledge enhancement	Details
	Students should know how to decide the appropriate type of sampling techniques for collecting random and non-random samples in a field, and how to use a quadrat for sampling in an area and along a transect. How to measure percentage plant cover within a quadrat and how to measure abiotic factors under field conditions should be understood.
Subject knowledge enhancement for teachers	Read: Ecological sampling techniques (countrysideinfo.co.uk) Sampling: The basics (field-studies-council.org) Ecosystems (savemyexams.com) Watch: Crash Course Ecology (youtube.com)

Chemistry

Topic Area C1: Atomic structure and Periodic Table

Area of study: 1.1 Atomic structure and 1.2 The Periodic Table

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
17	1.1.1 Atomic structure - The structure of atoms in terms of protons, neutrons and electrons - The existence of isotopes - Relative atomic mass - Mass spectra of elements - Electron configuration	2	By the end of the lesson students should: - know the structure of atoms in terms of the subatomic particles - understand the existence of isotopes - know how to interpret simple mass spectra in relation to calculation of relative atomic mass - understand how to work out the electron configuration of atoms in terms of main shells and subshells.	Start with a short quiz to assess key stage 4 knowledge of atomic structure from GCSE Science / Chemistry, e.g. Atomic Structure Quiz (footprints-science.co.uk). Show the Atoms and Ions video to introduce the structure of the atom. Discussion / teacher-led section to explain the modern atomic model. Include in the discussion: - position of the subatomic particles - relative mass and charges of protons, neutrons and electrons. Assess understanding by giving students the atomic number and mass number of different elements, and ask them to determine protons, neutrons, and electrons. Teacher instruction / recap:	Atoms and Ions (youtube.com) Video to support the initial discussion. Atomic structure and mass spectrometry (savemyexams.com) Notes on calculation of RAM from mass spectrometry.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- definition of an isotope - definition of relative atomic mass - how to calculate it from isotopic abundance. Introduce how mass spectra provide isotopic abundances, show a sample mass spectrum for an element. For independent practice provide students with isotopic data and ask them to calculate the relative atomic mass of an element. Explain electron shells and subshells (s, p, d,) up to $Z = 36$. Introduce the Aufbau principle and explain how to write electron configurations, examples: - hydrogen ($1s^1$) - oxygen ($1s^2 2s^2 2p^4$) - sodium ($1s^2 2s^2 2p^6 3s^1$) Independent practice: Provide atomic numbers and ask students to write the full electron configuration for different elements. As a challenge students could be given	Calculate relative atomic mass from isotopic abundance (chemistryguru.com) Resource to support the	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				shortened or full electron configurations and asked to identify the element.	independent research task.	
18	1.2 The Periodic Table - Periods - Groups - Blocks	2	By the end of the lesson students should: - know the arrangement of elements in the Periodic Table - know the arrangement of elements in periods showing repeating trends in physical and chemical properties (periodicity) - understand the trend in electron configurations in periods 2 and 3 - understand how to classify elements into s-, p- and d-block elements - understand the relationship between electron configuration and the position of the element in the Periodic Table.	Give students a jumbled Periodic Table (with missing atomic numbers) and ask them to arrange it in order. Discuss: - how they decided the order - describe the patterns in the arrangement. Discussion / teacher-led section describing the arrangement of elements in the modern Periodic Table. To include: - elements are ordered according to increasing atomic number - elements in groups have similar chemical properties (linked to similarities in electron configurations) To support with recall, a demonstration of the reaction of the alkali metals with water could be carried out here. Alternatively, the Alkali metals video could be shown. Students may also be able to recall the trends in group 7 elements' properties. The details of the reaction are not required, but they may help with discussing changes in reactivity and	Alkali metals demonstration (edu.rsc.org) Technical notes for carrying out the alkali metals demonstration. Alkali metals video (youtube.com) Video alternative to demonstration.	The Periodic Table, electron shells and orbitals (khanacademy.org) Notes to support students with consolidation / independent study.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				position on the table. Extend the discussion to other groups and periods in the table. Ask students to write the electron configurations for elements in period 2. Discuss: • Trend in terms of elements gaining one additional proton and electron moving across the period. • Relationship between electron configuration and position in Periodic Table. • Compare trends in atomic radii across the period with trends down group 1, etc. Assess understanding by giving students random electron configurations and asking them to place the element in the correct period and group. Introduce s-, p- and d- blocks, explain that block corresponds to the highest energy subshell being filled. Assess understanding by providing students with electron configurations and ask them to classify the element as s-, p-, or d-block.		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	Students will probably have some prior knowledge of this area from GCSE science throughout key stage 4. Students should have some understanding of the history of atomic theory and the definition of an atom as the simplest particle of an element. There should also be some understanding of the discovery of the three subatomic particles. Similarly to atomic structure, students will have some familiarity with the development of the Periodic Table and should understand that it consists of all naturally occurring and synthetic elements in order of atomic number, and that previous attempts to organise the elements were based on atomic mass, prior to the discovery of the proton. Students will have learned how to relate reactivity of group 0, 1 and 7 elements with their ease of gaining or losing of electrons. They are expected to also know how to predict the reactivity of elements from their positions in the Periodic Table. However, they will not have spent much time considering elements other than those in these three groups. They may also not have noticed the trend in filling of outer shells across period 2 and 3.
Common misconceptions	There is a misconception that the Bohr model, which shows electrons orbiting the nucleus in concentric circles, is often assumed to apply to all atoms. In reality, the Bohr model is an oversimplification and only works well for hydrogen-like atoms (with a single electron). More complex atoms require quantum mechanical models that account for electron behaviour in orbitals.
Key concepts	The definitions of atomic number (Z) and mass number (A) should be known, along with how to represent an atom's structure using the Bohr model of the atom up to Z=20. The relative charges and masses of the subatomic particles should be known along with the definition of an isotope and how to calculate the relative atomic mass from isotopic abundance (including how to interpret simple mass spectra of elements). It should be understood how to work out the electron configuration of atoms in terms of main shells and subshells (s, p and d) up to Z = 36. Students should know how the elements are ordered in the Periodic Table according to atomic number and the repeating trends in physical and chemical properties. It should be understood how to classify elements into s-, p- and d- blocks and the relationship between electron configuration and the position of the element in the Periodic Table. Links to specification: Unit F183: 3.1.1 Mass spectrometry

Subject knowledge enhancement	Details
Subject knowledge enhancement for teachers	Read: A simple view of atomic structure (chemguide.co.uk) Periodicity (bbc.co.uk/bitesize) Watch: Electron configuration (youtube.com) Periodic Table trends (youtube.com)

Topic Area C2: Quantitative chemistry

Area of study: 2.1 Amount of substance

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
19	2.1.1 The mole and molar mass - The mole - Molar mass - Calculation of the number of moles from the mass in g and the molar mass - Empirical formula - Molecular formula - Formula unit	2	By the end of the lesson students should: - understand the terms amount of substance, mole and molar mass - know the difference between empirical formula, molecular formula and formula unit - know how to calculate the empirical formula of a compound.	Show students a small object, e.g. grains of rice or sugar, and ask how many grains do you think are in the sample? Explain that some things (atoms) are too small to count individually, so chemists use the mole as a unit of measurement. Define key terms: amount of substance (n) mole (in terms of the Avogadro constant) molar mass (g/mol). The discussion can be supported by showing the video of The Mole. Demonstrate a worked example of calculating molar mass. For example:	Note and sample calculations (pmt.physicsandmathstutor.com) Notes and worked examples to use for demonstration. The Mole (youtube.com) Video to support the discussion.	Moles - Chemical calculations: Video playlist - BBC Bitesize (bbc.co.uk/bitesize) For students to use for consolidation. Mole calculations explained (centraltutors.co.uk) Notes and worked examples to support students.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Molar mass of $\text{H}_2\text{O} = (2 \times 1.0) + (1 \times 16.0) = 18.0 \text{ g/mol}$. Ask students to calculate the molar mass of simple compounds like NaCl, CO_2, and CH_4. Explain and demonstrate a worked example using the formula: $\text{Amount of substance} = \frac{\text{mass of substance}}{\text{molar mass}}$ Provide students with masses of various compounds and ask them to calculate the amount of substance (moles). Define empirical formula, demonstrate a worked example of calculating empirical formula from the % by mass of its elements. Explain that the molecular formula is a multiple of the empirical formula. To assess understanding give students a set of percentage compositions and ask them to calculate the empirical formula and molecular formula of the compounds.	Percent Composition and Molecular Formula Worksheet (studylib.net) Worksheet to accompany the activity.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Explain that ionic compounds don't exist as molecules but as a ratio of ions, called the formula unit .		
20	2.1.2 Balancing equations and reacting masses - Classification of typical types of reaction - Calculations involving reacting masses	2	By the end of the lesson students should: - understand how to classify types of reactions - know how to write balanced equations for the types of reactions listed - know how to calculate reacting masses and masses of products based on balanced equations.	Start with a short quiz on mole calculations to check understanding of the previous lesson. Demonstrate an example of each of the types of chemical reaction, without identifying which one is which. Independent research task: students should research a definition and an example of each of the following categories of chemical reaction: - acid-base - acid-carbonate - acid-metal - thermal decomposition - redox - precipitation. Allow time to compare definitions and examples, to collect as many examples as possible. Ask students to match their definitions with the reactions shown in the demonstration.	Types of chemical reactions (thoughtco.com) Examples of reactions for to use for the demonstration. How to balance chemical equations (youtube.com) Video to support the balancing worked example. Calculate mass in reactions (cognitoedu.org) Resource to	Reacting masses calculations (bbc.co.uk/bitesize) BBC Bitesize resource to support students with consolidation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Demonstrate with worked examples how to balance chemical equation including the definitions and examples of state symbols This can be aided by showing the How to balance chemical equations video. Students can independently practice the process using the Equation balancer. (phet.colorado.edu) Give students a selection of unbalanced chemical equations from the list of types of equation to balance. Demonstrate how to calculate reacting masses and masses of products using a worked example, and work through an example together. Practice: Provide students with balanced equations and masses of various compounds and ask them to calculate reacting masses and / or products.	support the delivery of the worked example. Exemplar worksheets and answers (templatelab.com) E.g. Creative Chemistry Reaction problems 1 and Reaction problems 2 with answers (creative-chemistry.org.uk) Types of chemical reactions (chemistrytalk.org) Resource to support the	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
					independent research task. Equation balancer (phet.colorado.edu) Online equation balancer to use for practice balancing chemical equations.	
21	2.1.3 Number of moles in aqueous solutions and preparation of a standard solution - Calculations involving volume and concentration of solutions - Standard solution	2	By the end of the lesson students should: - understand how to perform calculations involving volume and concentration of solutions - know how to prepare a standard solution.	Start by assessing prior understanding of key terms: ask students to define on a whiteboard: solute solvent solution concentration. Address any gaps in knowledge and discuss examples, for example saltwater, sugar in tea. Introduce the units of volume and concentration: - cm³ and dm³	Making a standard solution (edu.rsc.org) Notes on the preparation of a standard solution.	Concentration in mol dm⁻³ (savemyexams.com) Notes and calculations for consolidation and revision.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• mol dm⁻³ • g dm⁻³ Demonstrate using worked examples how to use the formula: $\text{Concentration} = \frac{\text{amount of solute}}{\text{volume}}$ to work out volume, mass or moles of solute, and concentration. The explanation may be supported by showing the Moles, concentration and volume calculations video. After demonstrating how to use the equation above, and then doing an example together, give students questions in which they need to calculate either concentration (in mol dm⁻³ or g dm⁻³), volume of solvent or mass of solute. Class practical: students to prepare a standard solution of sodium carbonate. Discuss with students the answers to the following questions: • Why do we dissolve the solute in a small amount of water first?	Moles, concentration and volume calculations (youtube.com) Video to support the worked example explanation. E.g. Calculating concentration worksheet with answers (everettcc.edu) Making a standard solution (sites.google.com) Instructions for students on how to	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Why is the glassware rinsed between stages? - What would happen if we exceeded the final volume before dissolving all the solute?	make a standard solution.	
22	2.1.4 Neutralisation	2	By the end of the lesson students should: - understand neutralisation as the reaction between acids and bases - understand the formulae of common acids - understand how to determine the formulae and names of salts produced by acids.	Start with a recap of the pH scale to establish understanding of acids and bases. Get students to place household substances at the correct pH on the scale. Discussion / teacher-led section defining neutralisation as a reaction between an acid and a base to form a salt and water. Use the general equation: $\text{Acid} + \text{Base} \rightarrow \text{Salt} + \text{Water}$ Explain differences between reaction with alkali and reaction with carbonate (effervescence). Give examples of each type of neutralisation reaction, explaining how to name the salt produced using the naming rule: First part of the salt name comes from the metal in the base.	Neutralisation (youtube.com) Video to support the teacher-led section. Acids and bases (cognitoedu.org) Notes and video to support the teacher-led section.	Seneca: Acids and alkalis (senecalearning.com) Independent study for consolidation and revision.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Second part comes from the acid used. Show the Neutralisation video to support the discussion. Class practical: prepare a salt from a neutralisation reaction. Practical would reinforce some of the practical competencies needed for Unit F182. It can be extended by asking students to calculate theoretical mass yield of salt and find mass of actual salt produced. Allows discussions of errors and evaluation of method. Independent practice: Students match a given acid and base to determine the salt name and formula. Then write balanced equations for their reactions. Acids to be used include: HCl, H_2SO_4, HNO_3, and CH_3COOH. Alkalis to be used include: NaOH, KOH and NH_3.	e.g. RSC Preparing a soluble salt by neutralisation (edu.rsc.org)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
23	2.1.5 Practical 3: volumetric analysis	2	By the end of the lesson students should: - understand the use of acid-base titration to determine concentration - understand appropriate indicators to use to determine the end point of a titration - understand structured titration calculations based on experimental results.	Start with a recap of neutralisation reactions of acids with alkalis from previous lesson - naming of salts produced and balancing equations involving common acids and alkalis. Demonstrate the titration procedure prior to students completing the practical. Include in the explanation: - the purpose of the technique (to determine an accurate concentration of an unknown solution) - appropriate indicators and the expected colour change, e.g. methyl orange, phenolphthalein - apparatus used including the rationale behind each piece of apparatus. Alternatively the Titration procedure video can be shown. Class practical: Volumetric analysis using acid-base titration. Discuss how to improve results by reducing zero, random and systematic errors. Students repeat the procedure until they obtain concordant results.	Acid-base titrations (chem.libretexts.org) Notes to support the teacher-led demonstration. Titration practical resources (edu.rsc.org) Resources to support the delivery of the class practical. Titration procedure (youtube.com) Video to support the explanation of the procedure. Sources of error in titrations (titrations.info)	Perfecting acid-base titration (birmingham.ac.uk) Resource to support students with consolidation and revision. Titration screen experiment (virtual.edu.rsc.org) Titration simulation for students to work through independently.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				If the equipment is available students could repeat the procedure using data logging equipment to obtain a titration curve, or use a digital pH meter to record pH on addition of acid or base and manually construct a titration curve. Demonstrate with a worked example how to use the experimental results to calculate the concentration of the unknown solution. Independent practice: Give students experimental results from titrations involving other known acids and alkalis and ask them to calculate the concentration of the unknown solution.	Titration Calculations (scienceskool.co.uk) This worksheet will provide a more structured approach for students who find this challenging.	
24	2.1.6 Moles and volumes of gases	2	By the end of the lesson students should: understand that molar gas volume is the volume occupied by 1 mole of gas at RTP	Start with a short quiz reviewing calculations of numbers of moles and calculations involving the Avogadro constant.		How to find volume of gas (crunchchemistry.co.uk) Resource to support students with the independent practice.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			know how to calculate reacting masses and volume of gases from balanced equations.	Discussion / teacher-led section describing molar gas volume as the volume of gas occupied by 1 mole of gas at RTP. Show, using a worked example, how to calculate the number of moles of a gas from the volume it occupies at RTP using the formula: $\text{Amount of gas} = \frac{\text{volume of gas}}{24}$ Show the How to calculate gas volumes video to support the discussion [ideal gas equation not required]. Independent practice: Students solve three gas volume calculations in pairs and swap answers to check. Use a worked example to demonstrate how to use balanced chemical equations to determine how much gas is produced in a reaction. Practical activity: measuring the volume of hydrogen gas. Discuss what errors might affect gas collection. Independent practice: Give students balanced equations and reacting masses to practice determining volumes of gas produced.	How to calculate gas volumes (youtube.com) Video to support the teacher-led section. e.g. Gases and molar volumes (science-revision.co.uk) for questions with answers e.g. The volume of 1 mole of hydrogen gas (edu.rsc.org) available with free registration	Consolidation: provide students with a good range of different questions to bring this topic together, e.g. STEM Learning Revision of KS4 Calculations in Chemistry for KS5 (stem.org.uk)

