Science units
Grade 11 advanced

Contents

Science scheme of work: Grade 11 advanced units

180 hours

1st semester
83 teaching hours

Biology: 30 hours

Unit 11AB.0: Revision unit
Revision of key ideas from Grade 10.
2 hours

Unit 11AB.1: Relating cell structures to function
Mitochondria, ATP and the biochemistry of aerobic respiration. Cell membrane structure and transport.
7 hours

Unit 11AB.2: Transport systems in dicotyledonous plants
Vascular systems of plants. Movement of water, transpiration and translocation.
4 hours

Unit 11AB.3: Physiological regulation in mammals
Homeostasis. Thermoregulation. Oestrous cycle. Nervous and hormonal control systems.
8 hours

Unit 11AB.4: Human gas exchange system and health
Gas exchange structures and functions. Exercise, pulse rate and blood pressure. Lung diseases. Effect of smoking.
9 hours

Chemistry: 28 hours

Unit 11AC.0: Revision unit
Revision of key ideas from Grade 10.
3 hours

Unit 11AC.1: Bonding in more detail
Intermolecular forces. Dative bonding. Physical properties related to bonding type. Electron orbitals.
9 hours

Unit 11AC.2: How much is there?
Quantitative treatment of moles, molarity and molar volume. Empirical and molecular formulae calculations. $PV = nRT$.
9 hours

Unit 11AC.3: Electrochemistry
Oxidation, reduction and oxidation numbers. Electrochemistry including cell potentials and the reactivity series, half-cells and standard electrode potentials, quantitative calculations, fuel cells and associated environmental issues.
7 hours

Physics: 25 hours

Unit 11AP.0: Revision unit
Revision of key ideas from Grade 10.
1 hour

Unit 11AP.1: Forces and movement
Newton's laws of motion. Mass and weight. Centre of gravity. Force, mass and acceleration. Inertial and gravitational mass. Momentum conservation in one dimension. Principle of moments.
10 hours

Unit 11AP.2: Work, energy and power
Work, force and displacement. Kinetic and potential energy. Energy transfer and conservation. Efficiency. Power.
7 hours

Unit 11AP.3: Thermal physics
Thermal energy transfer and equilibrium. Conduction, convection and radiation. Convection currents and weather. Specific heat capacity and latent heat.
10 hours

Science scheme of work: Grade 11 advanced units — 180 hours

2nd semester
97 teaching hours

Biology: 30 hours

Unit 11AB.5: Biological basis of inheritance
DNA structure and replication. The genetic code. Protein synthesis, mRNA and tRNA. Chromosomes and reproduction. Mitosis and meiosis. DNA, genes and gametes. Mutations. Monohybrid crosses. Genetic variation. Sex-linked characteristics.
11 hours

Unit 11AB.6: Evolution by natural selection
Predation, disease and competition. Diversity and adaptation of species. Selective advantage. Natural selection and isolation.
4 hours

Unit 11AB.7: Ecological relationships and populations
Food chains, webs and pyramids of numbers. Energy flow through ecosystems. Interactions between organisms. Factors limiting size of populations.
6 hours

Unit 11AB.8: Microbiology and biotechnology
Viruses, bacteria and fungi. Micro-organisms in recycling. Carbon and nitrogen cycles. Mutualistic relationships. Micro-organisms in food production. Cell culture techniques. Genetic engineering and related moral and ethical issues.
9 hours

Chemistry: 32 hours

Unit 11AC.4: Chemical patterns: part 2
Chemistry of O, S, N, P, C, Si and transition metals.
6 hours

Unit 11AC.5: Organic chemistry
Nomenclature, structure, bonding and shape of alkanes, alkenes and arenes. Aliphatic electrophilic and nucleophilic addition and substitution reactions. Alcohols, halogen compounds, aldehydes and ketones, carboxylic acids and their derivatives. Comparison of arenes and aliphatic compounds. Amines and amides.
15 hours

Unit 11AC.6: Making and using chemicals
Haber process, nitric acid and fertilisers. Sulfur and the contact process. Limestone and cement. Addition and condensation polymerisation. Fats and oils. Natural polymers.
11 hours

Physics: 35 hours

Unit 11AP.4: Properties of waves
Reflection and refraction. Refractive index and wave velocity. Diffraction, superposition and interference. Doppler effect. Properties and nature of electromagnetic waves. Coherence. Polarisation of transverse waves.
9 hours

Unit 11AP.5: Electronic devices
Capacitors and diodes. Variable resistors and their use in potential divider circuits. Logic gates and truth tables. Switches and memory circuits.
6 hours

Unit 11AP.6: Electromagnetic induction
Production of induced e.m.f. Magnetic flux. Faraday's and Lenz's laws. Eddy currents. AC generation. The transformer.
10 hours

Unit 11AP.7: Atomic and nuclear physics
Rutherford scattering. Nuclear model of atom. Nuclear transformations. Nuclear decay and half-life. Properties of nuclear radiations. Uses of radioisotopes. Nuclear fission and fusion. Cathode ray tubes.
10 hours

GRADE 11A: Biology 1

Relating cell structures to function

UNIT 11AB.1
7 hours

About this unit

This unit is the first of eight units on biology for Grade 11 advanced.

The unit is designed to guide your planning and teaching of biology lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications

Previous learning

To meet the expectations of this unit, students should already be able to explain how substances get into and out of cells. They should be able to explain and give equations for aerobic and anaerobic respiration and fermentation, and know how conditions affect respiration.

Expectations

By the end of the unit, students describe the structural features of mitochondria and chloroplasts and how these relate to the chemical processes of respiration and photosynthesis, respectively. They understand the mechanisms of diffusion, osmosis and active transport, and relate these processes to the fluid mosaic model of a cell membrane. They know that ATP is the immediate energy source in cellular processes and relate this to respiration and photosynthesis. They outline the reaction steps in the glycolysis, Krebs cycle and oxidative phosphorylation stages of respiration. They outline the reaction steps in the light-dependent and light-independent stages of photosynthesis. They relate the structure of a plant leaf to its function in photosynthesis and understand the factors limiting the rate of photosynthesis.

Students who progress further understand the basic biochemistry of anaerobic respiration and compare this with aerobic respiration. They know the structure of ATP and ADP, the reactions in the three stages of aerobic respiration and the role of NAD and ATP. They understand why aerobic and anaerobic respiration yield different amounts of energy in the form of ATP. They understand respiratory quotient and relate this to energy values of respiratory substrates. They know the reactions in the two stages of photosynthesis and the importance of the Calvin cycle. They know about cyclic and non-cyclic photophosphorylation and the use of ATP in the light-independent stage of photosynthesis. They know how carbon-14 has been used to investigate photosynthesis. They understand the absorption spectrum of chlorophyll and know that the pigments of chlorophyll can be separated by chromatography.

Resources

The main resources needed for this unit are:

- overhead projector (OHP)
- electronmicrographs
- microscope attached to a video camera and monitor
- visking tubing
- simple modelling materials
- simple photosynthometers
- datalogger, with light, oxygen and temperature sensors
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *mitochondria*
- *glycolysis*, *the Krebs cycle*, *oxidative phosphorylation*
- *aerobic respiration, anaerobic respiration*
- *fluid mosaic model*
- *diffusion*, *osmosis*, *active transport*
- *photosynthesis*
- *light-dependent reactions*, *light-independent reactions*, *the Calvin cycle*
- *dicotyledonous leaf*
- *chloroplast stroma*, *grana*, *thylakoids*
- *limiting factors*

Standards for the unit

Unit 11AB.1

7 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS	
1 hour **Mitochondria and chloroplasts, and role of ATP** **1 hour** **The structure and function of the cell membrane** **1 hour** **Relating leaf structure to photosynthesis** **1 hour** **Biochemistry of aerobic respiration** **1 hour** **Biochemistry of photosynthesis** **2 hours** **Limiting factors**						
	10A.7.2	Recognise and know the function of a nucleus, mitochondria, chloroplasts, endoplasmic reticulum and ribosomes.	11A.5.1	Describe the structure of mitochondria and chloroplasts and link their structures to the biochemical and photochemical reactions of respiration and photosynthesis.		
	10A.5.1	Describe the composition and molecular structure of glucose, amino acids, glycerol, fatty acids, triglycerides, phospholipids, chlorophyll and haemoglobin.	11A.5.2	Explain the structure and functioning of the fluid mosaic model of the cell membrane in relation to the properties of phospholipids and the mechanisms of diffusion, osmosis and active transport.		
	9.7.2	Explain diffusion and osmosis as mechanisms for the movement of substances into and out of cells.	11A.5.3	Describe the structure of a dicotyledonous leaf and a palisade cell and relate their structures to their roles in photosynthesis.		
			11A.6.1	Describe the role of ATP as the universal energy currency in all living organisms and relate this to respiration and photosynthesis.		
	9.8.1	Give the word and formula equations for aerobic respiration; explain the process as a cellular biochemical reaction in animals and plants in which food acts as a respiratory substrate and reacts with oxygen to release energy and produce carbon dioxide and water.	11A.6.2	Describe the reaction steps in the three stages of aerobic respiration (glycolysis, the Krebs cycle and oxidative phosphorylation), including the roles of oxygen and ATP.	12A.5.1	Explain how the biochemistry, products and energy release of anaerobic respiration differ from those of aerobic respiration and how anaerobic respiration builds up an oxygen debt.
					12A.5.2	Explain the structure and function of ADP and ATP and the synthesis of ATP in the electron transport chain on the membranes of the mitochondria.
					12A.5.3	Outline glycolysis as the phosphorylation of glucose and the subsequent splitting of hexose phosphate (6C) into two triose phosphate molecules, which are further oxidised with a small yield of ATP and reduced NAD.
					12A.5.4	Explain that when oxygen is available, pyruvate is converted into acetyl coenzyme A (2C), which then combines with oxaloacetate (4C) to form citrate (6C).

7 hours	SUPPORTING STANDARDS	CORE STANDARDS Grade 11 standards	EXTENSION STANDARDS
			12A.5.5 Explain the Krebs cycle as a series of decarboxylation and dehydrogenation reactions in the matrix of the mitochondria that reconvert citrate to oxaloacetate; explain the role of NAD.
			12A.5.6 Explain the role of oxygen in the process of oxidative phosphorylation.
			12A.5.7 Explain respiratory quotient and the relative energy values of carbohydrates, proteins and lipids as respiratory substrates.
		11A.6.3 Describe the reaction steps in the light-dependent and light-independent stages of photosynthesis, including the role of ATP.	12A.6.1 Explain that energy is transferred by the photoactivation of chlorophyll resulting in the splitting of water molecules and the transfer of energy to ATP and NADPH; that this involves cyclic and non-cyclic photophosphorylation; that this generates hydrogen for the light-independent stage of the process; that gaseous oxygen is produced.
			12A.6.2 Explain that the Calvin cycle involves the light-independent fixation of carbon dioxide by combination with RuBP (5C) to form two molecules of GP (3C), that ATP and NADP are required for the reduction of GP to carbohydrate, and that RuDP is regenerated.
			12A.6.3 Describe how carbon-14 has been used to establish the biochemistry of photosynthesis.
			12A.6.4 Know that chlorophyll reflects green light and absorbs in the red and blue areas of the spectrum, and that the pigments of chlorophyll can be separated by chromatography.
		11A.7.1 Explain how carbon dioxide concentration, light intensity and temperature are interdependent limiting factors for photosynthesis.	

Objectives	Possible teaching activities	Notes	School resources
1 hour **Mitochondria and chloroplasts, and the role of ATP** Describe the structure of mitochondria and chloroplasts and link their structures to the biochemical and photochemical reactions of respiration and photosynthesis. Describe the role of ATP as the universal energy currency in all living organisms and relate this to respiration and photosynthesis.	Introduce this component by linking the mitochondria and chloroplasts to energy; ask students to recall earlier work from Grade 9 to see what they understand by the terms *respiration* and *photosynthesis*.	Recall Standards 9.8.1 on aerobic respiration and 9.11.1 on photosynthesis.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Start by asking students to recall earlier work from Unit 10AB.2 on cell ultrastructure. Show students a variety of electron micrographs of eukaryotic cells containing images of mitochondria among other structures. Ask students to work in pairs to identify, count and measure the mitochondria (if a scale or a magnification is given). Discuss their findings with the whole class to compare results and explain the variation found. Provide each student with an electron micrograph of a chloroplast with numbered arrows and a size scale and ask them to label the chloroplast (*grana*, *stroma*, *thylakoid membranes*, *outer membrane* and *inner membrane*), describe the features (e.g. presence of pigments) and identify the functions of the parts (sites of *light-dependent* and *light-independent reactions*).	**Mathematics:** Mathematical skills are needed to determine sizes from scales or magnifications. Prepare a suitable diagram.	
	Encourage students to make models of mitochondria from everyday materials found at home. Ask them to indicate the scale of the model produced. Ask students to draw a large diagram of a mitochondrion or chloroplast to show its detailed structure and to label the individual features. Then get them to annotate the diagram with further information identifying where specific events associated with aerobic respiration or photosynthesis occur (e.g. the Krebs cycle in the matrix, diffusion of oxygen through the outer membrane).	Simple materials such as empty drinks bottles, balloons or plastic bags could be used here. Colour always enhances diagrams.	
	As an interesting activity, ask students 'What is the most important reaction on the planet?' Discussion should lead them to decide that the answer is photosynthesis. If anyone is undecided, ask them 'Where does all the food and oxygen on the planet come from?'		
	Link the production of ATP to the other organic molecules, such as carbohydrates, lipids and proteins discussed in Unit 10AB.1. Ask students how these high-energy respiratory substrates are linked to ATP. With students working in pairs, ask them to list what ATP is used for in life. Collate their answers on the board or OHP by asking for one item from each pair in turn. If their answers are not totally inclusive, widen their answers by prompting them to include all forms of life in their lists. Summarise the importance of ATP to all life forms.	Recall Standard 10A.5.1.	

Objectives	Possible teaching activities	Notes	School resources
1 hour **The structure and function of the cell membrane** Explain the structure and functioning of the fluid mosaic model of the cell membrane in relation to the properties of phospholipids and the mechanisms of diffusion, osmosis and active transport.	A memorable and enjoyable opening to this topic is to begin by showing students a stream of bubbles blown from a child's bubble mix. Ask students what the bubbles have in common with the cell and the topic of the cell membrane is likely to be suggested immediately. Use about ten or more phospholipid molecular shapes cut out of OHT sheets and ask students how they might be arranged to form a cell membrane. Discussion of a single layer or a double layer can be developed to involve the molecules' properties. Introduce the concepts of *hydrophobic* and *hydrophilic* in relation to the phospholipids. The stability of the bilayer in water will follow logically. Tell students that chemical analysis reveals there are other molecules in the membrane: proteins. Introduce these varied larger molecular shapes to the model membrane.	Prepare bubble mix.	
	Show students diagrams (either on the OHP or from a computer connected to an interactive whiteboard) of the fluid mosaic model of membranes to illustrate and aid discussion on both structure and function. Show students electron micrographs displaying cell membranes of both individual and adjacent cells. Consider showing specialised cells with microvilli or the membranes of cells associated with the blood–air barrier in the lungs to introduce the adaptation of the cell membrane and to link structure to function. Give pairs of students replicate sets of such micrographs and ask them to suggest how these structures are adapted for their specific function(s).	**ICT opportunity**: Use of PowerPoint or the Internet with an interactive whiteboard.	
	The following activities on osmosis could be demonstrated or carried out by students in pairs. • Take three 20 cm lengths of visking tubing, each tied at one end. Add a measured volume of water to one, weigh it and place it in a beaker containing 5% glucose solution. Add an equal volume of 5% sugar solution to the second and 10% sugar solution to the third and weigh them. Place these in beakers containing water. After 1 hour weigh all three again. Compare the weight changes and ask students to explain them. • Place weighed samples of root vegetable discs in one of a range of salt and sugar solutions. Also put one in water for comparison. Reweigh them after 1 hour and compare the weight changes. Ask students to draw a graph and to explain the shape found.	Using visking tubing normally produces very reliable results when treatments are set up with different solutions and differences in weights at the start and end are compared.	
	Tell students to carry out microscopic observations of single layers of cells (e.g. red onion epidermal cells immersed in water), and compare their appearance with cells in different strengths of salt or sugar solutions. Ask them to explain the observed phenomena, such as plasmolysis and turgidity, and to suggest how animal cells would behave in similar solutions. Present students with graphs and/or data on a process such as the take up of minerals by plant roots in different conditions (e.g. aerobic and anaerobic), to compare and contrast active transport with passive means such as diffusion. Ask students to explain the results.		

Objectives	Possible teaching activities	Notes	School resources
1 hour **Relating leaf structure to photosynthesis** Describe the structure of a dicotyledonous leaf and a palisade cell and relate their structures to their roles in photosynthesis**.**	Ask students to work individually to observe prepared slides of cross-sections of leaf cells under a microscope.	Students will need: microscopes, selected microscope slides, microtome.	
	Ask them to count the number of chloroplasts in palisade cells and spongy mesophyll cells to find out which contain most chloroplasts and what variation exists.	Enquiry skill 3.1	
	Ask students, working individually, to cut cross-sections of leaves, prepare slides, study them with a microscope and draw selected views. Suggest that they draw the morphology of a range of different plant leaves. Ask students to use graph paper to find the total surface area of some plant leaves by drawing around each leaf and calculating the total area of each leaf. The total surface area of all the leaves of the plant can be estimated from this data. Ask students to draw a table to show a list of the features of a leaf in one column and to explain how each feature is adapted to assist photosynthesis in the next column (e.g. 'large flat surface' and 'intercepts Sun's light energy').	A microtome cuts excellent sections. Alternatively, use a carrot split in half to make a suitable support for a leaf while sectioning by hand using a safety razor blade.	
1 hour **Biochemistry of aerobic respiration** Describe the reaction steps in the three stages of aerobic respiration (glycolysis, the Krebs cycle and oxidative phosphorylation), including the roles of oxygen and ATP.	Ask students to recall the word and formula equations for aerobic respiration.	Recall Standard 9.8.1.	
	Then link to Unit 10AB.3 on enzymes by introducing the idea that aerobic respiration is an extremely complex multi-enzyme regulated process that is best described in three stages (glycolysis, the Krebs cycle and oxidative phosphorylation). Display a diagram of a cell on the OHP and ask students where they think each of the three stages occurs. Show them using OHT overlays.	Prepare an OHT diagram of a cell showing mitochondria, nucleus and cytoplasm, with overlay(s) showing the three stages identified at correct sites (glycolysis in cytoplasm, the Krebs cycle in mitochondrial matrix and oxidative phosphorylation on cristae).	
	Outline the main events in the three reaction stages by showing students an OHT of the molecules at the start and end of each stage (e.g. glycolysis begins with a glucose molecule being primed with ATP and ends with two molecules of pyruvic acid, the net production of two molecules of ATP and two molecules of $NADH_2$). The oxidation of $NADH_2$ and associated production of ATP should clearly show students where most ATP is produced after the reactions of the Krebs cycle. Ask students to identify the site of oxygen consumption and its role in respiration.	Prepare OHTs with the events of the three stages on separate overlays so the stages can be shown in sequence.	
	Give pairs of students a set of cards displaying different events in respiration and tell them to arrange the cards in the correct order.	Prepare sets of cards in which each card shows a different respiration event.	
	Ask students to produce a wall chart to illustrate the reactions in aerobic respiration.		
	Ask students to use the library and/or the Internet to find out about the work of Hans Krebs.	**ICT opportunity:** Use of the Internet. Enquiry skill 11A.2.3	

Objectives	Possible teaching activities	Notes	School resources
1 hour **Biochemistry of photosynthesis** Describe the reaction steps in the light-dependent and light-independent stages of photosynthesis, including the role of ATP.	Ask students to find out on the Internet about the work of Robert Hill at Cambridge on chloroplasts. Ask students what happens to water in the light-dependent reaction. The answer is that chloroplasts split water molecules using light energy (photolysis) and so the simple equation for photosynthesis that suggests carbon dioxide as the source of oxygen needs to be rewritten. To describe the reaction steps, use an OHT or whiteboard to develop and illustrate how the absorption of light by the photosynthetic pigments, especially chlorophyll, in the thylakoid membranes of the chloroplast causes electrons from the chlorophyll photosystem to be raised to a higher energy level. The electrons are then passed along an electron transport chain during which energy is released and used to synthesise ATP from ADP and inorganic phosphate: a process known as *photophosphorylation*. The chlorophyll's lost electrons are replaced by those from the splitting of water (photolysis) resulting in the release of oxygen gas and hydrogen ions. The electrons that have passed along the electron transport chain are used together with the hydrogen ions to reduce NADP. Use an OHT or whiteboard to outline the light-independent reactions that take place in the stroma of the chloroplasts, where carbon dioxide from the atmosphere is fixed using ATP and reduced NADP from the light-dependent reaction to reduce carbon dioxide to carbohydrate.	**ICT opportunity:** Use of the Internet.	
	Ask students to use the Internet to investigate how Melvin Calvin contributed to our understanding of photosynthesis. Use the following activities to improve their understanding. • Prepare sets of cards displaying the events and components of the Calvin cycle. Each card should describe a single reaction or give the name of a single chemical intermediate or enzyme (e.g. ribulose bisphosphate carboxylase – the commonest enzyme in the world). Ask students to work in pairs to arrange a set of these cards in the correct sequence. Begin by using a simple set of cards showing just the number of carbon atoms in each compound rather than names of compounds. Add more detailed cards for more advanced students as required. • Use a set of cutout OHT shapes showing the events of the Calvin cycle, as described above, and build the cycle up sequentially with a logical progression and explanation. • Provide students with a template of the Calvin cycle with empty boxes in which they can write the names of the intermediates. Either ask students to complete the exercise from their own research or use the template in conjunction with the card activity above. Ask students to identify the way that the light-dependent reaction helps the light-independent reaction (via ATP and reduced NADP).	**ICT opportunity:** Use of the Internet. Write out sets of suitable cards: a simple set and a more complex set. Unit 12AB.1 develops the understanding of the Calvin cycle. Prepare OHT cutout shapes of Calvin cycle components. Prepare Calvin cycle template.	

2 hours **Limiting factors** Explain how carbon dioxide concentration, light intensity and temperature are	Demonstrate the rate of photosynthesis of a culture of algae using a datalogging technique with sensors for light, oxygen and temperature determination. The opportunity is presented here for students to conduct one or more practical investigations on how the rate of photosynthesis is affected by a change in an environmental factor. Students can work individually but, unless they are being assessed, working in pairs is recommended for ease and use of equipment in the following investigations.	**ICT opportunity:** Use of dataloggers and sensors.	

Objectives	Possible teaching activities	Notes	School resources
interdependent limiting factors for photosynthesis.	Get students to use a simple photosynthometer to investigate the effect on the rate of photosynthesis of an aquatic plant (e.g. algae or *Elodea*) of changing one factor while keeping all other factors constant. Aquatic plants release bubbles of oxygen as photosynthesis occurs and students can obtain quantitative results by collecting these bubbles over a period of time and measuring the volume of gas produced. They can also get useful results simply by counting the number of bubbles released over a given period of time. However, because of variations in bubble size, this method is at best semi-quantitative and will not yield precise results. Suitable factors to investigate include: • light intensity: move a light source to measured distances from the apparatus in an otherwise darkened room; • the wavelength of light: use coloured filters in a darkened room; • carbon dioxide concentration: vary the concentration of hydrogen carbonate ions in the solution; • temperature: use water baths at set temperatures to hold the apparatus.	Simple photosynthometers can be made from syringes and capillary tubing. Enquiry skills 11A.1.3, 11A.3.1–11A.3.3, 11A.4.1, 11A.4.2 A light meter can produce more accurate measurements of light intensity for plotting graphs. Alternatively, intensity can be determined from the inverse square law; for example, if the distance of the light source is doubled then the light intensity falls to a quarter of its previous value.	
	Ask students to explain the results of experiments (such as those above) in which light intensity, carbon dioxide or temperature have been varied.		
	Use the OHP to show students graphs comparing the effects of light intensity on the rate of photosynthesis of a plant exposed to (e.g. four) different treatments, such as the following: (a) 0.03% CO_2 at 20 °C; (b) 0.03% CO_2 at 30 °C; (c) 0.13% CO_2 at 20 °C; (d) 0.13% CO_2 at 30 °C.	Prepare suitable OHTs.	
	Ask students to use the Internet to investigate the work of F.F. Blackman, who formulated the principle of limiting factors: ‘At any given moment, the rate of a physiological process is limited by the one factor which is in shortest supply.’	**ICT opportunity:** Use of the Internet. Enquiry skill 11A.2.3	
	Ask students to explain the shape of the graphs by reference to limiting factors. A typical answer might be: ‘In all the graphs (a, b, c and d) the rate of photosynthesis will increase with light intensity up to a point and then tail off. At this point some other factor, such as the concentration of carbon dioxide, is in short supply and so limits the rate. An increase in the carbon dioxide concentration again increases the amount of photosynthesis until some further factor, such as temperature, limits the process.’		

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Sort cards on which are written statements about aerobic respiration into a logical sequence.*	Issue students with cards on which are written statements about aerobic respiration (e.g. 'produces two molecules of ATP' or 'oxygen is used here').	
	Draw up an energy balance sheet for the stages of respiration to show where ATP was produced.		
	Label the following cross-section of a dicotyledonous leaf and write an account to describe how the leaf 's structure is related to its function in photosynthesis	Give students a suitable diagram with numbered arrows.	
	Explain why ATP is regarded as the universal energy currency in all living organisms		
	Describe the reaction steps in the light-dependent stage of photosynthesis		
	Describe the reaction steps in the light-independent stage of photosynthesis		
	Explain how carbon dioxide, light and temperature affect the rate of photosynthesis by reference to the accompanying graph.	Give students a suitable graph showing carbon dioxide, light and temperature as limiting factors	
	Why might a glasshouse grower be interested in limiting factors?		

GRADE 11A: Biology 2

Transport systems in dicotyledonous plants

UNIT 11AB.2
4 hours

About this unit

This unit is the second of eight units on biology for Grade 11 advanced.

The unit is designed to guide your planning and teaching of biology lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 7.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already be able to describe how water and nutrients enter and pass through a plant, and know that nitrogen and other nutrients are required for plant growth.

Expectations

By the end of the unit, students understand the need for a transport system in multicellular plants. They recall the structure, function and distribution of phloem and xylem in the roots, stems and leaves of a dicotyledonous plant. They describe translocation and transpiration. They explain water movement between cells, and between cells and their environment, in terms of water potential.

Students who progress further know that organic materials are transported in plant phloem by translocation and that there are several hypotheses to explain the mechanism. They understand the factors affecting the rate of transpiration and the adaptations of xerophytic plants for water conservation.

Resources

The main resources needed for this unit are:

- microscopes, prepared slides and stain(s)
- microtome
- video camera plus monitor
- overhead projector (OHP) and transparencies (OHTs)
- large number of 1 cm^3 cubes
- visking tubing
- potometer(s)
- anhydrous cobalt chloride paper

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *surface area to volume ratios*
- *xylem*, *phloem*
- *translocation*, *transpiration*
- *water potential*
- *symplast pathway, apoplast pathway*
- *cohesion tension theory*
- *source, sink, mass flow*

Standards for the unit

Unit 11AB.2

4 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
2 hours **Plant organ vascular systems**			11A.8.1	Explain why large plants need transport systems for gases, water and food in terms of their surface area to volume ratios.		
			11A.8.2	Describe the vascular systems of the roots, stems and leaves of dicotyledonous plants and relate the structure and distribution of xylem and phloem to their functions.		
1 hour **Movement of water**			11A.8.3	Explain the movement of water between plant cells, and between plant cells and their environment, in terms of water potential.		
1 hour **Transpiration and translocation**	7.9.1	Describe how water and nutrients enter a root hair and pass up through a plant.	11A.8.4	Describe the processes of translocation of photosynthetic products in the phloem and transpiration of water and dissolved minerals in the xylem.	12A.8.1	Explain how temperature, wind speed and humidity affect the rate of transpiration and how plants control their water loss by regulating stomatal opening.
	7.9.2	Know that nitrogen and other nutrients are required for plant growth.			12A.8.2	Explain some of the adaptations that help xerophytic plants to conserve water.
					12A.8.3	Explain some of the hypotheses being put forward to explain translocation.
					12A.8.4	Know how autoradiography and aphids have been used in the study of translocation.

Objectives	Possible teaching activities	Notes	School resources
2 hours **Plant organ vascular systems** Explain why large plants need transport systems for gases, water and food in terms of their surface area to volume ratios. Describe the vascular systems of the roots, stems and leaves of dicotyledonous plants and relate the structure and distribution of xylem and phloem to their functions.	Ask students why large plants need transport systems and collate the answers on the board or OHP and discuss. An alternative introduction is to adopt a historical or evolutionary approach, if this is appropriate. Tell students that many millions of years ago the largest land plants were mosses (Bryophyta), which were only about 15 cm tall. Then ask students how plants have changed since then to enable them to be so tall today, with some even in excess of 100 m tall, making them the largest living organisms on the planet. A discussion on the evolution of vascular systems and on the advantages these systems confer on plants will provide an answer this question. Ask students what problems are faced by plants (or animals) on land as they become larger. Collate the answers on the board or OHP and discuss. Their answers may include references to weight, water retention, supplying materials to cells and gas exchange, or they may refer directly to diffusion. All these issues can be addressed by considering adaptations to the plant transport system. Address the issue of diffusion limitations by asking students to work in pairs to investigate how the relationship of surface area to volume alters as a plant becomes larger. Distribute enough 1 cm^3 cubes to allow students to construct three cubes of increasing dimensions as a simulation exercise. Discuss the relationships. Demonstrate the rate of diffusion by investigating how long it takes for a drop of coloured dye to diffuse completely in different volumes of water.	One example of an adaptation is the xylem acting as both supporting tissue and transport tissue, so it can act as the plant's skeleton. Give each pair about 40 identical 1 cm^3 cubes; this will enable students to construct cubes of 1 cm^3, $(2\ cm)^3$ and $(3\ cm)^3$. Ensure water is absolutely still before adding dye.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Demonstrate the structure of plant cross-sections using a video camera attached to a microscope and a monitor. Allow students to use the microscope and video camera to examine professionally prepared slides of sections of roots, stems and leaves. Ask them to make drawings of low-power views, indicating the distribution of tissues: a tissue map of the plant organ. Tell them to label the tissues and ascribe function(s) to each tissue. Then ask them to view the sections under high power and make drawings of selected tissues, showing details of the individual cells. They should relate the structures of the cells to their position and function(s) in the plant organ.	You will need a microscope attached to a video camera and monitor, and commercial slides. Enquiry skills 11A.3.1, 11A.4.1	
	Ask students, working individually, to cut longitudinal and transverse sections of roots, stems and leaves, and then examine these with a microscope. The sections can be cut carefully by hand using safety razorblades or with a microtome (either hand type or a rocking model), if one is available. The herbaceous stems of members of the Cucurbitae and Labiatae families are suitable for cutting by hand. Show students how to carry out differential staining techniques to reveal specific structures more clearly. For example, differentiate xylem from phloem by using toluidene blue stain, which stains cellulose cell walls purple but stains lignified (xylem) structures bright blue.	**Safety:** Take care when cutting sections by hand. Thin roots, stems and leaves can be supported by polystyrene pieces or by split carrots while sections are cut. Toluidene blue stain clearly distinguishes cellulose from lignin. Use a very dilute solution sparingly.	

Objectives	Possible teaching activities	Notes	School resources
	Ask students to examine cut sections of a tree trunk or branch to identify the growth patterns. They should be able to see growth through the years (annual rings) and pick out seasonal variations, distinguishing spring from summer wood. They should be able to determine the width and extent of growth each year as well as the age of the structure. They should also be able to distinguish heartwood from sapwood. Tell them to examine very thin sections of a stem/branch under the microscope to see the different cellular elements of the xylem and phloem.	Commercial microscope slides of woody branches should be available to students.	
	Ask students to make a model root and stem to show the vascular bundles. They can use cardboard or plastic tubing for the shape, and position bundles of appropriately coloured wool, twine, rope or electrical cable inside the tubing.		
1 hour **Movement of water** Explain the movement of water between plant cells, and between plant cells and their environment, in terms of water potential.	The following activity can be carried out as a demonstration or by students working in pairs or small groups. Make model cells from visking tubing. Fill one cell with water and put different concentrations of sugar solution in sets of other cells (e.g. 0.1, 0.2, 0.3, 0.4, 0.5 $mol\,dm^{-3}$). Weigh all the cells. Place the cells so that the water cell is touching all the others. Leave for some time and look for signs of movement of water into the various cells (e.g. change in appearance and/or weight).		
	The following activity can be carried out as a demonstration or by students working in pairs or small groups. Make slides of red onion epidermal tissue immersed in one of the following: water, 0.2 $mol\,dm^{-3}$ sucrose, 0.5 $mol\,dm^{-3}$ sucrose. Examine them under the microscope and make drawings of samples of cells from each slide. Then explain the differences in appearances. Plasmolysis will be clearly seen in the cells in 0.5 $mol\,dm^{-3}$ sucrose.	Red onion cells show plasmolysis very clearly because of the coloured sap vacuole. If doing this as a demonstration, use a microscope attached to a video camera and monitor to display the results of plasmolysis.	
	Show students an OHT displaying a cross-section of a root in the root hair region. Explain the movement of water into the root hairs down a water potential gradient. Point out in particular the way a water potential gradient is established across the root from the xylem to the root hair cells, which draws water across it through the symplast pathway. In addition, explain the movement of water across the apoplast pathway to give a complete picture of water entry into the root. Show students an OHT displaying a cross-section of a leaf. Ask them to explain the pathway of water movement through the leaf from the xylem to the surrounding air in terms of water potential changes.	Prepare OHTs of root and leaf cross-sections.	
	Show students an OHT displaying three plant cells, each in a solution of different water potential (one higher than, one the same as and one lower than the plant cells). Ask students to explain, in terms of water potential, which way the water will move.	Prepare a suitable OHT.	