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	In order to effectively engage with lessons on quantitative chemistry, students should already have a foundation understanding of some key concepts. This is the prerequisite knowledge and understanding for this area of study: Chemical equations: students should be familiar with the notation used for writing chemical formulae and equations and understand terms such as reactant and product. Some students may be aware of stoichiometry, but only students who studied higher tier content will have met moles and amount of substance. Only GCSE Chemistry students will have performed titrations. Maths skills: students should be able to use and rearrange an equation containing three quantities and also convert quantities from kg to g, cm^3 to dm^3 and vice versa. They should also be able to state and use simple ratios. Higher tier students only will have studied moles, molar volumes and concentrations.
Common misconceptions	There is often confusion around the use of the terms mass, molar mass and relative formula mass and these terms are frequently used interchangeably. It should be clearly distinguished that molar mass (in g/mol) is the mass per mole whereas mass is what we weigh in grams. It should also be reinforced that balanced equations show mole ratios, not grams. Molar gas volume can sometimes be assumed to be valid in any condition so it needs to be explained that 24 dm^3 applies only at room temperature and pressure.
Key concepts	Students need to understand the concept of the mole in terms of the amount of substance although this does not include the definition of the mole in relation to the mass of carbon-12. Students should be familiar with calculations involving the relationship $\text{amount (mol)} = \text{mass (g)} / \text{molar mass}$ along with using the Avogadro constant to calculate the number of particles of a substance. Students should be able to recognise and classify reactions as acid-base, acid-carbonate, acid-metal, thermal decomposition, redox and precipitation and balance equations accordingly. They should also be able to use the balanced equations to calculate reacting masses and masses of products given starting quantities. Calculation involving the use of the relationships $\text{concentration (mol dm}^{-3}\text{)} = \text{amount of solute (mol)} / \text{volume (dm}^3\text{)}$ and $\text{concentration (g dm}^{-3}\text{)} = \text{mass (g)} / \text{volume (dm}^3\text{)}$ should be understood, along with the conversion between g dm^{-3} and mol dm^{-3}. Students should be able to recognise neutralisation reactions between acids and bases, including alkalis and carbonates to form salts. The formulae of the common acids (HCl, H_2SO_4, HNO_3 and CH_3COOH) and alkalis (NaOH,

Subject knowledge enhancement	Details
	KOH and NH_3) should be known and students should be able to determine the formulae and names of salts produced by these acids and alkalis. The use of acid-base titration to determine concentration should be both understood and carried out. Students should know the appropriate equipment to use for the procedure and understand why the equipment is chosen for precision. The use of experimental results in a structured calculation to determine the concentration of an unknown familiar or unfamiliar acid or base should be understood. Students should know that one mole of gas occupies 24dm^3 at RTP and understand how to use this quantity to calculate reacting masses and volumes of gases from balanced equations. Links to specification: Unit F183 2.1.1 Quantitative analysis of solids Unit F183 2.1.2 Quantitative analysis of solutions
Subject knowledge enhancement for teachers	Read: Notes and sample calculations (pmt.physicsandmathstutor.com) Chemical calculations (chemistry.coach) Quantitative chemistry resources (edu.rsc.org) Making standard solutions and carrying out acid base titrations (sites.google.com) Watch: Chemical calculations (youtube.com) Moles and mass calculations (youtube.com)

Topic Area: C3: Structure and bonding

Area of study: 3.1 Bonding

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
25	3.1.1 Bonding - Ionic bonding: formation of ionic compounds / giant ionic lattices - Covalent bonding: formation of covalent substances - Electronegativity and bond polarity - Intermolecular forces - Metallic bonding	3	By the end of the lesson students should: - know the features of ionic bonding and the effect of ionic radius and ionic charge on the strength of ionic bonding - know the features of covalent bonding and how to represent covalent molecules as 'dot-and-cross' diagrams - understand electronegativity in relation to the Pauling scale and why bonds are	Start with a quiz (e.g. key stage 4 GCSE Science bonding) to assess prior understanding. Suggested questions to use are: - What happens to the electrons when an ionic bond forms? - How would you describe the arrangement of electrons in a covalent bond? - Which type of elements form ionic bonds? - Which type of elements form covalent bonds? Discussion / teacher-led section describing transfer of electrons in the formation of an ionic bond. Key concepts for the discussion are: - Ionic bonds form between metals and non-metals.	What is ionic bonding? (youtube.com) Covalent bonding (youtube.com) Videos to support the teacher-led section. Ionic bonding (chemguide.co.uk) Ionic and covalent bonds (chem.libretexts.org) Bond polarity (chem.libretexts.org)	Bond polarity and electronegativity quiz (chemquiz.net) Quiz for students to test their own understanding. Use OCR ExamBuilder to generate exam questions assessing the learning of the unit so far. You will need to check the questions and mark schemes align with the AAQ specification and

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			polar - understand the basis of the different types of intermolecular forces in comparison to giant covalent lattices - know the features of metallic bonding.	- Metals lose electrons to form positive ions (cations). - Non-metals gain electrons to form negative ions (anions). - Oppositely charged ions attract to form a giant ionic lattice. The discussion can be supported by showing the What is ionic bonding? video. Modelling ionic bonding Using coloured paper circles (to represent different atoms), students cut out electrons and show their transfer. Label charges and final compounds. Give students pairs of ionic compounds and ask them to identify which would have the higher and which would have the lower strength of ionic bond, for example: Na_2O and Cs_2O MgCl_2 and NaCl Na_2O and Al_2O_3 Ask students to give their rationale for their choices and discuss the effect of ionic radius and ionic charge on the strength of ionic bonding.	Metallic bonding (chemguide.co.uk) Resources to support the teacher-led sections. Intramolecular and intermolecular forces (khanacademy.org) Notes to support students with the independent task.	approach. (ocr.org.uk)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Discussion / teacher-led section describing the sharing of electrons between non-metal atoms to form a covalent bond. Get students to practice drawing dot-and-cross diagrams for covalent compounds on whiteboards. For example: • water (H₂O) • carbon dioxide (CO₂) • methane (CH₄) • diamond (C) vs. graphite (C) Explain the concept of electronegativity being the ability of an atom to attract shared electrons. The discussion can be supported by showing the Covalent bonding video. Predicting polarity • Give students electronegativity values for elements (Pauling scale). • They must determine whether bonds are polar or non-polar. • Compare bonds like H–Cl, O–H, and C–H.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Explain how the 3 different forms of intermolecular forces arise and the properties that result from each type. Key concepts: • London forces (weakest, between all molecules). • Dipole-dipole forces (between polar molecules). • Hydrogen bonding (strongest, between molecules with H–O, H–N, or H–F bonds). Students could practice drawing H bonding diagrams between different molecules. Comparing boiling points • Provide students with a list of substances (water, methane, ethanol, oxygen). • Students should predict their relative boiling points based on intermolecular forces. Discuss why water has a higher boiling point than ethanol (stronger hydrogen bonds) and how the boiling points of both would be much lower than that of a giant covalent lattice.	Intermolecular forces (youtube.com) What are hydrogen bonds? 16-18 years (edu.rsc.org)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Demonstrate metallic bonding using small magnets to represent metal cations. Use marbles or beads to show delocalised electrons moving through the structure. Ask students to use the demonstration to build a diagram of metallic bonding, including the key features: • Metal atoms lose electrons to form a sea of delocalised electrons. • Strong electrostatic attraction between positive metal ions and delocalised electrons holds the structure together. Use OCR ExamBuilder to generate exam questions assessing the learning of the unit so far. You will need to check the questions and mark schemes align with the AAQ specification and approach.		
26	3.1.2 Formulae of ions and compounds • Cations and anions • Formulae of ionic compounds and covalent substances	2	By the end of the lesson students should: • know how to write formulae of ionic compounds from ionic charges • understand how to predict ionic charge from the position of an element in the Periodic Table	Ask students to write definitions on a whiteboard for: • ion • anion • cation Discuss answers and address any misconceptions. Give students a blank Periodic Table and ask them to label the common ionic charges and highlight any trends: • groups 1 to 3, +1 to +3	Determining ionic formulae (thenational.academy) Lesson resources on ionic formulae.	Formulae of ionic compounds (bbc.co.uk/bitesize) BBC Bitesize notes to support consolidation and revision. Deducing formulae using common ions (savemyexams.com)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			- know the names and formulae of common compound ions - know how to use chemical symbols to write the formulae of elements and covalent and ionic compounds.	- groups 5 to 7, -3 to -1 - transition block is variable. Demonstrate through worked examples how to write the formulae of ionic compounds using a step-by-step method: - Identify the ion charges. - Balance the charges so that the total charge is zero (by changes the numbers of anions and / or cations). - Write the formula using the correct ratios of ions. Match the ions to make compounds - Provide students with cards of different ions (Na^+, Mg^{2+}, Cl^-, O^{2-}, etc.) - Students must pair up ions to form correct ionic compounds. - Write the correct formula for each compound. Give students the names and formulae of common compound ions (NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+) and repeat the matching activity using compound ions. Specification link: 2.1.1	Covalent compounds: formulae and names (chem.libretexts.org) Notes to support the teacher-led sections.	Revision notes to support students' consolidation and revision. Naming ionic and molecular compounds (youtube.com) Video to support students' self study.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Remind students that for ionic compounds the formula unit is quoted (the simplest ratio of anions to cations). Identify the formulae - Provide students with names of common covalent compounds. - They must write the correct chemical formulae. Example: - hydrogen peroxide → H_2O_2 - ammonia → NH_3 - sulfur dioxide → SO_2 Assess understanding with a quickfire quiz. Suggested questions include: - What is the charge on an ion formed by oxygen? - Write the formula for calcium nitrate. - What type of bonding is present in carbon dioxide? - What is the formula of aluminium sulfide?		
27	3.2.1 Physical properties of metals, ionic compounds and	1	By the end of the lesson students should: understand the physical properties	Start by showing students samples of copper, sodium chloride, glucose and graphite and ask them to describe them. Ideally looking for answers which describe	Properties of ionic compounds (chem.libretexts.org)	Small molecules quiz (bbc.co.uk/bitesize) Quiz for students to

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	covalent substances		of metals, ionic compounds and covalent substances (both simple molecular and giant covalent) including melting point and electrical conductivity understand how to explain the properties in terms of the type of bonding, particles present and forces between the particles.	the appearance of the substances particularly in relation to: hard or soft flexible or brittle. Practical activity: Testing electrical conductivity and melting behaviour - Give students samples of copper, sodium chloride, glucose and graphite. - Test electrical conductivity: connect each substance to a simple circuit and check if the bulb lights up. - Test solid ionic compounds and then test them when dissolved in water. - Observe melting behaviour: Heat a small sample of each substance using a Bunsen burner. Discuss the results obtained by the students and explain the behaviour shown: - Metals conduct due to delocalised electrons. - Ionic compounds conduct in solution or molten state because ions are free to move.	Covalent or molecular compound properties (thoughtco.com) Metals (chem.libretexts.org) Notes to support the teacher-led section. Investigating properties of ionic and covalent compounds (creative-chemistry.org.uk) Instructions for the class practical.	test their understanding. Bonding, structure and properties (bbc.co.uk/bitesize) Podcast for students to use for consolidation. Use OCR ExamBuilder to generate exam questions assessing the learning so far. (ocr.org.uk)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• Covalent substances do not conduct (except graphite) due to a lack of free charges. • Substances with strong bonds (ionic, metallic, giant covalent) have high melting points. Test students understanding of the properties of each type of compound along with their ability to identify the type of bonding - give students a list of compounds and ask them to identify the type of compound and make predictions as to the properties. Independent research task: Students can produce a comparison Venn diagram or produce a table with bullet points so they have a summary of each type of bonding.		
28	3.3.1 Core concepts of organic chemistry • Nomenclature • Structure of common organic compounds	3	By the end of the lesson students should: • understand how to use IUPAC rules for naming organic compounds • know the definition of structural isomers	Start by asking students to draw the electron configuration of a carbon atom on a whiteboard and suggest why carbon is unique in the way it bonds. Answer: it can form single, double and triple bonds and also bond to itself in long chains.	Organic chemistry (a-levelnotes.co.uk) Types of alcohols (byjus.com) Isomers (chem.libretexts.org)	Basic concepts of organic chemistry (thesciencehive.co.uk) A general resource to support students with consolidation and revision. Create a worksheet of naming exercises to

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	- Structural isomerism - Intermolecular forces - Combustion equations of alkanes and alcohols		- understand how to draw structural / displayed formulae of the first 6 members of the alkanes - know classification of alcohols into primary, secondary and tertiary - know how to write balanced equations for the complete combustion of alkanes and alcohols - understand the advantages and disadvantages of alkanes and alcohols as fuels.	Discussion / teacher-led section explaining the IUPAC rules for systematically naming organic compounds. This should be limited to alkanes, alkenes, alcohols, aldehydes, ketones, carboxylic acids and haloalkanes. The discussion can be supported by showing the IUPAC nomenclature of alkanes video. Give students the opportunity to independently practice both naming given compounds and drawing compounds from given names. - provide students with 10 examples - students work in pairs to apply the IUPAC rules and write correct names / draw correct structures - swap with another pair to review answers. Assess understanding by giving students a short quiz on naming of structures. Describe structural formula and displayed formula, draw methane to hexane with molecular, structural and displayed formulae.	Notes to inform the teacher-led sections. IUPAC nomenclature of alkanes (youtube.com) Video on nomenclature of alkanes to support the teacher-led section.	cover all of the different organic compounds from the spec (this can be an amalgam of many different activities available online, but be careful to confirm the content is relevant). Flipped learning task: as an extension students can research the impact of combustion of alkanes on global temperature. For scaffolding they could be asked to answer the following questions: - How have CO₂ levels changed over the past 100 years? - How are CO₂ levels and global temperature linked? - What is the greenhouse effect? - What are the environmental

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Building isomers with molecular models Give students molecular model kits (or paper cutouts of atoms if kits are not available) of pentane (C_5H_{12}): - students to arrange the atoms in as many different ways as possible (constructing structural isomers) - ask students to draw their isomers and explain the differences. Give students other examples of molecules and ask them to draw all of the structural isomers that can be made from the molecule (with or without using molecular molecule kits) for example: - hexane (C_6H_{14}) - pentanol ($C_5H_{11}OH$) - chlorobutane (C_4H_9Cl) Use the students' answers to define structural isomers. Classification of alcohols: Ask students to look at their structural isomers of pentanol from the previous activity and describe the differences between the molecules. Explain the categorisation of alcohols as:		implications of increased global temperature? Resources to support students with the flipped learning task: The greenhouse effect (bgs.ac.uk) Climate Change (climate.gov) CO₂ and greenhouse gas emissions (ourworldindata.org)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• primary • secondary • tertiary. To assess understanding give students 6 different alcohol structures and ask them to classify them as primary, secondary or tertiary. Recap 2.1.2 (Balancing equations and reacting masses). Give students the (unbalanced) equations for the complete combustion of propane and ethanol and ask them to balance them. Write balanced equations for the combustion of butane (C_4H_{10}) and methanol (CH_3OH) to demonstrate that although the stoichiometry changes, the products of combustion of the homologous series are the same. Independent research task: split class into two groups and ask one group to research advantages and disadvantages of alkanes as fuels and the other alcohols as a better alternative.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Each group presents three arguments and challenges the other side. - Class votes on the best argument. Independent research task: split class into two groups and ask one group to research advantages and disadvantages of alkanes as fuels and the other alcohols as a better alternative. Each group presents three arguments and challenges the other side. Class votes on the best argument. Flipped learning task: as an extension students can research the impact of combustion of alkanes on global temperature. For scaffolding they could be asked to answer the following questions: How have CO₂ levels changed over the past 100 years? How are CO₂ levels and global temperature linked? What is the greenhouse effect? What are the environmental implications of increased global temperature?		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	In order to effectively engage with lessons on structure and bonding, students should already have a foundation understanding of some key concepts. Only alkanes and alkenes (straight chains) will have been covered as part of GCSE Combined Science. This is the prerequisite knowledge and understanding for this area of study: Bonding: In order to understand the nature of bonding, students need to understand the octet rule: the tendency of atoms to gain, lose, or share electrons to achieve 8 valence electrons (like noble gases). Students also need to have an understanding of changes of state of matter and the nature of the changes in interactions between particles (bonds between atoms / ions or intermolecular forces) when substances are heated and cooled i.e. interactions are weakened at the melting point and broken at the boiling point. Organic chemistry: Students need to be familiar with the valency of carbon atoms and the ability of carbon atoms to form single, double and triple bonds. There also needs to be an understanding of the fact that the functional groups determine the chemical properties and reactivity of the molecule.
Common misconceptions	A common misconception in ionic bonding is that ionic compounds exist as pairs of ions (e.g. NaCl is a single sodium ion and a single chloride ion), rather than understanding that the given formula is a formula unit which describes the simplest whole number ratio of ions in a giant lattice. The misconception that covalent bonds involve electron sharing in equal amounts should be addressed with the introduction of the concept of electronegativity and the description of covalent bonds as either polar or non-polar. From key stage 4 the incorrect statement that molecular covalent compounds have low melting points because covalent bonds are weak is commonly used, rather than identifying that it is the intermolecular forces that are weak and result in a low melting point. When naming organic molecules using IUPAC nomenclature, there is a misconception that the numbering of the carbon chain always starts from the left whereas the chain is numbered from the end closest to the functional group or double/triple bond. Students also commonly use the longest visible chain in a skeletal formula as the parent name, rather than identifying the longest continuous carbon chain, even if it is not drawn in a straight line.
Key concepts	Students should be able to describe ionic bonding as the electrostatic attraction between positive and negative ions and that the solid structures of giant lattices formed result from oppositely charged ions being attracted in all directions. The effects of ionic radius and ionic charge on the strength of ionic bonding should be understood. Students should be able to describe a covalent bond as the electrostatic attraction between a shared pair of electrons and the nuclei of bonded atoms and be able to draw 'dot-and-cross' diagrams of molecules to represent covalent

Subject knowledge enhancement	Details
	bonding. The concept of electronegativity should be understood including interpretation of the Pauling scale and the identification of bonds as either polar or non-polar. Students should be able to identify the three types of intermolecular forces: hydrogen bonding, dipole-dipole interactions and London forces in molecular covalent structures and compare these to giant covalent lattices such as diamond and graphite. The nature of metallic bonding as a strong electrostatic attraction between cations and delocalised electrons to create a giant lattice structure should be understood. Students should know how to write the formulae of ionic compounds from ionic charges and how to predict the ionic charge from the position of an element in the Periodic Table. They should know the names and formulae of NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} and Ag^+ and be able to use chemical symbols to write the formulae of elements and covalent and ionic compounds. Students should know the physical properties of metals, ionic compounds and covalent substances (both simple molecular and giant covalent), including melting point and electrical conductivity. They should be able to explain the properties in terms of the type of bonding, particles present and the forces between particles. The IUPAC rules for the systematic naming of organic compounds, including alkanes, alkenes, alcohols, aldehydes, ketones, carboxylic acids and haloalkanes should be understood along with the definition of structural isomers. Students should know how to draw the structural and displayed formulae of the first six members of the alkane series and their corresponding alkyl groups and write their chemical formulae. Students should be able to classify alcohols into primary, secondary and tertiary alcohols and write balanced equations for the complete combustion of alkanes and alcohols. Students should also be able to understand the advantages and disadvantages of using alkanes and alcohols as fuels. Links to specification: Unit F184 1.1.1 Distinguishing between different types of chemical substance Unit F184 2.2.1 Identification of inorganic substances
Subject knowledge enhancement for teachers	Read: Covalent bonding made easy (edu.rsc.org) How to teach ionic bonding (edu.rsc.org) Watch: Types of bonding (youtube.com) Basic concepts of organic chemistry (youtube.com) Listen: Bonding, structure and properties (bbc.co.uk/bitesize)

Area of study: 4.1 Rates of reaction and 4.2 Enthalpy changes

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
29	4.1.1 Factors which affect reaction rate - Collision theory - Boltzmann distribution of molecular energies - Activation energy	1	By the end of the lesson students should: - know the term rate of reaction - know what activation energy is - understand the effect of concentration, surface area, pressure, temperature and catalysts on reaction rate - understand the role of a catalyst - understand the Boltzmann distribution and its relationship with activation energy and temperature.	Start with a small practical activity: give students jelly, beakers and water and ask them to dissolve it as quickly as possible. Students should be thinking of cutting the jelly into small pieces, heating the water and stirring the jelly. Use the students decision-making process to discuss ways in which rates of chemical reactions can be made faster: - increasing concentration (of solutions) / pressure (of gases) - increasing surface area (of solids) - increasing temperature - addition of a catalyst. Independent research task: Divide the class into groups and assign each group a factor influencing reaction rate to research. For guidance, each group should answer the following questions: - How does it affect reaction rate?	Chemical reaction rates (openstax.org) Resource to support the initial discussion. Resources to support students with the independent research task: Controlling chemical reactions	<i>Flipped learning task:</i> For extension students could be asked to research real-world examples of catalysts being used in industrial processes, e.g. iron catalyst in the Haber process. Resource to support the students with the flipped learning activity: Catalysts in industrial processes (topsoe.com)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Explain the impact on rate in terms of collision theory. The groups should share their information with the rest of the class and students should complete a table to summarise all of the factors. Alternatively the decomposition of hydrogen peroxide video could be shown if there are not resources for the demonstration. Discussion / teacher-led section explaining the action of the catalyst, include in the discussion: - definition of activation energy - catalysts allow reaction to proceed via a different route with lower activation energy - catalysts are not used up in the reaction. Show students a Boltzmann distribution, explaining the distribution of energy in the particles, including how the relationship changes: - increasing temperature - addition of a catalyst. Assess understanding with a quick fire quiz on the lesson content. Questions could include:	(bbc.co.uk/bitesize) Reaction rates (a-levelnotes.co.uk) Decomposition of hydrogen peroxide practical instructions (edu.rsc.org) Notes to support the hydrogen peroxide demonstration. Decomposition of hydrogen peroxide (edu.rsc.org) Video alternative to the practical activity.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- How does increasing temperature increase reaction rate? - Define activation energy - How can surface area of a solid be increased?	The Boltzmann Distribution (savemyexams.com) Notes to support the teacher-led section.	
30	4.1.2 Practical 4: Investigating reaction rates - Experimental techniques for measuring rate - Analysis of results	1	By the end of the lesson students should: - understand the use of continuous monitoring methods to measure changes in mass or gas volume - understand the use of apparatus techniques and procedures to investigate reaction rates - understand that reaction rate can be calculated from	Discuss the results of the flipped learning activity from the previous lesson - students should present their findings to the rest of the class. Show students the equation for the reaction between calcium carbonate and hydrochloric acid and ask them to write on whiteboards what observations they would see in the reaction. Guide students towards answers of 'fizzing' and 'solid carbonate chips disappear'. Use these observations to introduce how chemical reactions can be monitored by measuring how quickly a product is made or how quickly a reactant is used up: - volume of gas produced - mass lost when a gas is produced	How to measure rate of reaction (youtube.com) Video to support the teacher-led section.	Measuring reaction rates (bbc.co.uk/bitesize) BBC Bitesize video and notes for students to use for consolidation. Other consolidation activities should also be made available including: Rates of reaction practical videos 16–18 students (edu.rsc.org) Or

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			the gradient of a graph or experimental data.	- formation of a solid (precipitate) - colour change by colorimetry (formation of colour as product is formed / loss of colour as reactant is used up). Show the How to measure rate of reaction video to support the discussion. Students carry out one or both of these practical activities. Alternatively the class could be split in half and one half carry out one activity and the other half carry out the second activity. Practical activity: Measuring mass lost - Weigh conical flask containing calcium carbonate chips and hydrochloric acid. - Start a stopwatch and record the mass every 30 seconds. - Continue until the reaction slows down. - Plot a graph of mass lost vs. time. Practical activity: Measuring gas volume - Add magnesium to hydrochloric acid in a conical flask and quickly attach the gas syringe. - Start the stopwatch and record the gas volume every 10 seconds. - Continue until no more gas is produced.	Teacher guide OCR A Level Chemistry PAG 9.2 and student sheet (teachcambridge.org) [ignore or remove reference to the rate equation and order of reaction] Teacher guide OCR A Level Chemistry PAG 9.3 and student sheet (teachcambridge.org)	Rate of Reaction using Graphs and Tangents (Higher Tier) Worksheet (api.thenational.academy)

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Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	- Examples of exothermic and endothermic reactions - Energy profile diagrams		exothermic and endothermic reactions - know combustion and respiration as examples of exothermic reactions - understand the signs and units of ΔH for exothermic and endothermic reactions.	Discussion / teacher-led section defining exothermic and endothermic reactions and describing the energy profiles for each type of reaction. Show the Exothermic and endothermic reactions video to support the discussion. Practical activity: investigating exothermic and endothermic reactions Give students examples of simple chemical reactions to measure the initial and final temperature to determine the associated temperature change. Example reactions: - hydrochloric acid and sodium hydroxide - ammonium chloride and water - zinc and copper sulfate. Discuss the results of the activity, ask students which reactions were exothermic and which were endothermic? Independent research task: Ask students to research photosynthesis, respiration, cracking and thermal decomposition as examples of endothermic and exothermic reactions. For scaffolding students could be asked to answer the following questions:	the teacher-led section. Exothermic and endothermic reactions (thesciencehive.co.uk) Notes to support the teach Photosynthesis (ssec.so.edu) Respiration (rsb.org.uk) Resources to support students with the independent	students with consolidation and revision.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Is the reaction exothermic or endothermic? - What are the reactants and products? - In what form is the energy released / taken in? Ask students to present the results of their research to the rest of the class.	research task er- led section.	
32	4.2.2 Enthalpy change of combustion of alcohols	2	By the end of the lesson students should: - know the definition of $\Delta_c H$ - understand how to determine $\Delta_c H$ of fuels directly - understand the assumptions and limitations of experimentally determined enthalpies.	Recap 3.3.1: ask students to write balanced equations for the combustion of an alkane and an alcohol, e.g. ethane and ethanol. Address any gaps in recall of knowledge and use the students' equations to construct a definition for $\Delta_c H$: enthalpy change when 1 mol of a substance undergoes complete combustion. Class practical activity: - Measure 100 cm³ of water into a calorimeter and measure initial temperature. - Weigh the spirit burner (including the alcohol), place it under the calorimeter and light. - Blow out the flame once a 20°C temperature rise is achieved. - Reweigh the spirit burner to determine the mass of alcohol burned.	Enthalpy change of combustion practical guide (edu.rsc.uk) Resources to support the practical activity. Enthalpy of combustion for alcohols (youtube.com) Video to support the practical activity.	Calculating enthalpy change of combustion (docbrown.info) Notes on the calculation to support students with the experimental results. Enthalpy change of combustion values (docbrown.info) Literature values of $\Delta_c H$ for students to use for comparison to experimental values. Use OCR ExamBuilder to select appropriate questions to practice skills from this lesson. (NB bond enthalpies, enthalpy of reaction and