Objectives	Possible teaching activities	Notes	School resources
1 hour **Translocation and transpiration** Describe the processes of translocation of photosynthetic products in the phloem and transpiration of water and dissolved minerals in the xylem.	To introduce this topic, show students an OHT displaying a diagram of a complete plant. Ask one student to come to the front of the class and suggest the route taken through this plant by: • organic molecules; • water • minerals Show students an OHT displaying a longitudinal view of phloem sieve tube elements and companion cells, with numbered arrows pointing at the unlabelled structures. Give students a copy each. Have an overlay OHT sheet with the labels ready to place on the first OHT sheet. Ask students to label the diagram. Then, using the overlay, explain the structures and their relationship. Show students an OHT table displaying the composition of phloem sap. Ask them which of the substances in the table have been synthesised by the plant. (They should choose sucrose and amino acids.) Show students an OHT displaying the whole plant with the leaves as sources and the roots as sinks, and mass flow in the phloem. Give students a copy. Describe the mechanism of translocation by mass flow. Explain the flow by reference to sucrose loading at the source and sucrose removal at a sink. Ask students to make a table comparing and contrasting the structure and function of phloem sieve elements with xylem vessels. Discuss the tables as a class. Show students an OHT displaying a longitudinal view of xylem tissue with numbered arrows pointing at the unlabelled structures. Give students a copy and ask them to label it. Have an overlay OHT sheet with the labels ready to place on the first OHT sheet when students have finished labelling their copies of the diagram. Using the overlay, explain the structures and their functions.	The following activities all require suitable OHTs and student worksheets to be prepared.	
	Ask students to examine microscope slides of sections of stems displaying xylem and phloem tissue. Tell them to draw diagrams of these tissues.	Give students prepared microscope slides.	
	Demonstrate water loss by the leaves of a plant by tying a polythene bag over a few leaves and observing the result later. Test for water with anhydrous cobalt chloride paper (the colour changes from blue to pink).	**Safety:** Handle cobalt chloride paper with plastic gloves; store paper in a desiccator.	
	Show an OHT of the transpiration route through the plant. Explain the movement of water up the stem by the cohesion tension theory. Describe the mass flow of water molecules up the xylem vessels.		
	The following activities with a potometer can be carried out as demonstrations or by students working in pairs or small groups. • Use a potometer to investigate water loss by plants. Measure the rate of water loss and draw graphs of the results in each case. • Use a potometer to investigate factors that affect the rate of transpiration of a plant, for example: – wind speed (use a fan at different speeds); – humidity (use a clear plastic bag); – air temperature (use a radiant heat source); – low light intensity (compare semi-blackout with brightly lit laboratory); – removal of 50% of the leaves; – coating 50% of the leaves in petroleum jelly.	Cut the stem carefully under water to avoid air bubbles blocking xylem elements. Enquiry skills 11A.1.1–11A.1.3, 11A.3.2, 11A.4.1	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Use the accompanying diagram of a cross-section of a root to explain, by reference to water potential, how water enters the root.*	Give students a diagram of a cross-section of a root in the root hair region.	
	Two neighbouring plant cells are shown in the diagram, each with a different water potential. *In which direction will there be a net movement of water? Explain your answer.*	Give students a diagram of two plant cells with different water potential values (e.g. –250 kPa and –400 kPa).	
	Complete the following task sheet by adding the most suitable word(s) to the spaces indicated by lines.	Produce a task sheet with key words omitted (e.g. ‘xylem’, ‘phloem’, ‘potential gradient’).	
	Describe how organic molecules are moved within a plant by reference to mass flow.		

GRADE 11A: Biology 3

Physiological regulation in mammals

UNIT 11AB.3
8 hours

About this unit

This unit is the third of eight units on biology for Grade 11 advanced.

The unit is designed to guide your planning and teaching of biology lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 9.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already know how insulin operates and be able to contrast the hormonal and nervous control systems. They should understand the importance of homeostatic mechanisms and be able to explain temperature and water regulation. They should know the structures and function of nerve cells and about nerve impulses. They should know the importance of the reflex arc and the structure and function of the ear and the eye.

Expectations

By the end of the unit, students know that organisms that can respond to changes in their environment have an increased chance of survival. They understand the principles of homeostasis and negative feedback. They compare and contrast the hormonal and nervous control systems. They describe mammalian thermoregulation and the oestrous cycle.

Students who progress further know about thermoreceptors in the hypothalamus and understand body thermoregulation. They know the causes and effects of heatstroke. They know the structure and function of neurones and how nerve impulses are transmitted. They know the main structures and functions of the brain. They know the main endocrine glands of the human body and their functions. They understand how human blood glucose levels are controlled.

Resources

The main resources needed for this unit are:

- overhead projector (OHP) and prepared transparencies (OHTs)
- video clips about how animals detect danger and human survival in hot and cold conditions
- video recorder and monitor
- round-bottomed flasks
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *homeostasis*
- *environmental stimuli*
- *internal environment*
- *negative feedback*
- *thermoregulation*
- *hormone*, *TRH*, *TSH*, *thyroxine*, *oestrogen*, *progesterone*, *FSH*, *LH*, *HCG*
- *oestrous cycle (sexual cycle)*, *gonadotrophic*
- *hypothalamus*, *neurotransmitter*
- *dynamic equilibrium*

Standards for the unit

Unit 11AB.3

8 hours	SUPPORTING STANDARDS	CORE STANDARDS Grade 11 standards	EXTENSION STANDARDS
1 hour **Responding to environmental stimuli**	9.10.5 Know the structure and function of the human eye and ear. 9.10.1 Explain the importance of maintaining a constant internal environment.	11A.9.1 Explain the importance to the survival of organisms of being able to respond to environmental stimuli. 11A.9.2 Explain the importance of homeostasis in mammals and describe the process in terms of receptors, effectors and negative feedback.	
1 hour **Homeostasis** **2 hours** **Thermoregulation**	9.10.6 Know how the body controls temperature and water balance.	11A.9.3 Describe thermoregulation in humans and the roles of TRH and TSH.	12A.9.4 Explain the role of thermoreceptors in the hypothalamus in thermoregulation and describe some physiological and behavioural responses of mammals to hot and cold conditions. 12A.9.5 Describe the symptoms of heatstroke and explain why it occurs and how it can be avoided.
2 hours **Oestrous cycle regulation**		11A.9.4 Describe the mammalian oestrous cycle and the roles of oestrogen, progesterone, LH and FSH.	
2 hours **Nervous and hormonal control systems**	9.10.2 Explain the ways in which hormonal control occurs and the effects of insulin. 9.10.3 Know the general structure and functions of the human nervous system, the structure and function of types of nerve cells, and the pathways taken by a nerve impulse in response to a stimulus. 9.10.4 Know the functioning and importance of the reflex arc. 9.10.7 Know the similarities and differences between hormone and nervous control systems.	11A.9.5 Describe the similarities and differences between nervous and hormonal control systems in mammals.	12A.9.6 Describe, compare and contrast the structure and function of sensory, motor and intermediate neurones and know where they are found. 12A.9.7 Explain the function and importance of a reflex arc and differentiate between a simple reflex and a conditioned reflex. 12A.9.8 Explain: the nature of a nerve impulse and the way it is transmitted; resting potential; membrane depolarisation and action potential; refractory period; the passage of sodium and potassium ions. 12A.9.9 Explain the operation of sensory receptors as energy transducers. 12A.9.10 Describe the roles of synapses in the nervous system in determining the direction of nerve impulse transmission and in allowing interconnections of nerve pathways.

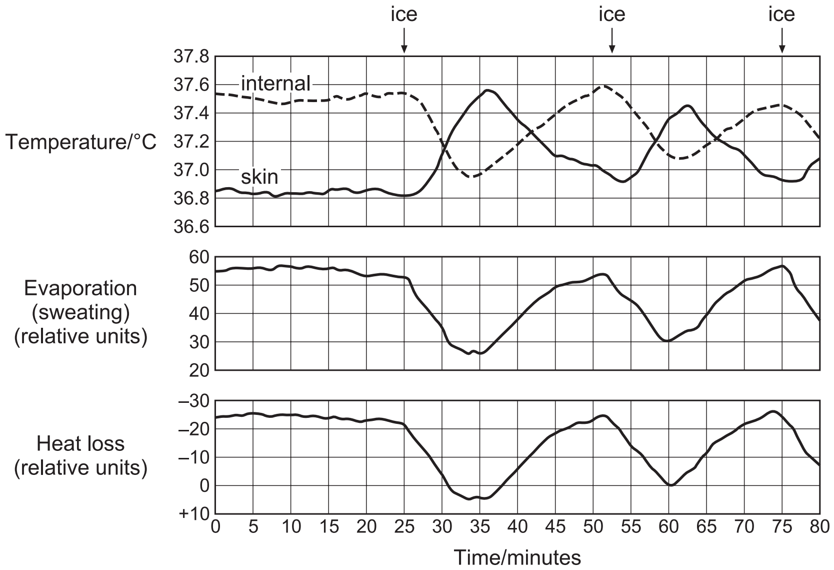
8 hours	SUPPORTING STANDARDS	CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
			12A.9.11	Describe the main structures of the human brain – cerebral hemispheres, cerebellum, medulla oblongata – and their functions. Know that the hypothalamus is the link between the nervous and the endocrine control systems.
			12A.9.12	Know the names, locations and functions of the main endocrine glands of humans.
			12A.9.13	Explain how insulin and glucagon control the blood glucose level and how failure of the system results in diabetes.

Objectives	Possible teaching activities	Notes	School resources
1 hour **Responding to environmental stimuli** Explain the importance to the survival of organisms of being able to respond to environmental stimuli.	Introduce this topic by asking students to identify as many environmental stimuli as possible to which mammals are responsive. Expected answers include: light, sound, smell, taste, temperature, pressure, touch, pain, gravity. Ask students the location in the body of the receptors that detect external environmental stimuli. This will identify the main sense organs (eyes, ears, skin, nose and tongue). Ask students why we/mammals are sensitive to these environmental stimuli. Expected answers include 'awareness of the immediate environment'. Now ask why this 'awareness' is important to mammals. Someone should suggest 'increased probability of survival in a changing environment'. Ask students to give examples of how we/mammals increase the chances of survival. Expected answers include: • avoidance of harmful stimuli (e.g. food tasting bad or smelling off); • attraction to other stimuli (e.g. pheromones from female mammals ready for mating); • increasing day length bringing mammals into breeding behaviour at the right time; • predators: finding food by sight, sound, or smell; • prey: avoiding predators by sight, sound or smell.		Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Show students a wildlife video that illustrates a range of ways in which animals detect potential dangers. Ask them to make a note of all the types of stimuli identified and how each impacts on the animal's survival.	**ICT opportunity:** Use of video for illustration.	
	Ask students, in pairs or small groups, to conduct an investigation into taste by blindfolding one subject and asking them to identify food items. This investigation reveals how we often rely on a combination of our senses to identify items.	Enquiry skills 11AB.3.1, 11AB.3.3	
1 hour **Homeostasis** Explain the importance of homeostasis in mammals and describe the process in terms of receptors, effectors and negative feedback.	Introduce the concept of *homeostasis* to students by a brief definition of the principle: 'Homeostasis is the relative constancy of the body's internal environment.' Add historical interest by mentioning the original statement made by the nineteenth-century French physiologist Claude Bernard: 'La fixité du milieu intérieur est la condition de la vie libre.' (The constancy of the internal environment is the condition of the free life.) Ask students why the body's internal environment is likely to change. Make sure they appreciate that the human body is, like all organisms, an open system, since there is an exchange of materials between it and the environment – this will raise the possibility of changes. Examples of factors in the body subject to change are often the easiest illustrations for students to understand. Ask students to suggest internal body factors that are likely to change – they will probably mention temperature, and possibly water and blood sugar too.		

Objectives	Possible teaching activities	Notes	School resources
	Show students an OHT of the fluctuations of Qatar's average monthly temperatures. Briefly outline the changes in the environmental temperatures (e.g. average Qatar summer and winter temperatures) and ask students what the body's normal responses are. Clarify that body temperature does not stay absolutely constant but is allowed to fluctuate above and below a particular value; in other words, homeostasis involves maintaining a *dynamic* equilibrium. Ask students what they understand by the term *internal environment* of the body. (This usually refers to the tissue fluid surrounding each body cell.) Ask students why maintaining the internal environment within narrow limits is so important to mammals. Their answer should be something like 'it enables mammals to live comfortably in almost any environment and maintain a constant level of activity at all times of the day throughout the year'. The advantages of homeostasis are most easily illustrated by the example of temperature. Ask students to consider two animals, A and B. Animal A has no homeostatic mechanisms and animal B has a range of homeostatic mechanisms. What would be the problems, if any, experienced by animals A and B in a seasonal temperate climate? What differences in behaviour might animal A display compared with animal B?	Prepare a suitable OHT. Introduce temperature regulation briefly, but note that this topic is explained in more detail in the section on thermoregulation below. Animal A may survive the winter by hibernating.	
	Show students an OHT illustrating the homeostatic mechanism in the body and explain the concept of *negative feedback*. Explain the role of the individual components: • receptors or sensors (detect a change in the internal environment); • a regulatory centre (activates effectors); • effectors (reverse the change and bring conditions back to normal again).	Prepare an OHT displaying the general principle of the homeostatic control mechanism with receptors, regulatory centre, effectors and negative feedback.	
	Construct a chart and show students an OHT of a typical mechanical control system using a room thermostat set to a particular temperature. Ask one student to study the scheme and explain it to the class; make sure they refer to negative feedback. Construct a chart and show students an OHT of a human control system (e.g. regulation of blood pressure). Ask one student to study the scheme and explain it to the class; make sure they refer to negative feedback.	Prepare OHTs of a mechanical control system and a human control system	
2 hours **Thermoregulation** Describe thermoregulation in humans and the roles of TRH and TSH.	Show students an OHT of a chart on the regulation of body temperature (*thermoregulation*). Explain the chart. Explain the role of the hypothalamus as the site of the temperature receptors and as the regulatory centre directing the effectors (i.e. blood vessels in the skin, sweat glands, erector pili muscles and thyrotropin releasing hormone (TRH)). Emphasise the process of negative feedback in this example, where the temperature is returned to normal when it fluctuates above and below the relatively stable set point of around 37 °C (36.1 °C to 37.8 °C).	Prepare an OHT of thermoregulation.	
	Show students an OHT diagram of a cross-section of the skin, give each student a copy and then ask them to label the features involved, indicating how each part contributes to the processes in thermoregulation. Ask students, in pairs, to use the Internet, the library or their textbooks to find out how the body loses heat (radiation, conduction, convection and evaporation) or gains heat (radiation, conduction, convection and metabolism). Discuss the heat balance between gain and loss. Ask them to make a table comparing the normal response of the body to over-heating and over-cooling.	Prepare an OHT and student worksheets showing a cross-section of the skin. **ICT opportunity:** Use of the Internet.	

Objectives	Possible teaching activities	Notes	School resources
	Ask students why involuntary shivering occurs.		
	Ask students to identify the relationship between body temperature and metabolic rate, and to suggest why individuals become less active in warm weather.		
	Use a prepared OHT to explain how metabolism is regulated by the hypothalamus and its production of thyrotropin releasing hormone (TRH), which stimulates thyroid stimulating hormone (TSH) to secrete the hormone thyroxine. (Thyroxine increases the metabolic rate of all the body's cells; heat output is increased by this increase in metabolism.)	Prepare a suitable OHT.	
	Ask students to investigate, in pairs or small groups, the effect of an animal's size on heat loss by comparing the cooling rate of three similar-shaped glass flasks of different sizes that have been filled with warm water.	Use three round-bottomed flasks of different sizes, thermometers and a clock for this investigation.	
	Ask students to investigate the problems of heat balance faced by small babies.	Enquiry skills 11AB.3.1–11AB.3.3	
	Show students a video of human survival in hot and cold conditions. Ask them to research the library or the Internet in order to write an account of how people respond to extreme cold and heat, and survive hypothermia and heat exhaustion.	**ICT opportunities:** Use of video for illustration; use of the Internet.	
	Ask students to work in small groups to write a play about human survival in hot or cold conditions.		
2 hours **Oestrous cycle regulation** Describe the mammalian oestrous cycle and the roles of oestrogen, progesterone, LH and FSH.	Introduce this topic by telling students that the female mammal's reproductive physiology is a carefully synchronised series of events. The events occur in a cycle called the *sexual cycle* or *oestrous cycle*.		
	Ask students to use the library or the Internet to find out about the timing of reproductive behaviour in mammals. Get them to discuss the involvement of breeding seasons for some mammals and the differences in oestrous cycles between mammals.	**ICT opportunity:** Use of the Internet.	
	Show students an OHT diagram summarising the events of the human menstrual cycle: the cycle begins with the menstrual flow (menstruation), ovulation occurs on day 14, and if no fertilisation takes place the uterine lining breaks down again on day 28. The control of the cycle is regulated by hormones to ensure that the production of the ovum is synchronised with the readiness of the uterine lining to receive it, should it be fertilised. The set pattern of events is regulated by hormones from the pituitary gland and the ovaries. The control process is an excellent example of hormone interaction, with the production of one hormone leading to the stimulation or inhibition of another.	Prepare an OHT showing the human menstrual cycle.	
	Ask students to examine an OHT graph showing the fluctuating levels of the pituitary hormones (follicle-stimulating hormone (FSH) and luteinising hormone (LH) – also known as the gonadotrophic hormones) and the ovarian hormones (oestrogen and progesterone) during the oestrous cycle. Explain the sequence of events in the cycle.	Prepare a suitable OHT.	
	Give students a task sheet that outlines all the events of the oestrous cycle with key words missing; ask students to add the missing words.	Prepare task sheets.	
	Provide pairs of students with a series of cards, each containing a statement about an event in the oestrous cycle (e.g. 'the anterior pituitary gland starts to secrete FSH (follicle-stimulating hormone)', or 'the uterine lining becomes more vascularised'). Ask students to arrange these statements in the correct order. Alternatively, give students an A3-size graph summarising the events of the human menstrual cycle and ask them to place the cards on the relevant place on the graph.	Prepare suitable sets of cards.	