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Repeat for different alcohols. Demonstrate using a worked example of one of the alcohols how to calculate $\Delta_c H$ from the experimental results using the formula: $q = mc\Delta T$ Students can then calculate $\Delta_c H$ for the other alcohols tested independently. Remind students of the need to convert J to kJ and vice versa, where appropriate. Also take time discuss to how a negative enthalpy should be calculated using this equation and why. Discuss the key assumptions that are made in the experiment: - All heat energy is transferred to the water. - Complete combustion occurs. - No heat is absorbed by the calorimeter. Ask students to research the literature values for $\Delta_c H$ for each alcohol tested and list the limitations that result in the experimental values being different to the literature values. - Heat loss to surroundings. - Incomplete combustion (leading to CO and carbon formation). - Evaporation of alcohol from burner before reweighing. - Heat absorbed by the calorimeter.		Hess's law / cycles are not required.) (ocr.org.uk)

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	In order to effectively engage with lessons on rates of reaction and enthalpy changes, students should already have a foundation understanding of some key concepts. This is the prerequisite knowledge and understanding for this area of study: Collision theory: students need to have an understanding of collision theory and that particles need to collide with sufficient energy and in the correct orientation in order to collide successfully and a product be formed. Enthalpy changes: students need to understand that in every chemical reaction there is an associated energy transfer between the system and the surroundings which is a product of the difference between the energy taken in for the bond breaking process and the energy released in the bond formation process. How science works: students need to have familiarity with common laboratory equipment such as conical flasks, measuring cylinders, gas syringes, balances, stop clock and why each piece of apparatus is selected for precision. It would also be an advantage for students to have an understanding of terminology such as precision, accuracy and resolution. Students should also be able to identify the independent variable, dependent variable and control variables within an experiment. Maths skills: students should know what a tangent is and how to draw a tangent to a curve. They should also be able to calculate a gradient (of a line graph or a tangent).
Common misconceptions	There is a misconception that more collisions always means a faster reaction rate but in reality only successful collisions affect reaction rate. More frequent collisions do not necessarily mean faster reactions if activation energy is not met. It can be assumed that catalysts make reactions happen that wouldn't occur otherwise whereas a catalyst actually only speeds up a reaction that would already happen, it does not create new reactions. Students may also assume that catalysts get used up or that they speed up the reaction given in the equation, and not that they provide an alternative route for the reaction to occur, which has a lower activation energy. Some students can become confused by thermodynamics and kinetics and it is sometimes assumed that a reaction with a large negative enthalpy change ($-\Delta H$) must be very fast. In reality, enthalpy change (ΔH) describes energy transfer, not speed. A reaction can release a lot of heat but still be slow if activation energy is high.

Subject knowledge enhancement	Details
Key concepts	Students should know the definition of rate of reaction as the change in mass or volume of a reactant or product per unit time, and the definition of activation energy as the minimum amount of energy required for a reaction to occur. Students should be able to explain the effect of concentration of solutions, surface area of solids, pressure of gases, temperature and catalysts on reaction rate in terms of collision theory. The role of a catalyst in increasing reaction rate by allowing the reaction to proceed via a different route with lower activation energy without being used up should be understood. Students should be able to interpret a Boltzmann distribution, including the qualitative effects of temperature changes and catalysts on the proportion of molecules exceeding the activation energy. Students should understand how continuous monitoring methods can be used to measure changes in mass or gas volume, including the use of appropriate apparatus, techniques and procedures to investigate reaction rates. They should also be able to calculate reaction rate from the gradient of a graph or experimental data. Students should be able to draw energy profiles for exothermic and endothermic reactions, labelling activation energy and overall enthalpy change. They should be able to recognise examples of exothermic and endothermic reactions, including combustion, respiration, cracking and thermal decomposition. Students should know the definition of enthalpy change of combustion (including symbols and units). They should be able to determine enthalpy change of combustion by direct experimental procedures, using the formula: Thermal energy = mass × specific heat capacity × change in temperature to calculate the energy transferred and then enthalpy change.
Subject knowledge enhancement for teachers	Read: How to measure the rate of reaction (chem.libretexts.org) Rates of reaction classroom resources (edu.rsc.org) Measuring enthalpy changes: teaching tips for your classroom (edu.rsc.org) Watch: Enthalpy and Enthalpy changes (youtube.com) Rates of reaction - practical experiments (youtube.com)

Physics

Topic Area P1: Electricity

Area of study: 1.1 Circuits

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
33	1.1.1 Charge and current	1	By the end of the lesson students should: - know the definition and units of current - understand conventional current and electron flow, including direct current - know the definition and units of charge - understand how to use the equation that links	Assess students' understanding of electricity from key stage 4 GCSE Physics. Ask students to define on a whiteboard: - What is electricity? - How is it measured? Show the Conventional current and electron flow video to introduce the difference between conventional current and electron flow. Explain the difference between conventional current and electron flow: conventional current: Flows from positive to negative (historical convention) electron flow: Electrons move from negative to positive (actual flow in metals).	Conventional current and electron flow (youtube.com) Video to support the discussion on conventional current and electron flow Conventional vs electron flow (allaboutcircuits.com)) Notes to inform the	Charge, Current and Time (gcse.com) Practice questions to students to independently practice using the charge equation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			charge, current and time.	Practical activity: Investigating conventional current - Set up a circuit with a battery, bulb, and ammeter. - Observe the bulb lighting up and measure current in amps. - Discuss why current is shown flowing positive to negative in circuit diagrams but electrons actually flow the opposite way. The Phet Circuit construction kit can be used as an alternative simulation to visualise electron flow Practical activity: Investigating direct current - Connect a DC source and observe the straight line on the oscilloscope. - Explain how the straight line indicates current flowing in one direction only. Discussion / teacher-led section describing elementary charge (e) as the electric charge carried by a single fundamental particle, including: Charge of an electron = -1.6×10^{-19} C. Charge of a proton = $+1.6 \times 10^{-19}$ C.	teacher-led discussion. Phet Circuit construction kit (phet.colorado.edu) Virtual circuit construction kit to visualise electron flow.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Using the charge equation: Introduce the equation, where Q = charge (C), I = current (A), t = time (s): $Q = It$ - Set up a simple circuit with a resistor and ammeter. - Turn on the circuit and measure current. - Record the time the circuit is on. - Demonstrate how to calculate the charge using $Q = I \times t$. The Charge, Current and Time video can be used to support the discussion. Give students additional calculations to practice using the equation to calculate either charge, current or time if the other two quantities are known. Challenge can be increased by incorporating conversion of units before calculation.	Charge, Current and Time (youtube.com) Video to support the explanation of how to use the charge equation. Current and charge questions and some answers (wordpress.com) can be used. Please see guidance on using equation triangles below.	
34	1.1.2 Potential difference and resistance	1	By the end of the lesson students should:	Think-pair-share: Ask students: What makes a light bulb brighter?	Ohm's Law (allaboutcircuits.com)	Resistance (bbc.co.uk/bitesize)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
	I-V characteristics		- know the units and definition of potential difference, with respect to work done - understand how to use the equation that links resistance, potential difference and current, and the units of resistance - understand the I-V characteristics of a resistor, light-dependent resistor, filament lamp, thermistor, diode and light-emitting diode - know Ohm's law.	Expected answers: more power, more current, higher voltage, lower resistance. Resistance demonstration: - Set up two identical bulbs, but with one connected to a longer wire. - Show that the bulb with the longer wire is dimmer. - Ask students to predict why using their knowledge of current. Define resistance as a measure of how much a component opposes the flow of electric current, measured in ohms (Ω). Measuring I-V characteristics - Connect a fixed resistor in series with an ammeter and power supply. - Use variable resistor to vary potential difference and measure current for each setting. - Plot an I-V graph and calculate resistance using: $R = \frac{V}{I}$ Units: resistance (Ω), voltage (V), current (A)	Notes to support the teacher-led section. I-V characteristics (educating-physics.com) Notes to support the delivery of the IV characteristics practical activity.	BBC Bitesize resources for student consolidation and independent study. I-V characteristics (gcsephysicsonline.com) A resource to support students with completing the I-V characteristics practical activity. Ohms Law (isaacphysics.org) Resource for student

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Explain the nature of the fixed resistor as Ohmic (obeying Ohm's Law) because the graph is a straight line through the origin. Repeat the experiment using other components: • filament lamp (non-Ohmic, resistance increases as it heats up) • diode (only conducts in one direction) • LDR (Light-Dependent Resistor) (Resistance decreases with increasing light) • NTC Thermistor (Negative Temperature Coefficient Thermistor) (resistance decreases with increasing temperature). Compare the shapes of each of the graphs and discuss the answers to each of the questions: • Why does the filament lamp's resistance increase? (Due to heating) • Why does a diode only conduct in one direction? • What happens to an LDR in darkness vs. bright light? Activity: Measuring the resistance of an NTC resistor • Place the thermistor connected to a circuit in a beaker of water.		independent consolidation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Gradually increase temperature (using heater or warm water). - Measure voltage and current to calculate resistance ($R = V/I$). - Observe how resistance changes with increasing temperature. Discuss why this happens (increased charge carrier movement at higher temperatures). Independent research activity: Ask students to research how thermistors and LDRs are used in real-life applications.	What is an LDR? (electronicsforu.com) Thermistors (teamwavelength.com) Resources to support students with the independent research task.	
35	1.1.3 Power and energy in circuits	2	By the end of the lesson students should: - know the definition and unit of power - understand how to use the equations linking power, current, potential	Start by asking students to share the results of the independent research activity into how thermistors and LDRs are used in real-life applications. Demonstrate a comparison of a bright and a dim bulb. Use a low-power (10 W) and high-power (100 W) bulb and ask students why is one brighter? Direct students to the answer that the higher power bulb transfers more energy.	Power (savemyexams.com) Notes to support the discussion. Electrical power (youtube.com) Video to support	Power, work done and electrical power (isaacphysics.org) Resource for independent consolidation and calculation practice.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			difference and resistance - understand the definition of an electronvolt - understand how to use the equation linking work done, potential difference, current and time - understand how to use the equation linking work done, potential difference and charge.	The discussion could include the Electrical power video. Activity: measuring power in a circuit - Connect a resistor in a simple circuit with a variable resistor, voltmeter and ammeter. - Adjust voltage and measure the current. - Calculate power using all three equations: Basic formula: $P = IV$ Ohm's Law: $V = IR$ Using Ohm's Law: $P = I^2R$ Rearranging for voltage: $P = \frac{V^2}{R}$ - Discuss which equation is most useful in different situations.	the demonstration of electrical power.	Electrical power and energy (bbc.co.uk/bitesize) For independent consolidation and revision. <i>Flipped learning:</i> Set students the task of learning the circuit symbols in Appendix G of the specification for a short quiz at the start of the next lesson.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Ask students to predict what happens when resistance increases. Give students the opportunity to independently practice further calculations using each of the formulae. measuring work done in a circuit - Set up a circuit with a resistor, ammeter, and voltmeter. - Record current, voltage, and time for 60 seconds. - Calculate energy transferred using: $W = VIt$ (useful when time is known) $W = VQ$ (useful when charge is known) - Compare values for different resistors. - Ask students how does energy change if the time is doubled? Discussion / teacher-led section defining an electronvolt (eV) as the energy gained by an electron when it moves through 1V (1 eV = 1.6×10^{-19} J). Discuss why the electronvolt is useful for describing small energy levels. The discussion could be supported by showing the Electronvolt explained video. It would be improved by providing some quick questions to practice converting between eV and J.	Electronvolts (phys.libretexts.org) Resource to support the teaching of electronvolts. Electronvolt explained (youtube.com) Video to support	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Assess student understanding with a quick quiz, for example: - Define power and electronvolt. - Write the three power equations.	the explanation of the electronvolt.	
36	1.1.4 Series and parallel circuits	1	By the end of the lesson students should: - understand the relationships between currents, voltages and resistances in series and parallel circuits - know conservation of charge and Kirchoff's first law - know conservation of energy and Kirchoff's second law	Start with a short quiz to assess students' recall of the relevant circuit symbols. As there are unfamiliar symbols in this lesson, spend time reviewing these to make sure students know what the role of each component is, i.e. with a match up activity. Use the Phet Circuit construction kit to investigate the relationship between current and potential difference in series and parallel circuits. Investigating series circuits - Construct a circuit with a power supply and two lamps in series. - Measure the current with an ammeter in multiple places in the circuit. - Measure the potential difference with a voltmeter in multiple places in the circuit. Investigating parallel circuits	Phet Circuit construction kit (phet.colorado.edu) Virtual circuit construction kit. Series Circuits Parallel Circuits (youtube.com) Optional videos to introduce series and parallel circuits. Resistors in series and parallel (phys.libretexts.org)	Investigating series and parallel circuits (savemyexams.com) Notes to support students with completion of the practical activity. Resistors in series and parallel (issacphysics.org) Practice questions for students to complete for independent practice of the calculations.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			- understand how to calculate total resistance for two or more resistors in series and in parallel - understand how to solve problems for series and parallel circuits.	- Construct a circuit with a power supply and two lamps in parallel. - Measure the current with an ammeter in multiple places in the circuit. - Measure the potential difference with a voltmeter in multiple places in the circuit. Discuss the results of the investigations and explain these in terms of Kirchoff's first and second laws: - First law (conservation of charge) At any junction in a circuit, the total current entering = total current leaving. - Second law (conservation of energy) The total potential difference around any closed loop in a circuit is equal to the sum of potential differences across the components. Demonstrate the total resistance when two or more fixed resistors are placed in series using the formula: $R_T = R_1 + R_2 + \dots$ Where R_T is the total resistance in series, R_1 is the resistance of resistor 1 and R_2 is the resistance of resistor 2.	Notes to support the teacher-led sections of the lesson.	Kirchoff's Laws (issacphysics.org) Resource for students to use for independent consolidation and revision.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Demonstrate the total resistance when two or more fixed resistors are placed in parallel using the formula: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} \dots$ Give students series and parallel circuit problems to solve. Example problems: A series circuit has a 12V battery and two resistors (4Ω & 6Ω). Calculate: - the total resistance - the total current - the voltage across each resistor. A parallel circuit has a 9V battery and two resistors (3Ω & 6Ω). Calculate: - the total resistance - the current in each branch - the total current from the battery. <i>Independent research task:</i> Get students to research real-life applications of series and parallel circuits. For example: - Household circuits: Why are lights in parallel instead of series?		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Car batteries: How do multiple cells in series increase voltage? - Electricity grids: How does parallel wiring prevent power loss?		
37	1.1.5 Potential dividers	2	By the end of the lesson students should: - understand the principles of a potential divider circuit - understand the use of a potentiometer as a potential divider - understand the use of potential divider circuits with LDRs and thermistors - understand how to solve problems for potential divider circuits with potentiometers, LDRs and thermistors.	Think-pair-share: Ask students: How does a volume control knob work? How does a streetlight turn on automatically? Guide students towards answers related to voltage control, light sensors and resistance change. Discussion / teacher-led section explaining the principle of potential dividers. - A potential divider circuit splits an input voltage into two parts using resistors. - Used to control voltage levels for sensors, circuits, and variable devices. - Consists of two resistances in series; the potential difference of the input will be divided in the ratio of the two resistances to produce an output of lower potential difference. Use a worked example to demonstrate how to calculate how the input potential difference is	What is a potential divider / voltage divider? (kitronik.co.uk) Notes to support the teacher-led section of the lesson. What is a potentiometer (uk.rs-online.com) Notes on potentiometers to support the discussion.	Potential Dividers (isaacphysics.org) Resource for students to use for independent calculation practice and consolidation. Students could produce a glossary of key terminology or create / complete a match up activity, i.e. potential divider, potential difference, potentiometer.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				divided in the ratio of the two resistors to produce lower output potential difference. Describe a potentiometer as a variable resistor that acts as a potential divider. Often used in volume controls, brightness adjustments and joystick controls. Investigating a potentiometer • Connect a potentiometer to a power supply as a potential divider. • Rotate the knob and measure how V_{out} changes. Independent research task: Students to research the real-life applications of potential divider circuits with LDRs and thermistors. Students could be split into groups and given one application to research for example: • temperature sensors (thermostats) • fire alarm and overheat protection • street lighting and outdoor lighting • smartphone auto brightness control • solar panel tracking systems.	Potential Divider (a-levelphysics.co.uk)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Give students some scenarios involving potential divider circuits to solve. Example scenarios: - A 10 kΩ potentiometer is connected to a 9V power supply. The wiper is adjusted so that it divides the resistance into 6 kΩ and 4 kΩ. Calculate the output voltage (V_{out}) across the 4 kΩ section. - A potential divider circuit consists of a LDR (2 kΩ in bright light, 10 kΩ in darkness) and a fixed 5 kΩ resistor, connected to a 12V power supply. The output voltage is measured across the fixed resistor. Calculate V_{out} in bright light (LDR = 2 kΩ). Calculate V_{out} in darkness (LDR = 10 kΩ).	Further guidance on potential divider circuits for ECTs and non specialists.	
38	1.1.6 Practical 5: Potential divider circuits	1	By the end of the lesson students should: understand the apparatus, techniques and procedures used to investigate potential divider circuits which may include a sensor such as a thermistor or an LDR	- Start with a short quiz on previous lesson content on potential divider circuits. Example questions are: - How does a thermistor (NTC) work? - How does an LDR work? - What is a potentiometer? - Explain how to calculate V_{out} Investigating a potential divider with a thermistor (NTC) - Set up a potential divider circuit with a thermistor and a fixed resistor.	Potential Dividers (spark.iop.org) Resource to support teachers with the delivery of the practical activity.	Investigating potential divider circuits (savemyexams.com) Notes to support students with the practical activity. Students could also use this to produce a 'how-to' guide or a correct the text of the method and / or calculations involved for consolidation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			understand how to identify and fix faults in potential divider circuits.	- Connect a voltmeter across the fixed resistor to measure V_{out} - Record initial V_{out} at room temperature. - Place the thermistor in warm water and observe changes in V_{out} - Plot a graph of V_{out} vs. temperature. Investigating a potential divider with an LDR - Set up a potential divider circuit with an LDR and a fixed resistor. - Connect a voltmeter across the fixed resistor to measure V_{out} - Record initial V_{out} - Slowly reduce the light by covering the LDR and observe changes in V_{out} - Plot a graph of V_{out} vs. light intensity.		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	In order to effectively engage with lessons on electricity, students should already have a foundation understanding of some key concepts. This is the prerequisite knowledge and understanding for this area of study: Chemistry: There needs to be an understanding of atomic structure and that protons are positively charged whereas electrons are negatively charged. The structure of metals as an electrical conductor with delocalised electrons which are free to move through the structure should also be understood. Physics: From key stage 4 Physics there is likely to be some understanding of electricity as ‘a flow of electrons’ and some recall of the terms current, potential difference and resistance and how these quantities can be measured.
Common misconceptions	Electricity is a topic that often leads to misconceptions due to its abstract nature. It is thought that current is ‘used up’ as it moves through a circuit, however electric current is the flow of charge, and it is the same at all points in a series circuit. What gets ‘used’ is the energy transferred to components like bulbs or resistors, not the actual current. It can be assumed that a battery pushes a fixed amount of current into a circuit, whereas in reality the amount of current depends on the resistance in the circuit, according to Ohm’s Law: It is also sometimes assumed that a higher voltage always means a higher current but it depends on the resistance. If resistance is high, even a high voltage may result in a small current (e.g. a 230V power socket but very low current in a phone charger). A common misconception is that electrons flow in the same direction as conventional current. Conventional current flows from positive to negative, but electrons actually move from negative to positive. This historical mistake was made before electrons were discovered.
Key concepts	Students need to know the definition of electric current in metals and electrolytes along with the unit of current, the difference between conventional current and electron flow and what is meant by direct current. Students also need to know what is meant by elementary charge (e) and how to use the relationship between charge (C), current (A) and time (s). The definition of potential difference with respect to work done and the unit of potential difference should be understood, along with the mathematical relationship between resistance (Ω), potential difference (V) and current (A). Students should know the unit of resistance and be able to recognise a graphical representation of the I-V characteristics of a resistor, light-dependent resistor (LDR), filament lamp, thermistor, diode and light-emitting diode (LED). Students should also be able to use the equation: Potential difference (V) = current (A) $\times$ resistance (Ω).

Subject knowledge enhancement	Details
	Students should know Ohm's law and understand how the resistance of NTC thermistors changes with temperature, and the resistance of LDRs changes with light intensity. Students should know the definition and units of power and be able to use the formulae linking power (W), current (A) and potential difference (V), power, current and resistance, and power, potential difference and resistance. They should also be able to use the equation work done (J) = potential difference (V) × current (A) × time (s) and work done (J) = potential difference (V) × charge (C). Students should also know the definition of an electronvolt. Students should be able to recall the common circuit symbols as set out in the ASE publication Signs, Symbols and Systematics. There should also be an understanding of the relationships between currents, voltages and resistances in series and parallel circuits. Students should be familiar with Kirchoff's laws and how these are applicable to current, potential difference and resistance in series and parallel circuits. Total resistance of two or more resistors in both series and parallel should also be able to be calculated. Students should understand the principle of a potential divider circuit and how a potentiometer can be used as a potential divider. The application of potential divider circuits with thermistors and LDRs should be understood and students should be able to solve problems involving potential divider circuits with potentiometers, LDRs and thermistors. Students should be able to use apparatus, techniques and procedures to investigate potential divider circuits which may include a sensor such as a thermistor or an LDR and should be able to identify and fix faults in potential divider circuits.
Subject knowledge enhancement for teachers	Watch: Electricity tough questions (youtube.com) All of charge and current (youtube.com) Read: Electricity (alevelphysicsonline.com) Electricity...tackle the tricky bits (explorify.uk) Support: using equation triangles – these articles from RSC explore the challenge of presenting formulae as triangles and why avoiding them improves understanding. Why are formula triangles bad? by Jenny Keoning and Why I hate formula triangles by David Wait.

Topic Area P2: Motion

Area of study: 2.1 Energy

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
39	2.1.1 Energy stores and energy transfers - Energy stores and energy transfers - Conservation of energy - Sankey diagrams	1	By the end of the lesson students should: - understand how energy is stored - understand how energy is transferred via energy carriers or pathways - understand how diagrams can be used to represent energy transfers - understand Sankey diagrams.	Start by reviewing the law of conservation of energy. Ask students to list as many energy stores as they can remember from GCSE Physics. Show the Energy stores and transferring energy video to introduce energy stores and energy transfers. Discuss misconceptions and gaps in knowledge from the starter activity. Key points for the discussion are: - List the main energy stores: kinetic, gravitational potential energy (GPE), elastic potential energy (EPE), chemical, thermal, magnetic, nuclear, electrostatic. - Explain the pathways (energy carriers) through which energy is transferred: mechanical, electrical, heating, radiation.	Conservation of energy (youtube.com) Optional video on conservation of energy to support the discussion. Energy stores and transferring energy (youtube.com) Video introducing energy stores which can be shown to introduce the teacher-led section.	Energy Transfers (isaacphysics.org) Resource for students to use for independent practice and consolidation. Sankey diagrams (bbc.co.uk/bitesize) Support for the Sankey diagram drawing task.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Follow up with a think-pair-share task on the conservation of energy. Encourage the use of the energy stores and pathways. Demonstrating energy transfers: Students will observe and describe energy transfers between different stores. - Place a toy car at one end of a flat surface and attach an elastic band. - Stretch the elastic band, then release it. - Identify the energy stores involved. Introduce energy transfer diagrams as a way to visualise energy movement: Key points to deliver are: - Arrows show the pathway of energy transfer. - Length of arrows represents amount of energy transferred. - Waste energy is shown moving into the surroundings (usually as thermal energy). Assign students scenarios for which to create energy transfer diagrams. Example scenarios: - car engine - electric kettle - wind turbine.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Use a worked example to demonstrate how to draw scale Sankey diagrams to represent energy efficiency: A light bulb uses 100 J of electrical energy. 40 J is useful light energy, 60 J is wasted thermal energy. • Draw the total input arrow (100 J). • Use a scale (e.g. 1 cm = 10 J) to create proportional arrows. • Draw the useful energy arrow (4 cm wide) pointing forward. • Draw the waste energy arrow (6 cm wide) pointing downward or to the side. Give students scenarios to create Sankey diagrams for independent practice: • car engine (25% efficient) • hair dryer (60% efficient) • wind turbine (80% efficient).		
40	2.1.2 Work and energy	2	By the end of the lesson students should: • know the definition and unit of work done	Show the Calculating work done video to introduce the concept of work done in terms of energy transfers. Define work done in Physics:	Calculating work done (youtube.com) Video to show to start the lesson.	Work Done (isaacphysics.org) Resource for students to use for independent practice and consolidation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			- understand how to use equations linking work done (J), force (N) and displacement (m) - understand the law of conservation of energy - understand the relationship between work done and energy transferred.	- Work is done when a force causes an object to move in the direction of the force. Demonstration of work done by a force - Attach a small weight to a newton meter. - Pull the weight over a measured distance, e.g. 1m. - Record the force and displacement. - Calculate the work done using the formula: $W = Fs$ Where W = work done (J), F = force (N) and s = displacement (m) - Repeat the process at different angles (e.g. pulling at 45°) and discuss how the work done decreases with a larger angle - Use a protractor to measure the angle and apply the full formula: $W = Fscos\theta$ Calculating work done problems Provide students with problem scenarios to calculate work done in different scenarios: Example scenarios:	Work done (savemyexams.com) Notes to support the teacher-led section of the lesson.	Work done questions (pmt.physicsandmathstutor.com) GCSE style exam questions for independent revision and consolidation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- A person pushes a box with a force of 50 N over a distance of 3 m along a flat surface. - A sled is pulled with a force of 80 N at an angle of 30° to the horizontal over a distance of 5 m. Discussion / teacher-led section explaining the relationship between work done and energy transferred. When work is done on an object, energy is transferred to or from the object. Measuring energy transfer through work done - Put a toy car on an inclined ramp. - Use newton meter to measure the force needed to pull the car up the ramp. - Calculate the work done. - Compare the work done to the increase in gravitational potential energy. Assess understanding with a short quiz on the calculations of work done.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
41	2.1.3 Kinetic and potential energy	1	By the end of the lesson students should: - understand how to calculate kinetic energy (J) from mass (kg) and velocity ms^{-1}) - understand how to calculate gravitational potential energy (J) from mass, acceleration (m s^{-2}) and height (m) - understand how to calculate elastic potential energy (J) from (N) and extension (m), or from the spring constant and extension - understand how to apply conservation of energy to examples using gravitational potential energy, elastic potential	Give students a short quiz on energy stores - ask students to identify and define each of the energy stores from 2.1.1. Discussion / teacher-led section recapping the law of conservation of energy and the two types of energy: kinetic energy (KE): Energy of motion potential energy (PE): Stored energy due to position. In particular: gravitational potential energy (GPE): energy stored due to height elastic potential energy (EPE): energy stored in stretched or compressed objects. Calculating kinetic energy - Place a car at the top of the ramp. - Measure the mass of the car. - Use a stopwatch to time how long it takes the car to travel a fixed distance. - Measure the distance and calculate the velocity. - Calculate the kinetic energy using:	Kinetic Energy Gravitational Potential Energy Elasticity, spring constant and Hooke's Law (youtube.com) Videos to support the discussion to introduce kinetic and potential energies.	Kinetic energy calculations Gravitational potential energy calculations Energy, springs and materials (isaacphysics.org) Resources for students to use for independent practice and consolidation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			energy and kinetic energy.	$E = \frac{1}{2}mv^2$ Where m = mass (kg), v = velocity (m s⁻¹) Measuring gravitational potential energy • Use a spring balance to measure the force of gravity acting on the mass (weight). • Measure the height by lifting the object vertically. • Calculate the GPE using: $E = mg\Delta h$ Where m = mass (kg), g = acceleration due to gravity (9.83 m s⁻²), h = height (m). Measuring elastic potential energy • Attach one end of the spring to a fixed point. • Apply different forces using weights. • Measure the extension of the spring for each applied force. • Use the formulae to calculate the elastic potential energy:		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				$E = \frac{1}{2}Fx$ $= \frac{1}{2}kx^2$ Where k = spring constant (Nm^{-1}) and x = extension (m). Give students an opportunity for independent practice of the calculations (using Isaac Physics). Give students practice scenarios for them to apply conservation of energy to describe the energy transfers. Example scenarios: • A pendulum is lifted and released, swinging back and forth. • A roller coaster car starts from the top of a hill and descends into a loop. • A person jumps from a bridge with a bungee cord attached.		
42	2.1.4 Power and efficiency	1	By the end of the lesson students should: • understand how to calculate power (W) from work done (J) and time (s)	Display images of common household appliances, e.g. hairdryer, kettle, microwave, TV, and ask students: • To estimate the power rating of each device.	Power and work done (youtube.com) Video to support the explanation of	Power calculations Energy flow and efficiency (isaacphysics.com) Resources for students to use for independent