Objectives	Possible teaching activities	Notes	School resources
	Ask students to study and interpret data on the levels of hormones in the bloodstream of women over a monthly cycle and compare this with the levels of the same hormones in the bloodstream of pregnant women. Ask students to find out how a home pregnancy test works (the test detects another hormone present in pregnancy – human chorionic gonadotrophin (HCG) – which is secreted by the placenta and found in the urine). Ask students to use the library and the Internet to find out about the hormonal action of the female contraceptive pill. Ask students to use the library and the Internet to complete a table on birth control methods or contraception, such as sterilisation, prevention of ovulation, prevention of implantation, barriers that prevent sperm reaching an egg and natural methods. Tell them to give examples or outline details of each method's action, its advantages and its disadvantages.	Provide data for students. **ICT opportunity:** Use of the Internet.	
2 hours **Nervous and hormonal control systems** Describe the similarities and differences between nervous and hormonal control systems in mammals.	Introduce this topic by asking students to explain how the body's internal environment is kept constant. The recognition of the two coordinating systems – the nervous system and the endocrine (hormonal) system – will quickly be established. Ask students to work in pairs and provide each pair with a series of statements about the nervous and hormonal systems on cards. Ask them to sort the cards into sets of properties that are unique to each system and properties that are common to both systems. Discuss the results together as a class. Explain the similarities of both systems: • both involve the transmission of messages that are originated by stimuli and which produce responses; • both involve chemical secretion (neurotransmitters or hormones); • the hormone adrenaline is almost identical to the neurotransmitter substance noradrenaline from the sympathetic nervous system so has similar effects on the body's organs; • there is close cooperation between them with the hypothalamus acting to manage many of the hormone secretions of the pituitary gland. Explain the differences between the two systems: • the nature of the message – an action potential along a nerve fibre compared with a chemical messenger conveyed through the circulatory system; • speed of conduction of nerve impulses compared with hormones; • speed of response produced; • localised responses of nervous system compared with often widespread responses of hormones; • effector organs (e.g. muscles) are connected by nerves to the nervous system whereas target organs for hormones are only connected by the bloodstream; • short-lived responses in nervous system compared with often long-term responses of hormones; • nervous system involves irregular bursts of nerve impulses whereas hormones are often produced continuously at a steady trickle (e.g. growth hormone).	Prepare suitable sets of cards.	

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Explain the role of negative feedback in homeostasis by reference to the regulation of body temperature.*		
	Produce a table comparing the similarities and differences between the nervous system and the endocrine system.		
	Examine the following graphs; the top graph shows the variations in internal temperature (temperature of the hypothalamus) and skin temperature when the individual is given iced drinks at the intervals indicated; the middle graph shows evaporation through sweating over the same time period; the bottom graph shows heat lost by evaporation (sweating) over the same time period. Explain what the graphs show. 		
	Examine the graph of the hormones involved in the regulation of the oestrous cycle. Explain the control of the oestrous cycle.	Provide students with a suitable graph.	

GRADE 11A: Biology 4

Human gas exchange system and health

UNIT 11AB.4
9 hours

About this unit

This unit is the fourth of eight units on biology for Grade 11 advanced.

The unit is designed to guide your planning and teaching of biology lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For consolidation activities, look at the scheme of work for Grade 8.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already know the basic anatomy of the lungs and be able to describe the role of the lungs in breathing. They should know that inhaled air has more oxygen and less carbon dioxide than exhaled air, and that these gases are carried to and from the body's cells in blood vessels. They should also know why smoking affects health.

Expectations

By the end of the unit, students describe the features of the gaseous exchange system and relate these to function. They differentiate between tidal volume and lung capacity. They understand relationships between pulse rate and exercise and the importance of blood pressure. They understand the links between smoking and impairment of the gaseous exchange and cardiovascular systems. They know the nature of asthma, bronchitis, emphysema and lung cancer and how they affect the efficiency of gaseous exchange.

Students who progress further make in-depth studies of the human gas exchange system and research aspects of the associated health problems.

Resources

The main resources needed for this unit are:

- lungs or model lungs
- model thorax made from a bell jar, two balloons and a rubber sheet
- spirometer
- microscopes and prepared slides of anatomical structures
- video clips of lung structures and functions
- electronic blood pressure and pulse measuring meters
- exercise bike
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- gas exchange structures: *trachea*, *bronchus*, *bronchioles*, *alveoli*, *respiratory membrane*, *diaphragm*, *pleural membranes*, *thoracic cavity*, *external intercostals*, *internal intercostals*
- lung volumes: *tidal volume*, *expiratory reserve volume*, *inspiratory reserve volume*, *vital capacity*
- *spirometer*
- tobacco smoke: *carcinogens*, *tar*
- lung diseases: *chronic bronchitis*, *emphysema*, *asthma*, *lung cancer*
- blood pressure factors: *age*, *gender*, *size*, *weight*, *lifestyle*, *stress*, *activity*, *genetic make up*, *health*
- *pulse rate*

Standards for the unit

Unit 11AB.4

9 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
3 hours **The structure and function of the lungs**	8.7.1	Know the basic structure of the lungs and their role in gas exchange (breathing).	11A.10.1	Explain the structure, anatomy and function of the human lungs and related structures for gaseous exchange and the muscle and skeletal systems that enable breathing.	
	8.7.2	Know that inhaled air has more oxygen than exhaled air, and that exhaled air has more carbon dioxide than inhaled air.			
1 hour **Lung volumes**	8.7.3	Know that oxygen and carbon dioxide are carried round the body to and from cells in blood vessels.			
			11A.10.2	Differentiate between tidal volume and vital capacity of the lungs.	
1 hour **The effects of smoking**	8.7.4	Know that smoking damages the lungs and reduces the efficiency of gas exchange.	11A.10.3	Describe the effects of tar and carcinogens in tobacco smoke on the gaseous exchange system and the cardiovascular system.	
2 hours **Lung diseases**			11A.10.4	Describe the symptoms of chronic bronchitis, emphysema, asthma and lung cancer and their effects on the gaseous exchange system.	
2 hours **Exercise, pulse rate and blood pressure**			11A.11.1	Explain blood pressure and factors that affect it.	
			11A.11.2	Explain pulse rate and the effect of exercise on the pulse rate of fit and unfit individuals.	

Objectives	Possible teaching activities	Notes	School resources
3 hours **The structure and function of the lungs** Explain the structure, anatomy and function of the human lungs and related structures for gaseous exchange and the muscle and skeletal systems that enable breathing.	A demonstration of real lungs obtained from a butcher can be an interesting introduction to this subject. Demonstrate the position of the lungs and other associated organs in a model torso. Give students a diagram of the lungs with numbered arrows and ask them to identify the structures using their textbooks. Then ask them to annotate the diagram with a brief function for each labelled component. Get students to use their textbooks to provide more detailed information about lung structure and functions; ask them either to research and make notes on specific structures or to fill in missing key words on prepared handouts. Show students a video of lung structure and ask them to make notes for discussion. Get students to examine microscope slides of anatomical structures (e.g. trachea, alveoli) and ask them to make labelled diagrams identifying specific features.	Prepare copies of worksheets for students.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Demonstrate the principles of volume and pressure changes during breathing by inflating and deflating two balloons in an airtight bell jar that acts as a model thorax. Provide students with diagrams of the lungs and related structures, including associated muscle and skeletal parts, to label and use these to describe and explain the ventilation movements. Show students a video of the mechanism of breathing and ask them to make notes for discussion. Provide students with a table containing data comparing the percentage composition of inspired air, alveolar air and expired air, and ask them to explain the differences. This exercise will raise the issue of dead space air as part of the explanation.	A bell jar closed with a rubber sheet and containing two balloons is an excellent piece of apparatus for this demonstration. Prepare copies of worksheets for students.	
1 hour **Lung volumes** Differentiate between tidal volume and vital capacity of the lungs.	Provide students with a spirometer trace displaying all the lung volumes; ask students to label these volumes (tidal volume, expiratory reserve volume, inspiratory reserve volume and vital capacity) and determine typical average tidal volumes. Demonstrate the spirometer to students. One student needs to be the subject in order to provide data for the class on lung volumes. Ask students to set up and use the spirometer to record lung volumes. Ask students to perform calculations of volumes of air exchanged per unit time or volume of oxygen used per unit time to extend the range of useful information from the spirometer results. The following activity can be carried out as either a class activity or in small groups. You may or may not wish to demonstrate first. A simple (and entertaining) way to measure vital capacity is by displacing water from an upturned graduated bell jar resting on a beehive shelf in a large sink. Ask each student in turn to take a deep breath and blow air through a piece of tubing that has one end sited beneath the bell jar to displace the equivalent volume of water, which is then measured and recorded. The data can be compared with other data on the students' body size to see if there is any correlation.	Prepared spirometer traces are needed. **ICT opportunity:** Connect the spirometer to the computer for real-time online interactivity. Enquiry skills 11A.1.2, 11A.3.1, 11A.4.1 **Safety**: Tubing mouthparts must be sterile for each student. Water may be spilt on the laboratory floor – make sure no one slips.	

<table>
<tr><th>Objectives</th><th>Possible teaching activities</th><th>Notes</th><th>School resources</th></tr>
<tr><td>

1 hour

The effects of smoking

Describe the effects of tar and carcinogens in tobacco smoke on the gaseous exchange system and the cardiovascular system.

</td><td>

Use a simple home-made smoking machine to give a graphic demonstration of how much tar is produced by cigarettes. Tell students to observe and compare the amount of tar produced by different cigarettes by examining the colour of the cotton wool, or, more precisely, by weighing the cotton wool, before and after smoking.

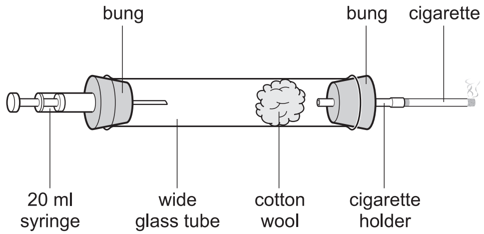
Allow students to research the Internet for the components of cigarette smoke and descriptions of the harmful effects of tar and carcinogens on the body.

Other possible activities for students on the harmful effects of smoking include:

- interview people about their smoking habits and present the data in a newspaper article;
- find and present evidence related to the possible effects of passive smoking;
- write a magazine article aimed at alerting young people to the health risks associated with smoking;
- produce an anti-smoking poster based on their research.

</td><td>

A smoking machine can be made using simple apparatus, such as a 20 ml syringe connected to a short length of wide glass tubing, which has a bung at the other end fitted with a piece of plastic tubing to act as a cigarette holder. Inside the wide glass tubing pack a small ball of absorbent cotton wool.



A simple smoking machine

ICT opportunity: Use of the Internet.

Enquiry skills 11A.1.6, 11A.2.2, 11A.3.4

</td><td></td></tr>
<tr><td>

2 hours

Lung diseases

Describe the symptoms of chronic bronchitis, emphysema, asthma and lung cancer and their effects on the gaseous exchange system.

</td><td>

Give a PowerPoint presentation to students using material downloaded from the Internet combined with materials you have produced.

Allow students to research the Internet or library to find information that enables them to describe the symptoms of chronic bronchitis, emphysema, asthma and lung cancer, and their effects on the gaseous exchange system.

Tell students to investigate one of the above lung diseases in detail and produce an illustrated account or a poster presentation to display to the other students.

Ask students to research the Internet or published health statistics to discover the incidence of lung diseases (e.g. lung cancer) in Qatar and compare this with data from other countries..

Show students graphs of the incidences of smoking related diseases correlated with the number of cigarettes smoked by individuals.

</td><td>

ICT opportunity: Use of the Internet.

</td><td></td></tr>
<tr><td>

2 hours

Exercise, pulse rate and blood pressure

Explain blood pressure and factors that affect it.

Explain pulse rate and the effect of exercise on the pulse rate of fit and unfit individuals.

</td><td>

Ask students to recall earlier work in Unit 10AB.4, concerning the circulatory system.

Let students work in pairs to use combined electronic blood pressure and pulse measuring meters to record systolic and diastolic values. Collate the figures on the whiteboard/OHT or Excel spreadsheet and discuss the values.

Provide students with a graphical display of the changing blood pressures in the systemic and pulmonary circulations and ask them to explain the patterns shown.

Invite a doctor or nurse to come and demonstrate blood pressure measurement using the mercury sphygmomanometer and explain the significance of blood pressure as an indicator of health.

Ask students to identify factors that influence blood pressure variations in individuals (e.g. age, gender, size, weight, lifestyle, stress, activity, genetic make up, health).

</td><td>

This relates to Standards 10A.9.2–10A.9.6.

</td><td></td></tr>
</table>

Objectives	Possible teaching activities	Notes	School resources
	Ask students to recall earlier work from Unit 10AB.4 and explain how pulse rate is produced. Discuss the factors contributing to differences in resting heart rate (e.g. heart size, genetic factors).	This relates to Standard 10A.9.3.	
	Ask students to work in pairs or small groups either to carry out a set investigation to determine the effect of a specific exercise (e.g. cycling on an exercise bike at a preset speed for a predetermined time) on the pulse rate, or to design their own experiment to determine the effect of exercise on the pulse rate of one or more selected athletes and non-athletes. Provide students with a table of results from the above investigation and ask them to analyse the data, drawing a graph and explaining the pattern produced. Ask students to explain the relationship between cardiac output, stroke volume and heart rate. Obtain data displaying differences in resting pulse rates between athletes and non-athletes. Give this to students and ask them to explain the data.	Enquiry skills 11A.1.3, 11A.3.2	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Explain how inspiration and expiration are carried out by the body.*		
	Use the accompanying spirometer trace to determine the tidal volume and vital capacity of the individual.	Provide students with an appropriate spirometer trace.	
	Make a list of the harmful effects on the body of smoking.		
	Explain the composition of inspired air, alveolar air and expired air by reference to the accompanying data.	Provide students with a suitable table.	
	A person has a resting stroke volume of 80 cm^3. They measure their pulse rate as 72 beats per minute. What is their cardiac output?		

GRADE 11A: Biology 5

Biological basis of inheritance

UNIT 11AB.5
11 hours

About this unit

This unit is the fifth of eight units on biology for Grade 11 advanced.

The unit is designed to guide your planning and teaching of biology lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already know and understand the structure and function of chromosomes and that chromosomes carry DNA. They should know that somatic cells have the diploid (2*n*) number of chromosomes and gametes the haploid number (*n*). They should know that sexual reproduction is a mechanism for passing genetic materials from one generation to another. They should understand why male and female gametes differ in size, number and motility. They should be able to identify causes of variation within populations and distinguish between continuous and discontinuous variation.

Expectations

By the end of the unit, students know the nature of homologous chromosomes. They describe mitosis and meiosis and recognise the chromosome configurations in different stages. They understand how mitosis enables a constant number of chromosomes to be passed from cell to cell while meiosis enables a constant number to be passed from generation to generation. They understand that changes in DNA bases cause variation. They know some causes of mutation. They understand that a mutation causes a change in DNA and that this can reduce the efficiency of or block an enzyme. They know the difference between genes and alleles and that they are sections of DNA. They understand how genetic variation occurs through allele segregation and chromosome cross-overs. They understand how sex is determined in humans and the mechanism of sex linkage. They understand the difference between dominant and recessive alleles and calculate genotype and phenotype frequencies in monohybrid crosses.

Students who progress further calculate the frequency of different progeny from a cross with incomplete dominant alleles, from back crosses and from dihybrid crosses. They understand co-dominance and the inheritance of phenotypic traits through multiple alleles. They use the chi-squared test to determine the significance of results of genetic crosses. They know about the Human Genome Project, genetic fingerprinting and genetic screening and counselling.

Resources

The main resources needed for this unit are:

- microscopes, slides of mitosis, meiosis and chromosome cross-overs
- overhead projector (OHP), whiteboard
- video camera attached to microscope with monitor
- video of mitosis, meiosis and DNA
- DNA model and simple modelling materials
- micrographs of mitosis and meiosis
- coloured push-fit beads
- coloured children's modelling clay
- sets of cards of stages of mitosis and meiosis and genetic definition
- fruit fly cultures, laboratory mice
- lily flowers (immature)
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *homologous chromosomes*, *chromatids*
- *mitosis*, *meiosis*
- *interphase*, *prophase*, *metaphase*, *anaphase*, *telophase*
- *bivalent*
- *mutation*
- *Human Genome Project*
- *gene*, *allele*, *phenotype*, *genotype*, *dominant*, *recessive*, *codominant*
- *segregation of alleles*, *crossing over*, *chiasmata*, *bivalent*
- *monohybrid cross,* Drosophila melanogaster
- *sex linkage*, *haemophilia*, *colour blindness*
- *Punnett square*
- *karyotype*

Objectives for the unit

11 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS	
2 hours **Understanding cell division by mitosis**	10A.12.1	Describe a chromosome and know that chromosomes carry DNA and that all somatic cells are diploid (2*n*), and have a double set of chromosomes, while gametes are haploid (*n*), having a half set of chromosomes.	11A.13.1	Explain the significance of organisms having a set of homologous chromosomes.		
			11A.13.2	Recognise and describe the behaviour of chromosomes during mitosis and explain how this enables a constant number of chromosomes to be passed from cell to cell.		
2 hours **Understanding meiosis**	10A.12.2	Know that sexual reproduction allows genetic material to be passed from one generation to the next and understand why the sex cells of males and females differ in size, number and motility.	11A.13.3	Recognise and describe the behaviour of chromosomes during meiosis and explain how this enables a constant number of chromosomes to be passed from generation to generation.		
2 hours **Understanding genetic inheritance**	10A.13.1	Identify environmental and genetic causes of variation and distinguish between continuous and discontinuous variation within a population.	11A.14.1	Know that a base sequence in a location on DNA forms a gene and that different functional base sequences at that location form alleles of that gene; know that differences in the base sequences of DNA of the individuals of a species result in variation.		
2 hours **Understanding genetic inheritance**	10A.11.3	Know that the base sequence on DNA forms the genetic code and is passed from generation to generation.	11A.14.2	Know some causes of mutation and that a mutation is a change in the base sequence of DNA that can lead to changes in protein structure, which in turn can reduce the efficiency of or block an enzyme action.		
			11A.14.3	Explain the terms *gene*, *allele*, *phenotype*, *genotype*, *dominant*, *recessive* and *co-dominant*.		
2 hours **Variation through meiosis**			11A.14.4	Use genetic diagrams to solve genetic problems involving monohybrid crosses.	12A.12.1	Calculate the ratios of the genotypes and phenotypes in the progeny of incomplete dominant monohybrid crosses, dihybrid crosses (9:3:3:1 ratio) and back crosses.
1 hour **Sex determination and linkage**					12A.12.3	Use the chi-squared test to determine the significance of observed and expected frequencies of different progeny in genetic crosses.
	10A.13.1	Identify environmental and genetic causes of variation and distinguish between continuous and discontinuous variation within a population.	11A.14.5	Explain how variation occurs through segregation of alleles during gamete formation and through the crossing over of chromosome segments during meiosis.		
			11A.14.6	Know how X and Y chromosomes determine sex in humans and the inheritance pattern of sex-linked characteristics.		

Objectives	Possible teaching activities	Notes	School resources
2 hours **Understanding cell division by mitosis** Explain the significance of organisms having a set of homologous chromosomes. Recognise and describe the behaviour of chromosomes during mitosis and explain how this enables a constant number of chromosomes to be passed from cell to cell.	Introduce this topic by having a quiz to reinforce previous knowledge and consolidate the chromosome work completed in Unit 10AB.7. Discuss with students why the genetic information is organised into chromosomes in the cell. Ensure they appreciate that the genome is only manageable for cell division because the genes are packaged into discrete paired structures – homologous chromosomes. Replication and distribution of so many genes is only made possible by the possession of homologous chromosomes.		Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Ask students to work in pairs. Give each individual in a pair the same number of different coloured push-fit beads. Ensure that each has the same number of each colour. Different pairs can have different numbers of beads. Tell them each bead represents one gene. Now ask each student to make one chromosome using the beads. When they have finished, ask each pair to compare their chromosomes. Are they alike? Are they homologous? Discuss the need for cells to have homologous chromosomes: it enables the total complement of genetic information to be passed from cell to cell without omission or duplication in mitosis. Finish the exercise by asking students to produce homologous pairs of chromosomes and then collect them together to discuss the class results.	Enquiry skill 11A.3. 4	
	Use the chromosomes made from the beads to simulate the behaviour of chromosomes in different stages of mitosis. Ask students, working in groups of four, to show their chromosomes in one of the stages of mitosis. For example, the first group could illustrate chromosome behaviour in prophase, the second group metaphase, the third group anaphase. Then gather the whole class together around each stage in turn and ask a spokesperson from each group to explain the significance of the chromosome behaviour displayed.	Enquiry skill 11A.3. 4	
	Tell students to use their textbooks to find out how many chromosomes are in each cell of their body. Clarify which cells they are referring to and ensure they are all familiar with the difference between somatic cells and gametes (Standard 10A.12.1).		
	Ask students to explain why somatic cells (all body cells except the reproductive cells) have a double set of chromosomes. Ensure they understand that one set is inherited from each parent.		
	Let students, working singly or in pairs, observe human cells or cells from other organisms under the microscope to view the chromosomes.	Students will need microscopes and prepared slides of cells showing chromosomes.	
	Show students micrographs of the human karyotype and discuss their observations.		
	Show students fruit flies (*Drosophila melanogaster*) in a tube. A diagram of fruit flies would be a less effective alternative. Ask students whether they know how many chromosomes the fruit fly has. Use this example to introduce the concept of the number of chromosomes varying with species. To confirm this point, ask students to find out the number of chromosomes of a range of different organisms using the library or Internet. Discuss their findings later.	**ICT opportunity:** Use of the Internet.	

Objectives	Possible teaching activities	Notes	School resources
	Discuss with students the importance of cell division. Emphasise that the ability of organisms to reproduce their kind is the one phenomenon that best distinguishes life from nonliving material. (An analogy using the photocopier is useful here. The cell not only replicates itself, it also replicates the mechanism of replicating itself. It is as if when you copy something on a photocopier, you make not just a copy of what is on the paper but of the photocopier too!)		
	Show students a video of the process of mitosis in time-lapse to ensure they appreciate it is a continuous process and do not think of it as a set of discrete events because of association with the still pictures that are commonly used to describe the main stages of the process. Provide each pair of students with an A3-size sheet of paper with an outline of the shape of cells in each stage of mitosis in the correct sequence. Ask students either: • to colour and cut out a pair of homologous chromosomes (in paper, card or OHT) and stick them on the diagrams to show the chromosomes' behaviour through a mitotic cycle; or • to draw in the details themselves for one pair of chromosomes or, for the quicker students, two or more pairs of chromosomes. Ensure students appreciate that each chromosome consists of two chromatids containing duplicated DNA. The faithful replication process in interphase has resulted in the successful production of a complete new set of duplicated genes. Accurate copying ensures the continuity of the genetic line. Let students make model chromosomes using children's modelling clay. Help students to produce their own video of the process of mitosis. They could use time-lapse photography to produce an animation showing the movement of their model chromosomes/chromatids.	Students will need modelling clay in different colours. **ICT opportunity:** Use of video and time-lapse photography. Enquiry skill 11A.3.4	
2 hours **Understanding meiosis** Recognise and describe the behaviour of chromosomes during meiosis and explain how this enables a constant number of chromosomes to be passed from generation to generation.	Show students a video of the process of meiosis in time-lapse to ensure they appreciate it is a continuous process and do not think of it as a set of discrete events because of association with the still pictures that are commonly used to describe the main stages of the process. Stop the video at strategic points to explain what is happening or to ask students questions about what is happening. Ask them to explain how meiosis is different from mitosis. Compare and contrast the unique behaviour of chromosomes in the earliest phase of meiosis, first prophase, producing bivalents, compared with the prophase of mitosis. Show the class a series of photographs (temporarily numbered) of the process of meiosis which have been arranged in the correct order. Discuss the details by showing the same photographs as OHT slides. Mix up a sequence of photographs of meiosis and add numbers to these; ask students, working in pairs, to write down the correct sequence of numbers. Ask students to produce a flow chart of the process of meiosis. Ask students to match statements about meiosis with the specific stage of meiosis by having two sets of cards: one set of the stages and another set with the statements (e.g. statements such as 'homologous chromosomes form a bivalent', 'homologous chromosomes separate').	Printed photographs and OHT slides of the stages of meiosis are required. Enquiry skill 11A.3.4 Prepare suitable sets of cards on meiosis. Enquiry skill 11A.3. 4	

Objectives	Possible teaching activities	Notes	School resources
	Ask students to produce a poster (working individually) or a wall chart (working in pairs or small groups) of the process of meiosis.		
	In this activity students use chromosomes made from beads to simulate the behaviour of chromosomes in different stages of meiosis. Ask students, working in groups of four, to show their chromosomes in one of the stages of meiosis. For example, the first group could illustrate chromosome behaviour in prophase I, the second group metaphase I, the third group anaphase I. Then gather the whole class around each stage in turn and ask a spokesperson from each group to explain the significance of the chromosome behaviour displayed. Alternatively, ask each group of students to show the chromosome behaviour at the same stage of meiosis in turn and compare the results at each stage.	Provide the same mixtures of coloured push-fit beads to each pair of students.	
	Instead of using coloured beads, you could ask each group of students to make model chromosomes from children's modelling clay and demonstrate the behaviour of chromosomes in meiosis.	Students will need modelling clay in different colours. Enquiry skill 11A.3. 4	
	Help students to produce their own video of the process of meiosis. They could use time-lapse photography to produce an animation showing the movement of their model chromosomes/chromatids.	**ICT opportunity:** Use of video and time-lapse photography. Enquiry skill 11A.3. 4	
	Let students, working individually or in pairs, use microscopes to examine the stages of meiosis under high-power magnification. Ask them to record different stages of meiosis. Use a video camera attached to the microscope to demonstrate the slide on a monitor.	Students will need microscopes and a suitable slide (e.g. squashed locust testis sample, or section of rat testis).	
	Explain to students how the first meiotic division results in the reduction of the chromosome number by half and also how the random assortment of chromosomes results in the production of genetic variation in the gametes. Meiosis results in gametes that have half the number of chromosomes and possess a unique genotype. The production of such gametes by meiosis enables a constant number of chromosomes to be passed on from generation to generation.		
	Ask students to write down why meiosis is such an important process in life. Also ask them to draw and annotate a simplified human life cycle to illustrate and explain the involvement of both meiosis and mitosis in the life cycle.		

Objectives	Possible teaching activities	Notes	School resources
2 hours **Understanding genetic inheritance** Know that a base sequence in a location on DNA forms a gene and that different functional base sequences at that location form alleles of that gene; know that differences in the base sequences of DNA of the individuals of a species result in variation. Know some causes of mutation and that a mutation is a change in the base sequence of DNA that can lead to changes in protein structure, which in turn can reduce the efficiency of or block an enzyme action.	Reinforce previous knowledge by giving students a quiz on DNA structure and replication. Ask students to work individually to make a model of DNA using everyday materials (e.g. paper, cardboard, wire). Involve the class in a cooperative project in which they each produce a short length of DNA that are then joined together to form a longer length of DNA. Discuss the DNA model and use it to identify individual genes and gene loci. If you ask two or more individuals to make a DNA model consisting of the same number of bases but differing by only one base pair in the sequence you will have other possible options. • Students could use these DNA model sections to represent alleles at the same gene locus. Discuss the significance of alleles in producing genetic variation. Discuss an example of multiple alleles, such as blood groups involving A, B and O alleles, with the class. • Students could use these DNA model sections to represent a gene mutation. Discuss the significance of this mutation with the class. In particular, a change in the DNA results in genetic variation. Recall work in Unit 10AB.1 on protein synthesis. Give examples of gene mutations involving a single base difference (e.g. sickle cell gene).	Review Unit 10AB.6 concerning the structure and function of DNA. Students will need a variety of modelling materials (e.g. coloured paper, cardboard, wire, scissors, glue). Enquiry skill 11A.3.4	
	Provide each student with a DNA sequence of the coding strand of at least 30 bases. Also provide them with a chart of mRNA triplet base codes for amino acids and ask them to work out the amino acid sequence. Discuss students' answers. Next, tell students to change just one base in the DNA sequence and carry out the same determination of the amino acid sequence. Discuss the results. Determine whether such a base change in the cell would be likely to be beneficial or harmful. Assuming this DNA was coding for an enzyme, discuss the possible outcome of this base change with students. For example, the incorrect amino acid in the protein may result in the incorrect shape of the active site of the enzyme. (The tertiary shape of the protein/enzyme may be altered: see Unit 10AB.1.) The outcome of such a mutation therefore may prevent or significantly reduce enzyme action.	Find a chart of mRNA triplet base codes for amino acids. The students' textbook may contain this.	
	Demonstrate using the OHP. Cut out OHT templates of DNA nucleotides and use them as building blocks to illustrate the structure of DNA base pairing. You can then substitute a single base pair to represent the incorrect mutated sequence to compare with the 'normal' DNA. Discuss and explain the illustrations you are demonstrating.	Prepare OHT templates of DNA nucleotides.	
	Ask students to use their textbooks and the library or Internet to discover some of the causes of mutation. Suggest that, individually, they research the Internet to find out the causes of mutations and the incidence of cancers in specific case studies. For example: • radiation leakages (e.g. the incidences of cancers at and around Chernobyl); • use of chemicals such as dioxins (Agent Orange in the Vietnam war).	**ICT opportunity:** Use of the Internet. Enquiry skill 11A.1.8	
	Ask students, working individually, to produce a poster of the structure of DNA. For example, they could show a piece of normal DNA and then add a diagram illustrating a mutated portion of the same DNA after exposure to an environmental hazard. Mutation, the cause of genetic variation, could be illustrated and its outcome explained by the impaired synthesis of proteins.	Enquiry skill 11A.3.4	
	Show students a model and a video of the structure of the DNA molecule.		
	Ask students to use their textbooks and the library or Internet to find out about the human genome and write a brief report on the Human Genome Project. Discuss the Human Genome Project in class.	**ICT opportunity:** Use of the Internet.	

Objectives	Possible teaching activities	Notes	School resources
2 hours **Understanding genetic inheritance** Explain the terms *gene, allele, phenotype, genotype, dominant, recessive and co-dominant* Use genetic diagrams to solve genetic problems involving monohybrid crosses.	Explain the terms *gene*, *allele*, *phenotype*, *genotype*, *dominant*, *recessive* and *co-dominant*. Consolidate this information by getting students to take part in the 'loop game'. In the loop game, each student is given one card with a question on one side and an answer to a different question on the reverse side. Student A starts the proceedings by reading the question to the class. Other students must decide which of them has the card with the correct answer to this first question. This student, student B, raises the card in the air and is then asked to read their answer out to the class. The other students listen and decide whether the answer is correct by raising their hands when asked whether they agree with student B. The teacher confirms the answer and then student B reads out the next question. The game continues until all the definitions have been successfully established.	Prepare cards with questions on definitions on one side and answers to a different question on the reverse side. Make sure that the questions and answers are arranged so that a single loop uses all the cards no matter which card is used first.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Construct a quiz in which teams of students write correct and incorrect definitions of terms and ask other teams to select the correct one.		
	Demonstrate the use of genetic diagrams to solve genetic problems involving monohybrid crosses. Then put some incomplete genetic diagrams displaying just the phenotypes of the parents and offspring on the board or OHP and ask students to add the appropriate alleles; for example: • problems concerning a genetic disorder caused by a recessive characteristic (e.g. cystic fibrosis); • problems concerning a genetic disorder caused by a dominant characteristic (e.g. Huntington's disease). Demonstrate a Punnett square for one or two examples of monohybrid crosses. Get students to complete Punnett squares for other examples. Make sure students appreciate the difference between ratios and probabilities. For example, in monohybrid crosses a ratio of 3 to 1 is a probability of 1 in 4 (for a homozygous recessive).		
	Show and explain to students the classic genetic experimental crosses carried out by Gregor Mendel. Encourage them to use the library or the Internet to find out about the life and work of Mendel. Get them to rework Mendel's data from experiments with peas and discuss the certainty of the conclusions.	**ICT opportunity:** Use of the Internet. Enquiry skill 11A.3.3	
	Get students to carry out breeding investigations using either fruit flies or mice. These animals show clear phenotypic differences and so these features can be used to track the pattern of inheritance of characteristics in successive generations. If using fruit flies, explain the life cycle to students using live fruit flies and OHT diagrams. Get students to use binocular microscopes to examine the range of fruit flies' phenotypes to be investigated in the breeding experiments (e.g. normal long wings or short vestigial wings). Make sure students can handle and sex the fruit flies before the experiments begin. Ask students, working in pairs, to predict the outcome of their selected crosses and to check the progeny for confirmation and discussion. Tell them to draw diagrams to illustrate the inheritance of alleles through generations.	Cultures of the fruit fly, *Drosophila melanogaster*, and laboratory mice are readily available from educational suppliers. Binocular microscopes are required to see fruit flies most clearly. Enquiry skills 11A.1.2, 11A.3.1	

Objectives	Possible teaching activities	Notes	School resources
2 hours **Variation through meiosis** Explain how variation occurs through segregation of alleles during gamete formation and through the crossing over of chromosome segments during meiosis	Explain how variation occurs through segregation of alleles during gamete formation and through the crossing over of chromosome segments during meiosis. Use the whiteboard or OHT diagrams as well as bead models to help illustrate the process.		
	Ask students, in pairs, to make chromosomes from coloured push-fit beads (or from children's modelling clay) and simulate the behaviour of chromosomes in different stages of meiosis, resulting with the formation of gametes. Get students to use coloured push-fit beads (or children's modelling clay) to show the events of the first meiotic prophase in detail. Make sure they fully appreciate how important the events here are for establishing one of the causes of genetic variation: crossing over of chromosomes with chiasmata formation. Also emphasise bivalent formation as an important and unique feature of meiosis. Bring all student pairs together with their chromosomes arranged as bivalents with at least one cross-over in each. Ask them to arrange their chromosomes on a bench as if the chromosomes were all from the same cell undergoing their first metaphase of meiosis. Use this model to discuss the independent assortment and segregation of chromosomes to create genetic variation in the gametes. Now separate the chromosomes as if they were undergoing the first anaphase of meiosis.	Students will need: coloured push-fit beads and/or coloured children's modelling clay. Enquiry skill 11A.3.4	
	Let students, working individually or in pairs, use microscopes to examine prepared slides of the stage of crossing over in meiosis under high-power magnification. Ask them to record their observations in diagrams. Use a video camera attached to the microscope to demonstrate the slide on a monitor. Alternatively, let students, working individually or in pairs, examine the stage of crossing over in meiosis of the immature anthers of lily flowers under high-power magnification.	Students will need: microscopes and prepared slides showing crossing over in meiosis or immature lily flowers.	
1 hour **Sex determination and linkage** Know how X and Y chromosomes determine sex in humans and the inheritance pattern of sex-linked characteristics.	Give pairs of students large diagrams of human karyotypes – one male and one female. Ask them to cut out the chromosomes and match them into their homologous pairs. Then ask them to compare the karyotypes and reach conclusions about differences between the sex chromosomes. Discuss these conclusions with the whole class. Ask students to make models of the X and Y chromosomes using push-fit beads. Then use these models to explain gamete formation and also possible combinations in fertilisation. Also use the models as a basis for explaining the production of equal numbers of males and females. Get students to produce Punnett squares for these combinations of gametes. Let students use binocular microscopes to examine the fruit flies in the breeding experiments described above; ask them to count the numbers of male and female flies to support the discussion on equal numbers of each. Let students examine prepared slides of human X and Y chromosomes under high-power magnification. Ask them to record their observations in diagrams. Use a video camera attached to the microscope to demonstrate the slide on a monitor.	Students will need coloured push-fit beads. Enquiry skill 11A.3.4 Binocular microscopes are required to see fruit flies most clearly.	