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			understand how to calculate efficiency.	How does power relate to the rate of energy transfer? Teacher-led section defining power as the rate of energy transfer or work done. This could be supported by showing the Power and work done video. Demonstrate using a worked example how to use the formula to calculate work done: $P = \frac{W}{t}$ Where P = power (W), W = work done (J) and t = time (s). Students should then use the questions on Isaac Physics to practice and consolidate calculations using the formula. (isaacphysics.org) Recap how to draw a Sankey diagram (from 2.1.1 Energy stores and energy transfers) and demonstrate with a worked example how to calculate efficiency from useful energy output and total energy input: $\text{Efficiency} = \frac{\text{useful energy transferred}}{\text{total energy transferred}}$	power and how to calculate it. Calculating efficiency (youtube.com) Video to support the explanation of how to calculate efficiency.	practice and consolidation. Power and Work done (cognitoedu.org) This website provides quizzes and students to use for revision and consolidation. Power and efficiency (bbc.co.uk/bitesize) Can be used for independent revision and consolidation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				This could be supported by showing the Calculating efficiency video. Students should then use the questions on Isaac Physics to practice and consolidate calculations using the formula. (isaacphysics.org)		
43	2.1.5 Force - Newton's first and third laws of motion - Newton's second law of motion for constant mass - Scalar and vector quantities - SUVAT	2	By the end of the lesson students should: - understand how to calculate force (N) from mass (kg) and acceleration (m s^{-2}) - understand how to use Newton's laws of motion including free-body diagrams to solve problems - understand vector-scalar distinction - understand how to calculate average velocity	Assess students' recall of GCSE Physics. Display images or describe real-life scenarios, e.g. a car accelerating, a person lifting a box, a parachutist falling and ask students to identify the forces acting on the objects. Discussion / teacher-led section explaining Newton's Laws of Motion. Key points of the discussion are: First Law (Inertia): An object will remain at rest or in constant motion unless acted on by an external force. Second Law: The acceleration of an object depends on the net force acting on it and its mass. Third Law: For every action, there is an equal and opposite reaction. Calculating net force using Newton's Second Law	Newton's Laws of Motion (phys.libretexts.org) Notes to support the teacher-led section of the lesson. Newton's Second Law practical (youtube.com) Video which can be used as an alternative to the practical activity.	Drawing free-body diagrams (physicsclassroom.com) Notes and practice problems for students to complete for independent practice. Force and Acceleration calculations Calculating Acceleration SUVAT (isaacphysics.com) Resources for students to use for independent practice and consolidation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			and acceleration.	- Attach a string to toy car and connect it to a string and mass holder over a pulley. - Apply masses to the string and measure acceleration (using light gates or a stopwatch over a measured distance). - Calculate the net force using: $F = ma$ Alternatively the Newton's Second Law practical video can be shown. Discuss results with students and get students to answer the questions: - How does mass affect acceleration? - What happens if you double the force? Following on from the activity, as students to show all of the forces acting on the toy car (this could be done on a whiteboard). Define the individual forces and draw a free-body diagram to represent the forces acting on the car: weight: acts vertically downwards normal contact force: acts perpendicular to the surface	Scalar and Vector quantities (youtube.com) Video to introduce vector and scalar quantities. SUVAT equations (myexamrevision.com) Notes to support the SUVAT equation worked examples.	Ask students to add the new terms covered, and examples, to their glossaries. Alternatively, have them create flash cards following the Frayer model for vocabulary instruction.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• friction: opposes motion • tension: force in a string or rope. Describe the net force as the combined effect of all forces acting on the object. Students should complete the independent practice free-body diagrams. Show the Scalar and Vector quantities video to introduce the difference between vector and scalar quantities with respect to displacement and distance, velocity and speed. Use worked examples to demonstrate how to use the average velocity equation and the constant acceleration equation: $\text{Average velocity} = \frac{\text{displacement}}{\text{time taken}}$ $v = \frac{s}{t}$ Solving SUVAT problems Provide students with the SUVAT equations and SUVAT word problems with missing variables, e.g. find acceleration, displacement, or final velocity. Example problem:		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				A car starts from rest and accelerates uniformly at 3 ms^{-2} for 5 seconds. Find the final velocity and the displacement. Students need to select the correct equation from the SUVAT equations: $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ $s = \frac{1}{2}(u + v)t$ Where u = initial velocity (ms^{-1}), v = final velocity (ms^{-1}), t = time (s), a = acceleration (ms^{-2}), s = displacement (m). Graphing motion • Provide sample data for a moving object, e.g. car accelerating and decelerating. • Students plot velocity-time and displacement-time graphs based on the data. Give student mathematical tasks to complete using their graphs for example: • Find the acceleration from the slope of the velocity-time graph.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Find the displacement from the area under the graph. Give students further scenarios to construct motion graphs and complete calculations using data from the graphs, for example: A car starts from rest, accelerates uniformly at 2.5 ms^{-1} for 8 seconds, maintains a constant speed for 5 seconds, and then decelerates uniformly at 1.5 ms^{-1} until it comes to a stop. As a further challenge, students could construct their own graphs and other students interpret the motion.		
44	2.1.6 Practical 6: Investigating motion	1	By the end of the lesson students should: understand the use of apparatus, techniques and procedures to accurately determine the acceleration of free fall using trapdoor and electromagnet	Start by asking students what forces act on an object in free fall? The students could be asked to draw a free-body diagram to show the forces acting on the object. Introduce the aim of the experiment: Explain that students will use two different experimental methods to measure the acceleration due to gravity.	Investigating free fall with a light gate (spark.iop.org) Resource to support the delivery of the practical activity.	Acceleration of free fall (savemyexams.com) Notes to support the students with carrying out the practical. Students could also be given other data e.g. from exam questions found on ExamBuilder to provide more stretch and challenge.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			arrangement; light gates and timer.	- Emphasise the importance of accuracy and precision when measuring time and distance. Experiment 1: Electromagnet, ball bearing and trapdoor Apparatus setup: - Clamp the electromagnet on a retort stand. - Put the trapdoor directly below the electromagnet. - Connect the electromagnet and trapdoor switch to the timer. - Measure the distance from the bottom of the ball bearing (when held by the electromagnet) to the trapdoor (h). Procedure: - Turn on the electromagnet to hold the ball bearing in place. - Switch off the electromagnet, releasing the ball bearing. - When the ball hits the trapdoor, the switch stops the timer, record the time of free fall. - Vary the height and repeat the process. Students should use SUVAT equations to calculate the acceleration of the ball bearing.	Acceleration of free fall (youtube.com) Video to support the delivery of the practical activity.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Experiment 2: Light gates, weighted card and timer Apparatus set up: - Clamp two light gates vertically on retort stands, separated by a known distance. - Connect the light gates to the electronic timer or data logger. - Use a weighted card with a known mass to ensure it falls vertically and accurately triggers both gates. Procedure: - Hold the weighted card just above the first light gate. - Release the card, allowing it to fall through both gates (the timer records the time taken between the gates). - Vary the distance and repeat the process. Students should use SUVAT equations to calculate the acceleration of the ball bearing. Discuss the sources of error for each experimental procedure and how these could be mitigated.		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	In order to effectively engage with lessons on forces, students should already have a foundation understanding of some key concepts. This is the prerequisite knowledge and understanding for this area of study: Before learning about energy transfer, students must understand what energy is (the capacity to do work or cause change). Students need to understand the law of conservation of energy: that energy cannot be created or destroyed; it is only transferred or converted between stores and that in closed systems, the total energy remains constant. Students should understand that forces are pushes or pulls that can change an object's motion and are measured in newtons (N). There should also be some familiarity with common forces (gravity, friction, tension).
Common misconceptions	Students need to have a clear understanding of the law of conservation of energy. They can sometimes believe that energy is used up or disappears when work is done, rather than being transferred or dissipated. Students often confuse heat with temperature whereas heat is a form of energy transfer (measured in joules) and Temperature is a measure of the average kinetic energy of particles (measured in degrees Celsius or Kelvin). Students can often believe that energy transfers only occur with visible motion, ignoring potential energy changes. Energy transfers also occur in static situations e.g. when compressing a spring or charging a battery. Students often incorrectly believe that objects in motion must always have a force acting on them to keep moving, whereas according to Newton's First Law, an object will continue moving at a constant velocity unless acted upon by an unbalanced force.
Key concepts	Students need to understand how energy is stored and how energy is transferred via energy carriers or pathways. It should be understood how diagrams can be used to represent energy transfers and how to draw scale Sankey diagrams. The definition of work done by a force should be understood along with the unit of work done. Students should be able to use the equations linking work done (J), force (N) and displacement (m) to calculate work done along with being able to use the law of conservation of energy to describe the relationship between work done and energy transferred. Students should be able to calculate kinetic energy from mass (kg) and velocity (m s^{-1}) and gravitational potential energy from mass (kg), acceleration (m s^{-2}) and height (m). Students should also be able to calculate elastic potential energy (J) from force (N) and extension (m) and also from the spring constant (N m^{-1}) and extension (m). Students

Subject knowledge enhancement	Details
	should be able to apply conservation of energy to examples involving gravitational potential energy, elastic potential energy and kinetic energy. The definition of power as the rate of work done should be known, along with how to calculate power (W) from work done (J) and time (s). Students should also be able to calculate efficiency from the useful energy transferred (J) and the total energy transferred (J). Students need to be able to calculate net force (N) from mass (kg) and acceleration (ms^{-1}). There needs to be an understanding of Newton's three laws of motion including how to use free-body force diagrams to solve problems. The definitions of the terms tension, normal contact force, weight and friction should be understood along with the vector-scalar distinction as it applies to displacement and distance, velocity and speed. There should be an understanding of how to calculate average velocity (ms^{-1}) from displacement(m) and time taken (s) and the use of the constant acceleration equation to solve problems. Students should be able to use the SUVAT equations to solve constant acceleration problems and also plot and use velocity-time and displacement-time graphs to solve problems. Students should be able to plan and carry out an investigation into the acceleration of a free-falling object using either a trapdoor and electromagnet arrangement or using light gates and a timer.
Subject knowledge enhancement for teachers	Read: Newton's Laws and Momentum (alevelphysicsonline.com) 5 SUVAT equations explained - with examples (edumentors.co.uk) Energy stores and transfers (cowley.st-helens.sch.uk) Watch: Experiment to measure acceleration due to gravity by the free fall method (youtube.com)

Topic Area P3: Medical physics

Area of study: 3.1 X-rays and ultrasound

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
46	3.1.1 The atom - The Rutherford-Bohr model - Energy levels in atoms	1	By the end of the lesson students should: - know the Rutherford-Bohr model of the atom - understand energy levels in atoms including electron transitions, ground state, excited state and ionised state.	Start with a short quiz to assess student recall of key stage 4 GCSE Chemistry / Physics: models of the atom and the gold foil experiment. Show the video on The discovery of the atomic nucleus to explain Rutherford's gold foil experiment. Discussion / teacher-led section explaining the results of Rutherford's gold foil experiment and how it disproved the previous model (Thompson's plum pudding model) and, led to a new model: - dense nucleus at the centre - electrons orbiting around the nucleus. Introduce the Bohr model and describe the refinement of the model to include electron orbits and energy levels:	The discovery of the atomic nucleus (youtube.com) Video to explain the discoveries from Rutherford's gold foil experiment. Atomic emission spectra experiment instructions (chem.libretexts.org) Notes to support the atomic emission spectra demonstration.	Bohr electron excitation (youtube.com) Students can watch the video and make notes / answer questions for consolidation of the lesson. Emission spectra and energy levels (savemyexams.com) Notes to support the students with the diagram drawing task.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Visualising electron transitions with spectroscopy (emission spectra of hydrogen) - Set up an emission tube and connect to the power supply. - Students observe light emitted through a spectrometer. - Record the colours they observe. Discuss the results of the demonstration. Prompts for the discussion could be: - What happens to electrons when they absorb or emit energy? - Why are the spectral lines discrete rather than continuous? - How does this activity demonstrate quantised energy levels? Describe how the emission spectra give evidence for the Bohr model, namely that: - Electrons orbit the nucleus in fixed energy levels. - Electrons can absorb or emit energy when they move between levels. - Energy level $n=1$ (lowest) is ground state. - Levels $n=2, 3, 4$ are higher energy levels.	Models of the hydrogen atom (phet.colorado.edu) Phet hydrogen emission spectrum simulation.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Electrons jump between levels by absorbing or emitting photons. - If an electron absorbs enough energy, it escapes the atom, leaving it ionised. Get students to draw the Bohr model with electron orbits. Label the atom in the ground state, excited state and ionised state, describing the electron transitions happening in each state. Use the Phet Simulation: Models of the hydrogen atom to show an energy level diagram with electron transitions in the emission line spectrum of hydrogen. (phet.colorado.edu) If there is time, students could practice how to calculate the energy requirements of electrons to move between energy levels.		
47	3.1.2 Electromagnetic radiation - Types of electromagnetic radiation - Quantum energy - Photoelectric effect	2	By the end of the lesson students should: understand the similarities and differences between the types of electromagnetic radiation, including in terms of	Ask students to draw a transverse wave and label the amplitude and wavelength and define frequency . This could also be taught as a match up or correct the text activity to elicit misconceptions. Students could add rarefaction, displacement, crest, compression, period on to a provided diagram(s) to support with literacy.	Electromagnetic waves (youtube.com) GCSE level video introducing electromagnetic waves.	Quantum Calculations (isaacphysics.org) Students can use this for independent calculation practice.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			production, penetration, uses, frequency and wavelength • know the definition of a quantum and a photon • understand how to calculate the energy of a photo, in J.	Discuss students' responses and address any misconceptions or gaps in knowledge. Show the Electromagnetic waves video as an introduction to electromagnetic waves. Display an electromagnetic spectrum and explain the range of radiation types, from radio waves to gamma rays. Discussion / teacher-led section explaining the properties of EM waves and highlighting key similarities and differences: • All travel at the same speed in a vacuum. • Oscillations are perpendicular to the direction of travel of the wave. • Wavelength (λ) ranges from kilometres (radio waves) to picometres (gamma rays). • Frequency (f) ranges from 10^3Hz (radio) to 10^{20}Hz (gamma). • Photon energy increases with frequency. Independent research task: Get students to research the production and uses of each type of EM wave. They should	Waves (alevelphysicsonline.com) General notes on waves to support the teacher-led sections. The Electromagnetic Spectrum (science.nasa.gov)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				include penetrating power of each EM radiation and whether they need a medium to propagate. Assess engagement with the independent research task by giving students a short quiz on EM waves. Questions could include: • Which waves have the highest frequency? • Give one use of UV waves. • Are EM waves transverse or longitudinal? Introduce the concept of quantization and define photons: • Quantum: The smallest amount of energy that an atom can absorb or emit. • Photon: A quantum of electromagnetic radiation, carrying a specific amount of energy. Explain that the energy of a photon can be calculated using the frequency of the wave and the Planck constant using the equation: $E = hf$ Where E = energy (J), h = Planck constant (Js) and f = frequency (Hz)	Electromagnetic (EM) Spectrum (scied.ucar.edu) Resources for students to use for the independent research task.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				And also using the wavelength of the wave using the equation: $E = \frac{h c}{\lambda}$ where c = speed of light (ms^{-1}) and λ = wavelength (m). Demonstrate the use of the equations using worked examples: - A laser emits light with a wavelength of 650 nm, calculate the photon energy. - Determine the frequency of light with an energy of $4.2 \times 10^{-19} \text{J}$. Allow students to independently practice using Isaac Physics and then assess understanding with a short quiz. (isaacphysics.org)		
48	3.1.1 X-rays - X-ray tube - Beam intensity - Attenuation	1	By the end of the lesson students should: - understand the structure of an X-ray tube and how X-rays are produced - understand how current and voltage	Ask students to list the applications of X-rays (expected answers: medical imaging, security screening, industrial use, i.e. material flaw detection). Discuss student answers and display images of X-ray applications.	The history of X-ray (youtube.com) Video to support the initial discussion introducing X-rays.	X-ray attenuation calculations (isaacphysics.org) Platform for independent calculation practice. Provide students with appropriate tasks to support the most

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			affects the X-ray beam - understand how X-rays are attenuated by absorption and scattering - understand how to calculate the intensity of X-rays using the attenuation of X-rays equation - know mass attenuation and how to calculate it from the linear attenuation coefficient and density of the medium.	Show students the video on the history of X-ray to introduce a brief history of X-rays and their uses. Discussion / teacher-led section explaining the structure and working of an X-ray tube. Include in the explanation each of the X-ray tube components: cathode: heated filament that emits electrons tungsten anode (target): electrons collide and produce X-rays glass vacuum: allows electrons to travel without colliding with air molecules tube voltage (kV): potential difference with accelerates electrons towards target. Also include the X-ray production process: thermionic emission: electrons emitted from heated cathode acceleration: high voltage accelerates electrons towards anode - electron interaction with target - higher voltage (kV) will produce higher energy X-rays	X-rays (arpana.gov.uk) X-ray imaging (cognito.edu) Notes on X-ray image generation to inform teacher-led section.	challenging aspects of this lesson. E.g. creating revision notes / posters from the referenced videos, provide appropriate questions selected from OCR ExamBuilder or diagrams they should label and explain. (ocr.org.uk)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- higher current (mA) will increase X-ray intensity. Give students a diagram of an X-ray tube to label the key components and the key stages of how the X-rays are produced. Define attenuation as the reduction of the intensity of an X-ray beam due to scattering and absorption. Demonstration of absorption and scattering (attenuation) Model X-ray scattering and absorption using a laser beam and a suspension of particles, simulating how X-rays interact with matter. - Shine a laser pointer through a container of water (representing a vacuum). - Gradually add milk to the water to show the beam becoming less visible and scattering (higher density of particles, greater scattering effect). - Add food colouring to the suspension to introduce absorption of the beam.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Use a light meter to measure beam intensity before and after passing through the suspension. Record initial intensity (I_0) and final intensity (I) after attenuation. Use the X-ray attenuation equation to calculate the linear attenuation coefficient (μ) using the equation: $I = I_0 e^{-\mu x}$ where x = path length Give students further problems to solve using the X-ray attenuation equation for independent practice. Demonstrate a worked example to show how the linear attenuation coefficient (μ) can be used to calculate the mass attenuation coefficient which quantifies how X-rays are absorbed according to the density of the material using the equation: Mass attenuation coefficient (cm^2g^{-1}) = linear attenuation coefficient (cm^{-1}) / density of medium (g m^{-3}).		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Give students further problems to solve for independent practice using Isaac Physics (isaacphysics.org).		
49	3.1.4 Wave motion - Progressive waves - Longitudinal and transverse waves - Wave motion - Graphical representation of waves - Intensity of a progressive wave	1	By the end of the lesson students should: - understand examples of longitudinal and transverse waves - understand how to use equations involving frequency, time, wave speed and wavelength - understand the relationship between intensity and amplitude - understand how to calculate intensity using power and area.	Start with a demonstration of a longitudinal and transverse wave using a slinky. - For a longitudinal wave push and pull the slinky along its length to form compressions and rarefactions. - For a transverse wave move your hand side-to-side to show peaks and troughs. Discuss with the students: how are the movements of the particles different in the two waves? Define longitudinal and transverse waves: Longitudinal: particles oscillate parallel to the direction of wave travel, examples are sound. Transverse: particles oscillate perpendicular to the direction of travel, examples are water, electromagnetic waves. The Phet simulation can be used to support the discussion and demonstrate the features of each type of wave.	Waves Intro (phet.colorado.edu) The Phet simulation can be used to demonstrate the features of waves. Intensity of a wave (savemyexams.com)) Notes to support the teacher-led sections of the lesson.	Finding Wave speed Wavelength and the Wave equation (isaacphysics.org) Online platform for independent calculation practice. Properties of waves (bbc.co.uk/bitesize) Can be used by students for independent revision and consolidation. These questions may be useful for further practice. Worksheet 15 (physicsatbcs)

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Define frequency, wave speed and wavelength and introduce the fundamental wave equations: $f = \frac{1}{T}$ $v = f \lambda$ Where f = frequency (Hz), T = time period (s), v = wave speed (m s^{-1}), λ = wavelength (m). Demonstrate how to use the equations with a worked example: A water wave has a frequency of 5 Hz and a wavelength of 2 m, find the wave speed. Give students the opportunity to complete independent practice of the calculations using Isaac Physics. (isaacphysics.org) Explain how wave intensity relates to amplitude and power using the equations: $\text{Intensity } (W \text{ m}^{-2}) \propto (\text{amplitude } (m))^2$		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				$I = \frac{P}{A}$ Where I = intensity (W m^{-2}), P = power (W) and A = area (m^2). Demonstrate the calculation with a worked example. Give students the opportunity to independently practice using the equation. Assess understanding with a short quiz on the calculations for students to complete.		
50	3.1.5 Ultrasound • Transducer • Acoustic impedance • Intensity reflection coefficient • Attenuation • A-scans and B-scans	2	By the end of the lesson students should: • know the definition of ultrasound, including in medical contexts • understand the reflection and transmission of ultrasound • know the role of a transducer • understand how to use the equation	Give students a short quiz to assess their prior knowledge of sound waves. For example, ask students to identify whether sound waves are transverse or longitudinal. Use an online tone generator to demonstrate the range of human hearing and define ultrasound. Online Tone Generator (onlinetonegenerator.com) Define ultrasound and use the Phet simulation to demonstrate the reflection and	Cognito quiz (A Level Physics) may be appropriate here. (puppeteer.cognito.edu.org) A Beginner's Guide to Ultrasound (geekymedics.com) Notes to support the teacher-led sections of the lesson. Online Tone Generator (onlinetonegenerator.com)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			linking density, mass and volume - understand how to use the acoustic impedance equation and intensity reflection coefficient equation - understand the attenuation of ultrasound, impedance matching and coupling mediums - understand how to interpret and use A-scan to solve problems.	transmission of sound waves. (phet.colorado.edu) Discussion / teacher-led section: Explain what happens when ultrasound waves (transmitted from the transducer) encounter a boundary between two materials (tissues): - Some waves are reflected and some are transmitted. - The amount reflected depends on the acoustic impedance mismatch. Demonstrate using worked examples how to apply the density and acoustic impedance equations to calculate the acoustic impedance (resistance to the propagation of ultrasound waves through tissues, dependent on the density of the tissue). $\rho = \frac{m}{V}$ Where ρ = density (kg m^{-3}), m = mass (kg) and V = volume (m^3). Acoustic impedance ($\text{kg m}^{-2} \text{s}^{-1}$) = density of the medium (kg m^{-3}) $\times$ speed of sound in the medium (m s^{-1}).	Tone generator to demonstrate the range of human hearing. Phet: Sound waves (phet.colorado.edu) Phet simulation can be used to demonstrate reflection and transmission. Basics of Ultrasound (geekymedics.com) Ophthalmic ultrasound (eyewiki.org) A scan ultrasound biometry (keelerglobal.com)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Give students further examples for independent practice, for example: A material has a mass of 0.5 kg and a volume of $2.5 \times 10^{-4} \text{ m}^3$. Use the speed of sound in the material (1500 m/s) to calculate the acoustic impedance. Pose the question to students ‘How do we see bones using ultrasound?’. Lead discussion towards the boundary between a bone and muscle reflecting ultrasound to a certain extent. This supports introduction of the next definition. Define the intensity reflection coefficient in more detail as a measure of how much of an ultrasound wave’s intensity is reflected at the boundary between two media with different acoustic impedances. It is defined by the ratio of the reflected intensity to the incident intensity using the equation: $\alpha = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1} \right)^2$ where Z_1 = acoustic impedance of initial medium Z_2 = acoustic impedance of second medium	Resources to support students with the independent research task.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Demonstrate how to calculate α with a worked example and explain the meaning of the values obtained: • $\alpha = 0$ No reflection, full transmission. • $\alpha \approx 1$ Total reflection, no transmission. • The closer the acoustic impedances of the two media, the smaller the reflection. • The greater the impedance mismatch, the larger the reflection. Explain the attenuation of ultrasound waves: Ultrasound intensity decreases as it passes through a medium due to: • Absorption: Energy is converted to heat. • Scattering: Waves are dispersed in different directions. (The students could be referred back to the demonstration of scattering and absorption of X-rays from 3.1.1) Define impedance matching (and explain why it is necessary to reduce reflection when there is a high impedance difference at a boundary):		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• A coupling medium (i.e. ultrasound gel) is used to reduce reflection (by reducing the air gap). • It ensures similar acoustic impedance values between the transducer and the skin. <i>Independent research task:</i> • Get students to research the A scan type of ultrasound scan used in ophthalmology. For scaffolding students could be asked to research answers to the following questions: • What is an A scan used for? • What does an A scan measure? • Sketch and label a typical A scan • What defects can be detected on an A scan and what does this look like? • What is a coupling medium usually used for? • Does there need to be a coupling medium? If not, why not?		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	In order to effectively engage with lessons on X-rays and ultrasound, students should already have a foundation understanding of some key concepts. This is the prerequisite knowledge and understanding for this area of study: Students must understand the basic principles of wave behaviour, as both X-rays and ultrasound involve wave phenomena. This includes understanding waves as a transfer of energy and understanding the reflection, transmission and refraction of waves. Students need strong math skills in order to effectively manipulate data and utilise all of the equations in this area of study and to be able to interpret the values obtained from the calculations. There should also be some knowledge of the real-world uses of X-rays and ultrasound.
Common misconceptions	Some students believe that X-rays pass through all materials without being absorbed or scattered whereas X-ray penetration depends on the material's density and atomic number. Some students also may mistakenly think that X-rays are completely safe or that low doses have no biological effects. While diagnostic X-rays are considered safe in low doses, exposure to high or repeated doses can increase the risk of tissue damage and cancer. Many students incorrectly think that ultrasound waves are part of the electromagnetic spectrum like X-rays or light. Ultrasound consists of mechanical sound waves with frequencies above 20 kHz. It requires a medium to propagate (e.g. tissue) and cannot travel through a vacuum, also unlike X-rays, ultrasound does not involve ionising radiation.
Key concepts	Students need to be able to understand the Rutherford-Bohr model of the atom and the description of energy levels in atoms, including ground state, excited state and ionised state. Students need to have an understanding of the electromagnetic spectrum, in particular the similarities and differences between the types of EM radiation in terms of production, penetration, uses, frequency and wavelength. There needs to be an understanding of the terms quantum and photon and students should be able to use the equations linking energy (J), Planck constant (Js) and frequency (Hz), and wavelength (m). The basic structure of an X-ray tube, including the heater (cathode), anode, target metal and high voltage supply should be known, along with how X-rays are produced in an X-ray tube, including thermionic emission and energy transfers. Students should understand how tube current and voltage affects the X-ray beam and attenuation of X-rays by absorption and scattering. The use of the attenuation of X-rays equation to calculate intensity should be understood and students should know the mass attenuation coefficient and how to calculate it using the linear attenuation coefficient and the density of the medium.