Objectives	Possible teaching activities	Notes	School resources
	Present students with a human case study on colour blindness to explore the topic of sex-linkage. Show students a family tree displaying individuals who are colour blind and ask them to explain why more males are colour blind than females. Encourage them to illustrate their explanation by using different coloured beads for the alleles or, alternatively, by genetic diagrams and symbols and constructing a Punnett square. Get them to explain the whole family tree shown, indicating which individuals are carriers and which are sufferers, where this is possible.	Data from the earlier fruit fly breeding investigation can be used here. Students will need: microscopes and prepared slides of human X and Y chromosomes.	
	Challenge students with different parental scenarios of males and females as carriers or sufferers of colour blindness. Ask them to determine the situation that produces a female colour-blind baby.		
	Repeat the above case study with another sex-liked condition of a more serious nature: haemophilia.		
	Ask students to use the library or the Internet to find out about haemophilia and write a report about its occurrence. Get them to find out how common haemophilia is in Qatar (from the Qatar government health statistics) and what problems such individuals face in everyday living.	**ICT opportunity:** Use of the Internet.	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Draw labelled diagrams showing the behaviour of a pair of homologous chromosomes in:* a. *metaphase of mitosis;* b. *metaphase of meiosis.*		
	Describe how the behaviour of chromosomes in the first prophase of meiosis may lead to a halving of the chromosome number and genetic variation.		
	Arrange the accompanying micrographs of mitosis in the correct order and label the stages.	Supply suitable micrographs.	
	Explain the relationship between DNA, genes, alleles and variation.		
	a. *What is a mutation? Describe some of the causes of mutation.* b. *Explain how a mutation may cause a problem for enzyme action.*		
	Outline the importance of (a) mitosis and (b) meiosis in the human life cycle. Explain where and when the processes occur and what role each has in human health and/or survival.		
	Explain how meiosis creates genetic variation by drawing illustrated diagrams to show the behaviour of two pairs of homologous chromosomes.		
	a. *What is sex linkage?* b. *Explain why more men suffer from haemophilia than women.* c. *Explain the genetics of the following situation: neither of the parents suffers from haemophilia but they produce a baby with haemophilia.*		

GRADE 11A: Biology 6

Evolution by natural selection

UNIT 11AB.6
4 hours

About this unit

This unit is the sixth of eight units on biology for Grade 11 advanced.

The unit is designed to guide your planning and teaching of biology lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already know that species are clustered into groups. They should know about the hierarchy of classification and the key features of the kingdoms and main phyla of animals and plants

Expectations

By the end of the unit, students understand that predation, disease and competition result in differential survival rates and reproduction, and that organisms with a selective advantage are more likely to survive and pass on genes to the next generation, that natural selection and isolation can lead to new species, and that evolution over a long period of time has given rise to the diversity of living organisms.

Students who progress further know how some organisms are structurally and physiologically adapted to their environment and distinguish between acclimatisation and adaptation. They understand ecological colonisation and succession.

Resources

The main resources needed for this unit are:

- overhead projector (OHP), whiteboard
- pictures of a variety of organisms
- videos of wildlife in an African reserve and on the Galapagos Islands
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *evolution by natural selection*, *speciation*
- *palaeontology*

Objectives for the unit

4 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade11 standards		EXTENSION STANDARDS
1 hour **Natural selection of individuals**			11A.15.1	Know that predation, disease and competition within a population result in the survival and reproduction of the strongest individuals and that this natural selection allows the inheritance of their characteristics.	12A.13.1	Explain examples of structural and physiological adaptations of animals to their environment.
2 hours **Natural selection, speciation and diversity**	10A.14.1	Understand the term *species*, know that species can be placed in groups with shared features, and that the groupings of kingdom, phylum, class, order, family, genus and species form a hierarchy of classification.	11A15.2	Know that natural selection and breeding isolation can lead to speciation.	12A.13.2	Distinguish between the permanent adaptation of an organism to its normal environment and the temporary acclimatisation of a visitor.
	10A.14.2	Know the distinguishing features of the five kingdoms: Prokaryotae, Fungi, Protoctista, Plantae and Animalia.	11A.15.3	Explain how natural selection and evolution over a long period of time have resulted in a great diversity of forms among living organisms.		
1 hour **Adaptation to environment**	10A.14.3	Use knowledge of the key features of the major phyla of animals and plants to recognise a typical member.	11A.15.4	Give examples and explanations of how organisms are adapted to survive in particular environmental conditions.	12A.14.3	Describe the progression of the development of an ecological community from primary colonisation to climax community.

Objectives	Possible teaching activities	Notes	School resources
1 hour **Natural selection of individuals** Know that predation, disease and competition within a population result in the survival and reproduction of the strongest individuals and that this natural selection allows the inheritance of their characteristics.	Introduce natural selection by using familiar examples so that students become immediately involved. Animals are the most easily observed and familiar organisms for most students. Ask them, for example: • Have you seen a duck nesting in the local park or pond? • How many young did it produce? • What has happened to those young birds? • Why aren't we overrun with ducks when they reproduce so many young? Alternatively, show a video of predators and prey in an African wildlife reserve. Discuss the role of predators. Make sure students appreciate that predation is essential in maintaining stable populations of the strongest individuals. Reinforce previous knowledge on animal populations, including predator–prey interactions as well as inter- and intra-specific competition for food and space, by using further examples. Ask students how territorial behaviour helps natural selection. The territorial behaviour of animals, for example, deprives the weaker individuals of food and a suitable breeding location, leading to the loss of these genes from the gene pool. Ask students how disease helps natural selection. Tell them about rabbits and myxomatosis. Explain that 1% of the rabbits survived the disease – these were the resistant rabbits and so they became the naturally selected individuals for the future generations. Get students to find out about the work of Darwin and Wallace from the library. Discuss their findings in class and then ask them to write a report on the theory of evolution by natural selection.		
2 hours **Natural selection, speciation and diversity** Know that natural selection and breeding isolation can lead to speciation. Explain how natural selection and evolution over a long period of time have resulted in a great diversity of forms among living organisms.	Having introduced Darwin and Wallace in the earlier discussion, use this to provide a starting point to discuss how new species have evolved. Show students a video of the Galapagos Islands, including film of the unique fauna found there: the finches (Darwin's finches), the giant tortoises and the iguanas in particular. Use these animals to discuss isolation and speciation. Involve students in a discussion of the unique fauna of the Australian continent, which is another excellent example of isolation and speciation. Make sure the discussion includes the predominance of marsupials and the ecological niches they occupy, and compare these with the placental mammals of Asia or Africa. Hold a class debate in which teams of students put forward scientific evidence for and against the theory of evolution by natural selection. Ensure evidence is presented from scientific observations in: geographical distribution of organisms, comparative anatomy, molecular biology, embryology, taxonomy and palaeontology. Students could select or be allocated a specific piece of evidence to research to bring to the debate.		

Objectives	Possible teaching activities	Notes	School resources
	Get students to compare the Darwin–Wallace theory of natural selection with the theory of Lamarck, who proposed that evolutionary change could be achieved by the transmission of acquired characteristics. This could be part of the debate on evolution. Emphasise the mass of evidence in support of the Darwin–Wallace theory and the lack of support for Lamarck's ideas. The overwhelming direct evidence of natural selection comes from the fossil records, which provide a trace of evolutionary pathways over millions of years. Show students examples of fossils and/or visit a museum to see exhibits of fossils.	Provide specimens of fossils. **Visit opportunity:** Visit a natural history museum.	
1 hour **Adaptation to environment** Give examples and explanations of how organisms are adapted to survive in particular environmental conditions.	Select some examples of animals from a variety of environments and ask students to write a list of the ways the animal is adapted to its particular environment (e.g. polar bears or seals in the Arctic, whales or sharks in the oceans, swifts or swallows in the air of many continents, zebras or lions in the tropical savannah). Similarly, select some plants from a variety of environments and carry out the same exercise (e.g. aquatic plants such as water lilies, marginal plants such as reeds, marram grass (*Ammophilia arenaria*) of sand dunes, succulents and cacti of deserts). Present students with pictures of specific organisms and ask them to match these to descriptions of their adaptations for living in their natural habitat.	Provide a set of pictures of a variety of specific organisms and a separate set of descriptions of their adaptations.	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*How does the innate territorial behaviour of a bird help to ensure the survival of the species?*		
	Suggest a possible way the unique fauna of Australia may have arisen.		
	Give alternative explanations that might have been given by Lamarck and Darwin to explain the giraffe's long neck.		
	Explain the adaptations shown by the crocodile that have enabled this animal to survive as a species for many millions of years.		

GRADE 11A: Biology 7

Ecological relationships and populations

UNIT 11AB.7
6 hours

About this unit

This unit is the seventh of eight units on biology for Grade 11 advanced.

The unit is designed to guide your planning and teaching of biology lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already understand how energy flows through an ecosystem. They should be able to relate pyramids of numbers, biomass and energy to food chains and food webs. They should know the roles of micro-organisms in recycling and how they function in the carbon and nitrogen cycles. They should know that the nitrogen-fixing micro-organisms in root nodules have a mutualistic relationship with the host plant.

Expectations

By the end of the unit, students understand that predation, disease and competition result in differential survival rates and reproduction. They understand that ecosystems are dynamic and subject to change, and that human activities have an impact on the environment.

Students who progress further know how some organisms are structurally and physiologically adapted to their environment and distinguish between acclimatisation and adaptation. They understand carrying capacity of a habitat and can use population curves. They understand ecological colonisation and succession. The know examples of biological control of unwanted organisms. They distinguish between environmental preservation and conservation and understand the conflicts between nature conservation and production.

Resources

The main resources needed for this unit are:

- overhead projector (OHP), whiteboard, video recorder
- computer simulation of predator–prey relationship
- computer spreadsheet
- plant pots (75 mm), compost, radish seeds
- video clip about animals defending their territory
- OHT graphs and tables of a variety of data
- photographs of the Amazon rainforest
- maps of lichen distribution
- water sampling nets, white trays, specimen bottles
- identification keys for organisms of rivers, ponds and canals
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *intra-specific competition*, *inter-specific competition*
- *ecological niche*
- *competitive exclusion principle*
- *myxomatosis*, Yersinia pestis
- Locusta migratoria, Schistocerca gregaria
- *balance of nature*
- *desertification*
- *global warming*
- *acid rain*, *ozone layer*
- *eutrophication*

Objectives for the unit

Unit 11AB.7

6 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS	
2 hours **Interactions between organisms**			11A.16.1	Explain examples of a predator–prey relationship and the possible effects on the population size of both the predator and the prey.		
			11A.16.2	Explain examples of inter- and intra-specific competition for food and space and the effects on the distribution and size of the populations of organisms.		
			11A.16.3	Explain how disease affects the size of population of organisms and the significance of limiting factors in determining the ultimate size of a population.	12A.14.1	Explain and give examples to illustrate the carrying capacity of an environment.
2 hours **Ecosystems are dynamic**	10A.15.1	Describe how the organisms in a pyramid of numbers relate to their biomass and to energy flow through food chains and food webs.	11A.16.4	Explain how the diversity and numbers of organisms and the environmental factors in an ecosystem form a dynamic relationship that is open to disruption.	12A.14.2	Know how to construct and interpret population curves for different organisms; identify the stages in population growth and decline.
	10A.15.2	Draw energy-flow diagrams to illustrate how energy flows through an ecosystem.			12A.14.1	Explain and give examples to illustrate the carrying capacity of an environment.
2 hours **Impact of human activities**			11A.16.5	Explain examples of short- and long-term human impact on a variety of environments.		

<table>
<tr><th>Objectives</th><th>Possible teaching activities</th><th>Notes</th><th>School resources</th></tr>
<tr><td>2 hours

Interactions between organisms

Explain examples of a predator–prey relationship and the possible effects on the population size of both the predator and the prey.

Explain examples of inter- and intra-specific competition for food and space and the effects on the distribution and size of the populations of organisms.</td><td>Provide students with a graph of two population curves displaying the relationship between populations of a predator and its prey. Display the same graph on the OHP. Well-documented records exist for the relationship between populations of the Canadian lynx (predator) and the snow hare (its prey). However, other suitable examples can be substituted or used in addition (e.g. fox (predator) and rabbit (its prey), or zooplankton (predator) and phytoplankton (prey)).

Ask students, in pairs, to analyse and interpret the population curves and write their explanation. Invite one or two students to read out their answers to the class. Confirm that they explain the cyclic repetitive nature of peaks and troughs which are slightly out of phase. (The prey, as the food, begins to increase its population before the predator follows with a similar pattern. Then the prey decreases because of increased predation before the predator population falls after experiencing a food shortage. The cycle is then repeated.)</td><td>Prepare a suitable graph and OHT.</td><td>Use this column to note your own school's resources, e.g. textbooks, worksheets.</td></tr>
<tr><td></td><td>Use a computer simulation of a predator–prey interaction. These simulations allow students to alter the parameters of the relationship. For example, the simulation could be set with an increased number of predators or prey and the effects observed. If students work individually on their own computer, this gives the opportunity to investigate a wide range of variables.

Let students discuss, in pairs, what they understand by the term competition between organisms. Then regroup and organise a class discussion. Clarify the terms inter-specific and intra-specific competition as well as identifying the main factors involved in such competition: food and space.

Arrange for students to carry out a practical exercise on intra-specific competition investigating the density of seed planting on the productivity of plants. Organise students into pairs and tell them to carry out the following procedure.
• Fill five small plant pots of the same size with the same quantity of compost.
• Take some radish seeds and plant an increasing number of seeds per pot: one, two, four, six, eight seeds per pot, for example.
• Keep them in a warm light place for three to four weeks, watering carefully with the same amount of water in each pot.
• When young radishes are produced, harvest, wash, dry and weigh them.
• Record data in a table.</td><td>ICT opportunity: Use of a computer simulation to investigate a dynamic relationship.</td><td></td></tr>
<tr><td></td><td>• Collate results with those of other pairs of students by using a computer spreadsheet to record the data.

Tell pairs to enter their results in turn as they finish and then give each student a copy of all the data later.</td><td>ICT opportunity: Use of a spreadsheet to enter data from an investigation.</td><td></td></tr>
</table>

Objectives	Possible teaching activities	Notes	School resources
	Show students a video clip about animals defending their territory. Ask students to study how the animals behave in the defence of their territory. Stop the video at intervals to discuss the behaviour. Birds show both intra-specific and inter-specific territorial behaviour that can be easily observed. Such behaviour includes bird song, chasing away competitors or even fighting for control of their territory. Get students to talk about their own observations of birds' territorial behaviour, either in the school grounds or surrounding area or in their gardens. Encourage them to keep a diary of bird behaviour over a defined time period.	Enquiry skill 11A.3.1	
	Give some examples of animals whose population sizes fluctuate rhythmically. For one case study, get students to use the library or the Internet to investigate the lemming, a rodent found in the Arctic and sub-Arctic whose population size has four-yearly peaks. Ask students to draw graphs to show trends and use this to stimulate a teacher-led class discussion. Ask students to write a report after the discussion. Get students to produce a flow chart of the events in the fluctuations of lemming populations.	**ICT opportunity:** Use of the Internet.	
	Arrange students into teams and allocate each an 'invading species' (e.g. the crown of thorns starfish, which predates upon sea urchins, or the water hyacinth, which has invaded African lakes and waterways). Get each team to use the library or the Internet to gather information on their species. Tell teams to use the information to prepare and make a presentation on their invading species to the rest of the class.	**ICT opportunity:** Use of the Internet.	
	Introduce students to two key concepts in understanding ecological relationships: • the ecological niche; • the competitive exclusion principle. Tell students to find out about these key concepts from their textbooks or from the library. Discuss with students the importance of laboratory investigations: in particular, the classic experiments of the Russian biologist Gause in 1934 on competition between several species of *Paramecium*. Tell students to find out about Gauss's work using the library or the Internet. It was these investigations by Gause that led to the competitive exclusion principle.	The ecological niche is a precise description of all the physical, chemical, and biological factors that a species needs to survive and reproduce. The competitive exclusion principle states that 'no two species in the same ecosystem can occupy the same ecological niche indefinitely'. **ICT opportunity:** Use of the Internet. Enquiry skill 11A.2.1	
	Another example of the competitive exclusion principle is provided by the introduction of the grey squirrel into the UK from North America. Give students details of the data on the introduction of the grey squirrel to the UK and ask them to explain the population changes of the grey and red squirrels.	Source details on the populations of the grey and red squirrels in the UK from the Internet. The red squirrel was the only squirrel species living in the UK for thousands of years. Although the grey squirrel does not attack the red squirrel, the grey seems better able to exploit the niche and has spread rapidly through most of the UK; the red squirrel has become marginalised.	

Objectives	Possible teaching activities	Notes	School resources
2 hours **Ecosystems are dynamic** Explain how disease affects the size of population of organisms and the significance of limiting factors in determining the ultimate size of a population. Explain how the diversity and numbers of organisms and the environmental factors in an ecosystem form a dynamic relationship that is open to disruption.	Get students to examine case studies of the effect of disease on population numbers. Provide data on a population before and after the incidence of a disease and ask students to analyse it and write conclusions in each case. Tell students to use their textbooks, the library and the Internet to find information about the following examples. *The rabbit and myxomatosis* Make sure students understand that after its introduction into the UK and then into Australia, the population of the European rabbit followed a similar pattern: it grew extremely quickly and became a serious agricultural pest. The disease myxomatosis was introduced into both countries with devastating consequences for the rabbits: 99% were killed. *Humans and the plague* The important point for students to understand here is that the human population of Europe was significantly reduced in the Middle Ages by a disease called the plague, which was transmitted to people by the bite of a rat flea. The disease was caused by a bacteria called *Yersinia pestis* and was responsible for The Black Death in 1348 and the Great Plague of London in 1665–66.	**ICT opportunity**: Use of the Internet.	
	Introduce the effect of other limiting factors on populations by getting students to examine the case studies outlined below. First ask students to suggest why many populations remain relatively constant if censused at about the same time each year – they fluctuate from year to year within narrow limits – yet some species show marked cyclical variations. Make sure students appreciate that the population will remain the same when the birth rate is equal to the death rate unless there is immigration or emigration of the population. *Great tit populations* Provide information about the great tit, including graphs, and ask students to discuss: • the shape of each graph; • the conditions that distinguish the nests producing most offspring from those producing least offspring. *Locust populations* Ask students to find data from textbooks, the library and the Internet about the population changes of locusts (or provide selected data). They could investigate either one or both of the economically important species of locusts: the migratory locust, *Locusta migratoria*, or the desert locust, *Schistocerca gregaria*. Tell them to find out the conditions that result in the huge swarms that migrate long distances and devour all the vegetation on which they settle.	Information on the great tit can be found in: G. Monger (ed.) (1986) *Nuffield Advanced Science: Biology Study Guide 2*, Longman, pp.488–94. **ICT opportunity**: Use of the Internet.	

Objectives	Possible teaching activities	Notes	School resources
	Discuss with students the dynamic relationship between diversity and numbers of organisms and the environmental factors in an ecosystem. Also discuss how this ‘balance of nature’ may be disrupted by an addition of a new species into the community or by a significant change in an environmental factor. Typical examples for discussion might include the following. • The prickly pear cactus, *Opuntia sp*., introduced into Australia and South America. A garden escapee in Australia, the cactus covered over four million hectares of agricultural land at one time. • The giant kelp, from Japanese waters, which now competes with native seaweeds in the waters of the UK and Europe. • The cane toad introduced to Australia to control a pest of sugar cane has proved disastrous, with the toad devouring many of the rarer native species. The cane toad population is growing enormously and is itself becoming a pest.		
2 hours **Impact of human activities** Explain examples of short- and long-term human impact on a variety of environments.	Ask students to work in pairs or small groups to explore which human activities impact on the environment. Then reassemble the class for discussion of each group’s contributions. Get students to produce a flow chart showing the impact of humans through time from the Stone Age to the present day. Destruction of habitat is probably the single biggest impact on the environment made by humans.		
	Ask students to use their textbooks, the library and the Internet to find information about examples of long-term impact, including: • desertification as a result of climate change, vegetation being cut for fuel and overgrazing; • deforestation with loss of species, soil erosion, loss of soil fertility and soil water; • global warming; • acid rain; • destruction of the ozone layer; • over-fishing; • hunting (e.g. rhinos, tigers, whales); • pollution by, for example, chemicals, radioactive waste.	**ICT opportunity:** Use of the Internet.	
	Provide a series of photographs taken of the same environment over many years to allow students to determine the extent of human impact (e.g. aerial photographs of the Amazon rainforest). Provide a graph displaying the atmospheric levels of carbon dioxide together with another displaying the temperature records for the same period. Discuss the graphs. Provide maps displaying the atmospheric levels of sulfur dioxide accompanied by information on the distribution of lichens (the lichens are well-known indicators of atmospheric pollution). Discuss the maps and any correlations.	Provide suitable photographs, graph and maps.	
	Provide a graph or table displaying the numbers of whales caught by hunters related to the number of hours spent hunting. Discuss the significance of this. Tell students to use their textbooks, the library and the Internet to find examples of species that have become extinct, or are close to extinction, because of human activity (e.g. the dodo of Mauritius, the Tasmanian wolf of Australia).	A suitable graph can be found in M. Roberts, M. Reiss and G. Monger (1993), *Biology Principles and Processes*, Nelson. **ICT opportunity:** Use of the Internet.	

Objectives	Possible teaching activities	Notes	School resources
	Investigate an example of a short-term impact of human activity by conducting a field study involving all students working as a team. A good example would be to investigate the effect of a sewage outfall on a river community. As a class, collect samples of organisms using nets upstream from the outfall and compare these with other samples taken at intervals downstream beyond the outfall. Identify the organisms using keys for river organisms. If a field study is not possible, then use secondary evidence from textbooks or the library instead. Compare and explain graphs displaying the diversity of species found in the river community and their populations. Alternatively, students might investigate a waterway displaying evidence of eutrophication (i.e. one that has become artificially enriched with mineral ions such as nitrates or phosphates) and compare it with a body of water that has not been so affected. Let students sample the waterway as described above.	**Field work opportunity:** Sample a river community with appropriate equipment, including nets. Enquiry skill 11A.1.7 Enquiry skill 11A.1.8	
	Get students to carry out a laboratory investigation into the effect of sulfur dioxide on plant growth as follows: • grow six similar pots of plants (e.g. cereals); • water each pot with a particular concentration of weak sulfuric acid to simulate acid rain caused by sulfur dioxide; • observe the appearance of the plants over several weeks of treatment; • discuss the results. Encourage students to produce a poster displaying the impact of humans on the environment.	Enquiry skill 11A.1.3 Enquiry skill 11A.3.4	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Explain the population changes displayed in the accompanying graphs showing phytoplankton and zooplankton over several years.*	Provide a graph displaying population changes of phytoplankton and zooplankton.	
	*Give examples of organisms that display inter-specific competition. Explain competition between these organisms by referring to the terms **ecological niche** and the **competitive exclusion principle**.*		
	Explain how disease affected the population of a named organism.		
	*Explain what is meant by **the balance of nature** and how it might be affected by human activities.*		
	Explain the factors that regulate the cyclical fluctuations in lemming populations.		
	Examine and explain the graph showing the increase in the human population of the world for the last two thousand years.	Provide a graph showing the increase in the human population of the world.	

GRADE 11A: Biology 8

Microbiology and biotechnology

UNIT 11AB.8
9 hours

About this unit

This unit is the eighth of eight units on biology for Grade 11 advanced.

The unit is designed to guide your planning and teaching of biology lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already know that species are clustered into groups. They should know about the hierarchy of classification and the key features of the kingdoms and main phyla of animals and plants. They should know the roles of micro-organisms in recycling and how they function in the carbon and nitrogen cycles. They should know that the nitrogen-fixing micro-organisms in root nodules have a mutualistic relationship with the host plant. They should know about the body's defence systems. They should know the function of antibiotics and vaccination.

Expectations

By the end of the unit, students recognise the main features of viruses, bacteria and fungi. They know how micro-organisms and cells can be cultured. They understand the basic principles of genetic engineering. They know how micro-organisms are used in the food industry and in the treatment of wastewater. They know that the body produces antibodies against antigens, and understand the causes and transmission of HIV/AIDS, its global significance and problems of control.

Students who progress further understand how biosensors are used to monitor blood glucose levels in diabetes and how diabetes can be treated with genetically produced insulin.

Resources

The main resources needed for this unit are:

- overhead projector (OHP), whiteboard
- microscope, slides of specimens, models of specimens
- video camera attached to microscope and monitor
- sterile swabs, inoculating loops, immersion oil
- autoclave, strong disinfectant
- computer, datalogger, sensors (light, oxygen, pH and temperature)
- fermenter, magnetic stirrer, air pump
- video clips of genetic engineering and treatment of wastewater
- newspaper cuttings of genetic engineering
- 'Restriction digestion and analysis of lambda DNA kit'
- children's modelling clay, push-fit beads, coloured card
- gene cloning card set
- flour, yeast , milk, rennet
- yoghurt culture, lactase enzyme, calcium alginate beads
- government health statistics on HIV/AIDS
- teaching kit for antibody–antigen reaction
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *cyanobacteria*, *bacteriophages*
- *autotrophic*, *chemosynthetic*, *heterotrophic*, *saprobiont*
- *facultative anaerobe*, *obligate aerobe*, *obligate anaerobe*
- *aseptic technique*, *cross-contamination*
- *capsid*, *coccus*, *bacillus*, *hyphae*, *mycelium*
- *batch fermentation*, *continuous fermentation*
- *genetic engineering*, *gene cloning*, *recombinant DNA*
- *restriction enzymes*, *restriction endonucleases*, *DNA ligase*
- *plasmids*, *vectors*, *bacteriophage*, *lambda DNA*
- *micropipetting*
- *transgenic*
- *single cell protein*
- *immobilised enzyme*
- *human immunodeficiency virus* (*HIV*)
- *acquired immune deficiency syndrome* (*AIDS*)
- *retrovirus*
- *RNA reverse transcriptase*
- *antigen–antibody reaction*
- *immuno-suppressive drugs*

Objectives for the unit

Unit 11AB.8

9 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
2 hours **Micro-organisms: form and culture**	9.12.2	Know that antibiotics are effective against bacterial illness and explain why vaccination can protect against viral illness.	11A.12.1	Explain the causes and transmission mechanisms of HIV/AIDS, how its spread may be controlled and the significance of the pandemic.		
1 hour **Principles of gene cloning**	9.12.3	Know that antibodies help protect the body from the effects of microbial infection.	11A.12.2	Explain the action of antibodies against antigens in the human immune system.	12A.11.1	Explain the production and action of human antibodies against antigens and distinguish between the actions of B lymphocytes and T lymphocytes.
1 hour **Genetic engineering: for and against**			11A.17.1	Know the basic distinguishing features of viruses and types of bacteria and microbial fungi.		
1 hour **Micro-organisms and food production**			11A.17.2	Know methods for the laboratory and bulk culture of micro-organisms and cell lines.		
1 hour **Micro-organisms and wastewater treatment**			11A.17.3	Explain the principles of gene cloning and the roles of restriction enzymes, recombinant DNA, plasmids and bacteriophages.	12A.17.1	Explain how genetically engineered human insulin was developed and is now manufactured for use by diabetics.
2 hours **HIV/AIDS: causes, transmission mechanisms and control**					12A.17.2	Explain what is meant by a biosensor. Know about the use of glucose oxidase as a bio-recognition substance in biosensors used for monitoring the blood glucose levels of diabetics.
1 hour **Introduction to antibodies and antigens**			11A.17.4	Explain some of the potential advantages of, and ethical and moral concerns about, genetic engineering.		
			11A.17.5	Explain some uses of micro-organisms in food production.		
			11A.17.6	Explain how micro-organisms are used in the treatment of wastewater.		

Objectives	Possible teaching activities	Notes	School resources
2 hours **Micro-organisms: form and culture** Know the basic distinguishing features of viruses and types of bacteria and microbial fungi. Know methods for the laboratory and bulk culture of micro-organisms and cell lines.	Set students the task of using their textbook, the library or the Internet to find out the main distinguishing features of viruses. Consolidate the exercising by discussing their findings in class and making sure everyone agrees on the main features. Emphasise the unique characteristics of viruses. • Viruses are the ultimate parasites, being extremely small infectious agents that can only reproduce inside a specific host cell. • The basic viral particle consists of nucleic acid (either DNA or RNA) surrounded by a protein coat called the *capsid*. Some viruses can be crystallised • Viruses exhibit a range of forms, from simple rods through icosahedrons to complex symmetry. • Viruses can be considered to be on the border between living and non-living. (This is the reason they do not figure into the five kingdom classification system). Because of their extremely small size (20 nm to 300 nm), viruses can only be seen with electron microscopes. Provide students with electromicrographs of viruses. If a scale or magnification is given, get students to measure the size of individual virus particles.	**ICT opportunity:** Use of the Internet.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Viruses called *bacteriophages* (viruses that attack bacteria) are well researched because they are relatively easy to study and pose no risk to people. Show students photographs of bacteriophages. Tell them to find out about bacteriophages (using their textbook, the library or the Internet) and draw and explain their lifecycle.	**ICT opportunity:** Use of the Internet.	
	Bacteria, together with the cyanobacteria (blue-green bacteria), comprise the Prokaryotae and are the only living prokaryotic organisms. Reinforce previous knowledge of prokaryotic cells from an earlier unit (Unit 10AB.2) by giving students a quiz.		
	Bacteria are a very diverse group. They are the smallest cellular organisms and the most abundant. Set students the task of collecting information from their textbooks, the library or the Internet about the main distinguishing features of bacteria and then writing an account of the different types of bacteria. Discuss the classification of bacteria, which tend to be categorised by both structural and metabolic features. Include the features described in the following sections (shape, staining reaction, method of nutrition, method of respiration) in the discussion.	**ICT opportunity:** Use of the Internet.	
	Shape Bacteria fall into two types based on shape, these are: • spherical bacteria, called *cocci* (singular *coccus*); cocci may stick together in chains (streptococci) or in clusters (staphylococci – e.g. *Staphylococcus aureus*); • rod-shaped bacteria, called *bacilli* (singular *bacillus*) (e.g. *Escherichia coli*); bacilli may also be single or in chains; they may also be curved or spiral. Let students examine bacteria under the microscope to identify a range of different shapes. For greater resolution, use the oil immersion technique, if oil immersion lenses are available.	Provide microscopes and slides of a variety of bacteria. A video camera attached to the microscope and displayed on a monitor would be a useful teaching aid.	

Objectives	Possible teaching activities	Notes	School resources
	Staining reaction Bacteria can be divided into two categories by the Gram stain • bacteria that stain purple are Gram positive • bacteria that stain red are Gram negative. Let students examine bacteria under the microscope to identify whether they are Gram positive or Gram negative.	Provide microscope slides of Gram positive and Gram negative bacteria.	
	Method of nutrition Ask students to research the library or Internet and write an account on the nutrition of bacteria. Let students investigate the presence of bacteria in their classroom. They can do this by sampling the classroom environment with sterile swabs, using the swabs to streak sterile agar plates, sealing the plates with tape and incubating them at room temperature. View the plates after 24 and 48 hours to see the appearance of colonies. When they have finished, autoclave the plates (Petri dishes). Discuss the results as a class. Bacteria display a wide range of nutritional types including: • autotrophic nutrition, including both photosynthetic bacteria (e.g. sulfur bacteria) and chemosynthetic bacteria (e.g. nitrifying bacteria); • heterotrophic nutrition, including some bacteria that are parasitic. The majority of bacteria are saprobionts, feeding on the widest possible range of organic compounds. Only a few compounds are non-biodegradable.	**ICT opportunity:** Use of the Internet. **Safety:** Follow guidelines for safe handling and disposal of micro-organisms. **I**	
	Method of respiration Ask students to research the library or the Internet and write an account to distinguish between bacteria which are *aerobes*, *obligate aerobes*, *anaerobes*, *obligate anaerobes* and *facultative anaerobes*. Bacteria display a wide range of respiration methods including: • aerobes, which require oxygen for respiration; • anaerobes, which respire without oxygen. Set students the task of finding out the main distinguishing features of microbial fungi, using their textbook, the library or the Internet. Consolidate the exercise by discussing students' findings in class and making sure everyone agrees on the main features. Reinforce previous knowledge from the classification of fungi earlier in this unit. Ensure students appreciate the following main distinguishing features of microbial fungi: • they are eukaryotic organisms; • the majority are multicellular, although yeasts are unicellular; • they are organised into a network (mycelium) of thread-like, multinucleate hyphae which may be divided by cross-walls called *septa;* • they have cell walls mainly of chitin; • they are all heterotrophic – most are saprobiont, others are parasitic; • a number of fungi, called *mycorrhizae*, have a special relationship with plant roots, and are important in forestry.	**ICT opportunity:** Use of the Internet. **ICT opportunity:** Use of the Internet.	