Subject knowledge enhancement	Details
	Students should know examples of longitudinal and transverse waves including sound waves and electromagnetic waves. They should be able to use the equation linking frequency (Hz) and time period (s) and also the equation linking wave speed (ms^{-1}), frequency (Hz) and wavelength (m). The relationship between intensity and amplitude should be understood, along with use of the equation linking intensity (W m^{-2}), power (W) and area (m^2). Students should know the definition of ultrasound, including in medical contexts and understand the reflection and transmission of ultrasound. It should also be known that a transducer can both transmit pulses and receive reflected pulses. Students should be able to use the equation that links density (kg m^{-3}), mass (kg) and volume (m^3) and the acoustic impedance equation: Acoustic impedance ($\text{kg m}^{-2}\text{s}^{-1}$) = density of medium ($\text{kg m}^{-3}$) $\times$ speed of sound in medium (m s^{-1}) Students should also be able to use the intensity reflection coefficient equation and understand the attenuation of ultrasound by absorption and scattering. Impedance matching and coupling mediums should be understood along with how to interpret and use A-scans to solve problems. Specification links: Unit F186 Medical physics 1.2 Diagnostic ultrasound, 2.1.1 X-ray imaging, 2.2 Radionuclides, 3.1 Treatment with external source, 3.2 Treatment with internet source, 4.4 Ultrasound therapies.
Subject knowledge enhancement for teachers	Read: Ultrasound Imaging (fda.gov) Basic physics of diagnostic X-ray imaging (radcommons.org) Watch: Ultrasound physics - Image generation (youtube.com) Introduction to X-ray production (youtube.com)

Area of study: 3.2 Radioactivity

Lessons

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
51	3.2.1 Fundamentals of radioactivity - Radioactive decay - Properties of nuclear radiation (alpha, beta and gamma)	2	By the end of the lesson students should: - understand the spontaneous nature of nuclear radioactive decay - know the types of decay - understand how to complete nuclear decay equations.	Start with a short quiz to assess prior understanding of the fundamentals of radioactivity. Suggested questions to include in the quiz are: - What are the types of radioactivity? - What are the dangers of radioactivity? - How can we work safely with different types of radioactive materials? Random decay model (dice rolling simulation) - Give each student 20 dice representing unstable nuclei. - Roll all dice at once; dice showing a '6' represent decayed nuclei and are removed. - Repeat with the remaining dice. - Plot number of remaining dice vs. roll number (modelling exponential decay). Discuss how the activity models the random nature of radioactive decay and how the	Radioactive decay simulator (academo.org) Simulation which can be shown alongside / as an alternative to the decay model activity. Demonstrating physics: Radioactivity (stem.org.uk) Optional video which can be shown as an alternative to the demonstration of radiation penetration.	Radioactive decay (bbc.co.uk/bitesize) For independent consolidation and revision. Uranium decay chain game (tangerinedev.com) Student practice of completing decay equations.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				decay of individual atoms cannot be predicted. Optional demonstration (if the resources are available): Investigating radiation penetration • Measure background radiation with a Geiger-Müller tube. • Place an alpha source near the Geiger-Müller tube and observe count rate. • Insert a sheet of paper between the source and the GM tube and observe count rate. • Repeat for beta source with aluminium sheet. • Repeat for gamma source with lead sheet. Discuss the results of the demonstration and highlight the key differences between the three types of ionising radiation. Key points: • Alpha particles are large, slow, and highly ionising, but easily stopped. • Beta particles are smaller, faster, and penetrate further.	Alpha, beta and gamma radiation (youtube.com) Video to support the explanation of types of radiation.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Gamma rays are waves, not particles; travel far but are least ionising. - This could then be linked to asking for safety considerations when working with each type of radioactive material. The Alpha, beta and gamma radiation video could be shown to assist the explanation. Teacher-led section explaining how to write alpha and beta decay equations. Use worked examples to demonstrate the procedures for each decay equation. Key points: Alpha decay decreases atomic number by 2 and mass number by 4, example: ${}_{92}^{238}\text{U} \rightarrow {}_{90}^{234}\text{Th} + {}_2^4\text{He}$ Beta decay increases atomic number by 1 (neutron turns into one proton and one electron), example: ${}_{6}^{14}\text{C} \rightarrow {}_{7}^{14}\text{N} + {}_{-1}^0\text{e}$ - Decay equations are not written for gamma decay because gamma is an		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				electromagnetic wave rather than a particle. Give students the opportunity for independent practice. Give students unstable isotopes, e.g. radium-226, thorium-234 and ask them to complete the decay equation. Students could also complete the 'Uranium decay chain game' to assess understanding.		
52	3.2.2 Mathematical analysis of radioactivity - Activity of a source - Decay law - Half-life	2	By the end of the lesson students should: - understand how to use the activity equation - understand how to use equations to determine N, N_0, A and A_0 - understand biological, physical and effective half-lives and how to use the effective half-life equation - know how to graphically determine	Begin with an assessment of understanding of the previous lesson. Give students alpha and beta decay equations to complete on whiteboards. Define the key terms needed to understand the mathematical analysis of radioactivity: Activity (A): The rate at which unstable nuclei decay, measured in becquerels (Bq). Decay constant (λ): The probability of a single nucleus decaying per unit time, measured in (s⁻¹). Half-life ($t_{1/2}$): The time it takes for half the nuclei in a sample to decay.	Radioactive decay (exampaperspractic e.co.uk) Questions which can be used for worked examples and practice. Half-life and radioactive decay (youtube.com) Video to support the teacher-led section of the lesson.	Radioactivity: Half-life Quiz (isaacphysics.org) A number of half-life quizzes which students can complete for consolidation. Radioactivity: Half life (bbc.co.uk/bitesize) Resource for

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
			the physical half-life of an isotope.	Use a worked example to demonstrate how to use the relationship $A = \lambda N$. Introduce the equations: $N = N_0 e^{-\lambda t}$ $A = A_0 e^{-\lambda t}$ Where N = number of undecayed nuclei N_0 = initial number of undecayed nuclei λ = radioactive decay constant (s^{-1}) A = activity (Bq) A_0 = initial activity (Bq) Give students decay problems to solve using the equations. Example problems: - A sample of radon-222 starts with $N_0 = 1.0 \times 10^{12}$ nuclei. If $\lambda = 2.1 \times 10^{-6} \text{ s}^{-1}$, how many nuclei remain after 1 hour? - A radioactive source has an initial activity of 4000 Bq and a decay constant of $5 \times 10^{-35} \text{ s}^{-1}$. Find its activity after 200 s. Graphically determining half-life		independent revision and consolidation.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Give students decay data (or use results from the dice experiment). - Plot a graph of <i>N</i> vs. time. - Find <i>N</i>₀ and determine when <i>N</i> = 1/2 <i>N</i>₀ - Measure the time taken for this decay, this is the physical half-life. As an alternative method of calculating physical half-life show students the equation: $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$ Teacher-led section explaining the difference between biological, physical and effective half-lives: Physical half-life: Time for radioactive decay to halve the number of unstable nuclei. Biological half-life: Time for a substance to leave the body via metabolism / excretion. Effective half-life: The combination of both, given by: $\frac{1}{t_E} = \frac{1}{t_{\frac{1}{2}}} + \frac{1}{t_B}$		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Where t_E = effective half-life, $t_{1/2}$ = physical half-life, and t_B = biological half-life. Give students problems to solve involving the effective half-life calculation. Example calculation: Iodine-131 has a physical half-life of 8 days and a biological half-life of 12 days. Calculate its effective half-life.		
53	3.2.3 Radiation hazards - Effects of radiation - Ionisation - Absorbed and effective dose	1	By the end of the lesson students should: - understand the difference between irradiation and contamination - understand the physiological effects of radiation - understand the mechanism of direct and indirect ionisation of biological molecules.	Ask students to list the beneficial uses of radiation vs. the hazards, for example medical imaging, nuclear power plants, radiotherapy treatments, radioactive waste. Demonstrating irradiation and contamination - Shine a UV torch on students' hands. They 'experience radiation' but are unaffected after the torch is removed. - Sprinkle small beads (representing radioactive particles) on to gloves. When the 'source' is removed, the beads (contamination) remain. Discuss how irradiation only affects them temporarily, while contamination continues. Relate this to real-life scenarios:	Ionising radiation and health effects (who.int) Notes to support the teacher-led section on the effects of ionising radiation. How does radiation affect the human body? (britannica.com) Video to support the discussion on the physiological effects of radiation.	Irradiation and Contamination (bbc.co.uk/bitesize) Resource to support students with the completion of the table. Resources to support students with the independent research task.

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				• Irradiation: X-rays in medicine. • Contamination: Radioactive dust after a nuclear accident. You could include a discussion of Chernobyl, including why there is an exclusion zone, why possessions were left behind by those who evacuated, why and how scientists monitor the exclusion zone, whether it will ever be safe, etc. Get students to complete a table comparing irradiation and contamination in each of the following categories: • definition • cause • effect • how to control it • how to work safely if exposed • examples. Simulating radiation effects with UV beads (if available) • Using beads that change colour under UV light, (representing the effect of radiation exposure). • Shine UV light for different durations (5, 15, 30 seconds) to represent low, moderate and severe exposure.		

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Relate colour change to radiation exposure and physiological damage. Discussion / teacher-led section describing the physiological effects of radiation at different doses. Key points: - Low dose - minor DNA damage, cells repair themselves. - Moderate dose - radiation sickness (nausea, skin damage). - High dose - severe tissue damage, increased cancer risk and death. The discussion could be supported by showing the How does radiation affect the human body? video. Independent research task: Get students to research the difference between direct and indirect ionisation of biological molecules. Example questions to direct their research could include: - What is ionisation? Explain what happens to an atom or molecular when it becomes ionised.	Biological effects of ionising radiation (gla.ac.uk)	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- How do direct and indirect ionisations occur? Provide examples. - What is the role of free radicals? Which type of ionisation is more harmful?	Direct vs Indirect ionisation (dentalcare.com) Indirect ionisation (hps.org) Resources to support students with the independent research task.	
54	3.2.4 Using radionuclides - Radiopharmaceuticals - Radionuclides	2	By the end of the lesson students should: - know the definition of radiopharmaceuticals - understand the use of radiopharmaceuticals in sterilisation, cancer treatments and medical tracers - understand how to select a radionuclide for an appropriate use.	Brainstorm ideas from students about real-life applications where radiation can potentially be useful. Define radiopharmaceuticals as: - Radioactive compounds used for diagnostic or therapeutic purposes in medicine. - Usually consisting of a radionuclide bonded to a biologically active molecule that directs the radiation to a specific organ or tissue. The How do radiopharmaceuticals work? video can be shown to aid the explanation. Independent research task:	How do radiopharmaceuticals work? (youtube.com) This video can support the explanation of radiopharmaceuticals. What are radiopharmaceuticals? (iaea.org) Resource to support teachers with the definition of	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				Get students to research the different uses of radiopharmaceuticals. The class could be split into groups and each group given a different use to research from: - sterilisation - cancer treatment - medical tracers. For each use, for scaffolding students could be given the following questions to answer: - Which radionuclides are typically used? - How does it work? - What are the applications of the technique? - What are the risks? Discuss with students what factors need to be considered when selecting a radionuclide for each of the applications and collate ideas into a class list. Review definition of radionuclide together. Steer students towards answers along the lines of: Half-life of the radionuclide (particularly biological half-life for cancer therapies and medical tracers).	radiopharmaceuticals. Characteristics of radiopharmaceuticals (moravek.com) Radiopharmaceutical therapies (hopkinsmedicine.org) Resources to support students with the independent research task.	

Lesson number	Specification coverage	GLH	Lesson aims and outcomes	Lesson ideas, key words and activities	Useful resources	Student independent learning – ideas and useful resources
				- Type of radiation (alpha, beta or gamma). - Energy and penetration (low energy safer for diagnostics, high energy required for cancer therapy). Choosing the best radionuclide for a purpose - Give students cards describing radionuclides and their properties, e.g. technetium-99m, iodine-131. - Hand out application scenarios, e.g. a hospital needing to sterilise large quantities of surgical equipment. - Students must select the most suitable radionuclide and justify their choice based on radiation type, half-life, and penetration power.		

Subject knowledge support for this area of study

Subject knowledge enhancement	Details
Underlying knowledge and understanding	To fully understand the concepts of radioactivity, students need to understand fundamental aspects of chemistry. Atomic structure: Understanding the structure of atoms is essential, as radioactivity involves changes in the nucleus. Students should understand the position and nature of the subatomic particles. (Topic Area C1 1.1.1)

Subject knowledge enhancement	Details
Common misconceptions	A common misconception is that radiation is always dangerous. While high doses of radiation can be harmful, low-level radiation exposure is common and generally safe. Background radiation from soil, rocks etc. is always present and poses no health risk - this could be demonstrated by using a Geiger counter to measure background radiation. The terms radiation and radioactivity can often be confused and used incorrectly. Radiation refers to the energy emitted in the form of particles or electromagnetic waves, whereas radioactivity is the process by which unstable nuclei emit radiation. From media influence, it is sometimes thought that radioactive waste glows green. Although in some nuclear facilities, Cherenkov radiation (a blue glow) is visible in water surrounding spent fuel rods, radioactive waste does not have a green glow. Students can sometimes also think that all radiation is man-made, such as X-rays and nuclear power plants, however there are sources of natural radiation such as cosmic radiation from the sun and space and terrestrial radiation from rocks and soil.
Key concepts	Students need to understand the spontaneous and random nature of nuclear radioactive decay and know the properties of the different types of decay (alpha, beta and gamma). Students should understand how to interpret and complete nuclear decay equations for alpha and beta decay. Students should be able to use the activity equation to calculate either the radioactive decay constant or the number of undecayed nuclei. They should also be able to use equations to calculate N (number of undecayed nuclei), N_0 (initial number of undecayed nuclei), A (activity in Bq) and A_0 (initial activity in Bq) using the equations $N = N_0 e^{-\lambda t}$ and $A = A_0 e^{-\lambda t}$. Students should understand what biological, physical and effective half-lives are and be able to use the effective half-life equation linking effective half-life, physical half-life and biological half-life. It should also be understood how to graphically determine the physical half-life of an isotope. Students need to understand what irradiation and contamination are and the difference between them. They should also know the physiological effects of radiation and the mechanism of direct and indirect ionisation of biological molecules. The definition of radiopharmaceuticals should be understood along with how radionuclides are used for sterilisation, cancer treatments and medical tracers. Students should understand how to select a radionuclide for an appropriate use.

Subject knowledge enhancement	Details
Subject knowledge enhancement for teachers	Read: All about radioactivity (orano.group) Radioactivity and Nuclear physics (phys.libretexts.org) Watch: Introduction to radioactive decay (youtube.com) Uses of radioisotopes (youtube.com)

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