Objectives	Possible teaching activities	Notes	School resources
	Let students examine fungi under the microscope to identify the structure of hyphae and possible spore-bearing structures. Let students examine a culture of yeast under the microscope to identify the structure of the cells.	Provide microscopes and slides of a variety of fungi. A video camera attached to the microscope and displayed on a monitor would be a useful teaching aid.	
	Laboratory and bulk culture of micro-organisms and cell lines The following basic principles apply when culturing micro-organisms in the laboratory. • Microbiologists need to practise the aseptic, or sterile, technique at all times. This technique is essential for the safety of everybody who works in or uses the laboratory. It also reduces the risk of cross-contamination, which ensures that the cultures are kept pure and prevents the escape of micro-organisms from the culture. • Micro-organisms are normally cultured or grown in artificial culture media. (Viruses cannot be grown in artificial media unless cultured in bacteria as bacteriophages.) • Micro-organisms are grown under controlled conditions. In particular, the culture is incubated at a known temperature and the pH of the medium is often controlled by buffers. • Micro-organisms are normally grown in pure culture (i.e. in populations consisting of only one species). Micro-organisms are normally grown in either solid or liquid media, depending on the purpose of the investigation. Producing the media is a time-consuming process. Nutrient agar is the normal solid medium of choice. Nutrient broth is the normal liquid medium of choice.	**Safety:** Follow guidelines for safe handling and disposal of micro-organisms. Practical microbiology requires sterile equipment. The preferred method of sterilisation is autoclaving. Working surfaces should be sterilised by wiping with strong disinfectant before and after practical procedures.	
	Show students the aseptic technique for a solid medium and use it to inoculate a sterile Petri dish of nutrient agar (a plate) and an agar slope with a pure culture of a micro-organism. Secure the lid of the Petri dish by two strips of tape crossed over (Don't completely seal the lid as this would encourage the growth of anaerobic pathogens.) Label the dish clearly with a wax pencil on the base of the dish. Incubate at around 30 °C (this avoids favouring the growth of any contaminating human pathogens). Examine the cultures and then sterilise by autoclave before disposal. Colonies of bacteria or fungi can be cultured on solid media. These colonies each originate from one cell and so can be used as a method to isolate micro-organisms from mixed cultures and also in the identification of species of micro-organisms. The nutrient content of the medium and its pH can be adjusted to favour the growth of the particular organism being studied. Media like this are called *selective media*: they could be based on meat extract, blood, milk, yeast extract or other nutrients. Liquid cultures of micro-organisms can be grown in nutrient broth in an assortment of sterile plugged glassware or plastic containers.	Obtain specimens of micro-organisms for use in the practical from an accredited educational supplier. Prepare sterile nutrient agar Petri dishes and agar slopes in McCartney bottles. Supply inoculating loops. Enquiry skill 11A.4.1	
	Show students the aseptic technique for a liquid medium and use it to inoculate a sterile flask of nutrient broth with a specific bacteria or yeast.	Enquiry skill 11A.4.1	
	If a colorimeter is available, incorporate it into a demonstration measuring the relative growth rate of the micro-organism in the flask by taking samples and determining the light absorption change over the period of incubation.	Provide a colorimeter to measure growth of micro-organisms.	
	If a computer and datalogging equipment are available, incorporate them into a demonstration measuring the relative growth rate of the micro-organism in the flask by using a light sensor and determining the light absorption change over the period of incubation.	**ICT opportunity:** Use of a computer/datalogger to measure growth of micro-organisms.	

Objectives	Possible teaching activities	Notes	School resources
	Batch culture and continuous culture A fermenter can be used in the school laboratory to carry out a demonstration of the batch culture of micro-organisms. Batch culture is also used by industry for larger-scale production of micro-organisms so that their metabolites can be harvested at the end of their growth period. A simple fermenter for use in school can be made from a large flask or bottle with an air supply pumped through it (a typical fish aquarium air pump would be suitable). Use a magnetic stirrer to keep the culture contents evenly mixed. Fit syringes for several purposes: inoculating the medium with micro-organisms, adding materials during the growth of the culture, taking samples for analysis or population estimation.		
	If a computer and datalogging equipment are available, incorporated them into a demonstration monitoring the conditions in the fermenter and measuring the relative growth rate of the micro-organism by using a light sensor and determining the light absorption change over the period of incubation. Use other sensors (e.g. pH, temperature and oxygen sensors) to indicate the changing growth conditions in the fermenter and give a permanent record for analysis later. Print out a growth curve pattern from the light sensor data and compare it with data from other sensors for discussion. Give students a copy of the graph produced from the fermenter demonstration and ask them to analyse the graph and explain its shape. Continuous fermentation is used by industry to harvest metabolites produced when the micro-organisms are growing at their fastest rate in the fermenter. Nutrients are fed into the fermenter at exactly the same rate that the product is removed. The conditions in the fermenter (e.g. pH and oxygen levels) are constantly monitored and adjusted to maintain the environment and maintain the micro-organisms in the exponential phase of growth.	**ICT opportunity:** Use of a computer/datalogger to measure growth of micro-organisms and sensors for light, pH, oxygen, and temperature. Enquiry skills 11A.3.2, 11A.3.3	
	Set students the task of determining how micro-organisms are grown in bulk and providing examples of the products involved, using their textbook, the library or the Internet. Encourage them to produce a flow chart to display the stages in the process of industrial fermentation.	**ICT opportunity:** Use of the Internet.	
1 hour **Principles of gene cloning** Explain the principles of gene cloning and the roles of restriction enzymes, recombinant DNA, plasmids and bacteriophages.	Introduce the topic by showing students a video of genetic engineering. Discuss the video content with the class.		
	Sometime before studying this topic, ask students to make a collection of newspaper cuttings about reports of genetic engineering. Discuss these with students as examples of how important (and controversial – see next section) genetic engineering is becoming in the world.	Make a collection of newspaper cuttings about reports of genetic engineering.	
	Show students an OHT illustrating the stages of the process of gene cloning by a series of overlays. Explain the process. Ensure students appreciate that the process of genetic engineering became possible with the discovery of two enzymes: the restriction enzymes and DNA ligase.	Prepare OHTs illustrating the stages of the process of gene cloning.	
	Provide a handout explaining gene cloning with gaps in the text and also supply a list of key words. Ask students to use the key words to complete the text. Examples of key words include: *restriction enzymes / restriction endonucleases*; '*sticky ends*'; *DNA ligase*; *recombinant DNA*; *plasmids*; *vectors*; *viruses / bacteriophages*; *gene cloning*.	Prepare suitable handouts on gene cloning. Enquiry skills 11A.3.2, 11A.3.3, 11A.4.1	

Objectives	Possible teaching activities	Notes	School resources
	Ask students to use the 'Restriction digestion and analysis of lambda DNA kit' to investigate the effects of three restriction enzymes on lambda DNA. The lambda genome has approximately 48 000 base pairs, and each restriction enzyme will cut the DNA several times, generating restriction fragments of different sizes. Students will learn electrophoresis, micropipetting, graph analysis, and general lab skills and safety procedures.	A biotechnology catalogue and the 'Restriction digestion and analysis of lambda DNA kit' are available from Bio-Rad Laboratories Ltd at www.bio-rad.com.	
	Get students to make models of bacteria, such as *E. coli*, containing a plasmid. They should use string, coloured children's modelling clay or push-fit beads. Ask students, working in pairs or small groups, to simulate the process of gene cloning using the bacteria models. Get students to produce a poster of the process of gene cloning of a specific product. Ask students to produce a flow chart of the stages in gene cloning. Give students a set of cards with the stages of gene cloning in a deliberately muddled order and ask them to arrange the cards in the correct sequence.	Students will need: modelling materials such as string, coloured children's modeling clay or push-fit beads. Enquiry skill 11A.3.4 Produce a set of cards showing the stages of gene cloning.	
1 hour **Genetic engineering: for and against** Explain some of the potential advantages of, and ethical and moral concerns about, genetic engineering.	Tell students to use the Internet to find out about the advantages of genetic engineering and the ethical and moral concerns it raises. Organise students into two teams to debate the pros and cons of genetic engineering. Give each student copies of the same, possibly controversial, newspaper articles or reports on genetic engineering. Tell them to examine the reports and then hold a class discussion on the correctness of the science in each of them (e.g. is it factual or is it designed to sensationalise the subject or display the bias of the editor/reporter?). Get students to make two lists: one showing the advantages of genetic engineering and another showing the ethical and moral concerns about the process. Encourage students to write magazine articles about genetic engineering. Suggest that they write one article about the potential of genetic engineering to produce useful organisms and products, and that later they write a second article arguing why genetic engineering should not be used. Ask students to survey members of the local community to find out what the adults' attitudes are to genetic engineering. Suggest that they try to establish why people have either positive or negative attitudes towards this subject. Let students suggest the questions they will ask people, but discuss the suitability of each question and its wording with students so that it is not ambiguous or biased. Ask students how ethical it is to carry out genetic engineering experiments on humans. Alternatively, ask students how ethical is it to carry out genetic engineering experiments on animals purely for human benefit (e.g. a transgenic mouse that has been genetically engineered for cancer research).	**ICT opportunity:** Use of the Internet. Enquiry skill 11A.2.2 Select and copy newspaper reports about genetic engineering. Enquiry skill 11A.2.2	

Objectives	Possible teaching activities	Notes	School resources
1 hour **Micro-organisms and food production** Explain some uses of micro-organisms in food production.	Sometime before studying this topic, ask students to make a collection of containers of foods made by micro-organisms. Discuss the variety of the collection with students. Ask students to survey food shops for foods made by micro-organisms. Tell students to input the data into a spreadsheet and analyse the results. Collate the results in class and get students to draw bar charts or pie charts and write a brief report	**ICT opportunity:** Use of a spreadsheet.	
	Bread-making is one of the oldest examples of biotechnology, dating back to Ancient Egypt around 6000 years ago. Let students, working in pairs, carry out a range of different, entirely safe, investigations on bread-making using yeast, the rapidly reproducing micro-organism that causes the bread dough to rise. For example, ask students to follow the instructions below. • Mix 1 g of dried yeast in 50 cm^3 water. • Add 75 g of flour and mix well. • Roll the dough to a sausage shape and place it in a 100 cm^3 measuring cylinder. • Record the height of the dough every 10 minutes over a 1 hour period. • Repeat this process with other sets of apparatus for dough at different temperatures. Let the pairs carry out other experiments investigating the effects of adding of other ingredients (e.g. ascorbic acid or salt) in varying quantities to establish the quickest or highest rising of the dough.	Details of many biotechnology experiments, including those referred to here, can be found on the National Centre for Biotechnology Education (NCBE) website: www.ncbe.reading.ac.uk Provide bread-making materials: dried yeast, water, strong flour, additional ingredients as desired (e.g. ascorbic acid or salt). Enquiry skill 11A.1.3	
	Cheese production, another old example of biotechnology, has for thousands of years relied on the action of enzymes that coagulate the proteins in milk, forming solid curds (from which the cheese is made) and liquid whey. There are several sources of the enzyme rennet available today: animal, naturally occurring fungi and genetically engineered yeast. Ask students, working in pairs, to investigate the effect of rennet as follows. Add 10 cm^3 of pasteurised milk to a series of test-tubes. Add 1 cm^3 of rennet enzyme. Record the time taken for the milk to coagulate. Let the pairs try different controlled experiments using the same apparatus (e.g. place the tubes in different temperatures, use different pH values, use different enzymes). Ask students, working in pairs, to make yoghurt by following this simple procedure. • Pour 10 cm^3 of sterilised milk into each of two boiling tubes. • Add 1 cm^3 of yoghurt starter culture to one of the tubes. • Seal the tubes with self-sealing film. • Incubate the tubes in a water bath at 43 °C for several hours. • Observe any changes in the tubes. Let the pairs try different controlled experiments using the same apparatus (e.g. place the tubes in different temperatures, use different milks (goats', sheep's, cows'), use different starting cultures). The above experiments could be adapted by adding a sensor attached to a datalogger or computer. For example, a pH meter could be used to monitor the gradual change in pH by real-time online monitoring.	**ICT opportunity:** Use of computer, sensor and datalogger for real-time online monitoring.	
	Tell students how to make low lactose milk and then let them try the procedure. This technique involves treating pasteurised milk with the enzyme lactase. This hydrolyses lactose to glucose and galactose to produce a milk that is more readily digestible (an estimated 75% of the world's population are intolerant of lactose in adulthood).		

Objectives	Possible teaching activities	Notes	School resources
	Tell students to carry out an immobilised enzyme experiment. Follow a procedure to immobilise the enzyme lactase in calcium alginate beads held within a small column, over which milk is passed.		
	Ask students to use their textbook, the library or the Internet to find the information they need to produce flow charts and/or posters for the commercial / industrial production of, for example, single cell protein (SCP), beer, wine, vinegar, bread, cheese, or yoghurt. Ask students to match lists of micro-organisms to the products they produce (e.g. single cell protein (SCP), beer, wine, vinegar, bread, cheese, yoghurt).	**ICT opportunity:** Use of the Internet.	
1 hour **Micro-organisms and wastewater treatment** Explain how micro-organisms are used in the treatment of wastewater.	Show students a video explaining how micro-organisms are used in the treatment of wastewater. Take students on a visit to a wastewater treatment plant and ask them to write a report, explaining the stages of the process. Explain to students how micro-organisms are used in the treatment of wastewater using OHTs and the whiteboard. Ask students to explain the role of micro-organisms in two stages of the wastewater treatment process: • the aerobic stage by biological fitration; • the anaerobic stage of fermentation. Give students a diagram or flow chart of the process and ask them to explain the process using information they gather from the library or Internet. Ask students to draw a flow chart of the process emphasising how micro-organisms are used in the treatment of wastewater.	**Visit opportunity:** Visit a wastewater treatment plant. **ICT opportunity:** Use of the Internet.	
2 hours **HIV/AIDS: causes, transmission mechanisms and control** Explain the causes and transmission mechanisms of HIV/AIDS, how its spread may be controlled and the significance of the pandemic.	Introduce this topic by asking students whether they know what HIV/AIDS stands for and the origin of the term. Explain this to them, if necessary. Show students statistics displaying the world data on HIV/AIDS. Get them to produce graphs, bar charts or diagrams from data selected from the statistics. Prepare questions for students to answer about the known mechanisms for the transmission of HIV/AIDS. For example: • What are the known mechanisms for the transmission of HIV/AIDS? • How can each transmission route for HIV/AIDS be controlled? • Which particular groups of people are most at risk of catching HIV/AIDS and why? Prepare questions for students to answer on the myths and realities of the transmission of HIV/AIDS. For example: • Can you catch HIV/AIDS from someone with the virus by everyday contact? • Can you catch HIV/AIDS from someone with the virus by using the same toilet seat? • Can you be cured of HIV/AIDS by having intercourse with a virgin? Ask students to use the library or the Internet to find out how the spread of HIV/AIDS is controlled. Get students to create a PowerPoint presentation about the spread and control of HIV/AIDS.	**ICT opportunity:** Use of the Internet and PowerPoint. Enquiry skill 11A.3.4	

Objectives	Possible teaching activities	Notes	School resources
	Get students to draw a flow chart or a spider diagram to show the effect of HIV/AIDS on the economy of a country and on the lifestyle of its people.		
	Tell students to find data on the number of people living with HIV/AIDS in different countries and present these as percentages of population and as numbers per unit area of the country.	Enquiry skill 11A.3.2	
	Tell students to work in pairs to suggest reasons for the increase in HIV/AIDS in certain countries of the world. Then hold a class discussion and get them to write a report summarising the reasons.		
	Provide students with data, or ask them to find the data themselves, from the government's health ministry about the prevalence of HIV/AIDS in Qatar.		
	Get students to compare Qatar's statistics with those of other Middle Eastern states. Then ask them to write a report and draw bar charts, pie charts and any other appropriate graphs to display the data. Tell them to look for any trends or patterns which are developing.		
	Organise students into small groups and ask them to make one list of the ways in which science can help stem the HIV/AIDS pandemic and a second list of problems associated with HIV/AIDS that science cannot resolve. Tell each group to elect a spokesperson to present their list to the class. Then ask each student to write an individual report after class discussion.	Enquiry skill 11A.2.3	
	Tell students to find information about the life cycle of the HIV-1 virus in the library and to use the information to produce a large labelled diagram. Make sure they understand the role of the retrovirus enzyme RNA reverse transcriptase.	You can find such a diagram as an example in M. Rowland (1992) *Biology*, University of Bath Science 16–19, Nelson Thornes. Enquiry skill 11A.3.4	
2 hours **Introduction to antibodies and antigens** Explain the action of antibodies against antigens in the human immune system.	Explain the action of antibodies against antigens in the human immune system. Ask students to draw a flow chart or a diagram to show the action of antibodies against antigens.	Enquiry skill 11A.3.4	
	Ask students to make physical or diagrammatic models of an antibody–antigen reaction. Select two students to show the antibody–antigen reaction on the OHP using cut-out OHT template shapes.	Provide simple model-making resources (e.g. coloured card or OHT templates, scissors).	
	Use a teaching kit to demonstrate the antibody–antigen reaction. Ask students, in pairs, to investigate the antibody–antigen reaction using a teaching kit.	Teaching kits for the antibody–antigen reaction are available from educational suppliers.	
	Survey the class to determine how many students suffer from hayfever. Tell students to find out and write a report on what happens in the body when individuals suffer from hayfever		
	Present students with some possible scenarios concerning transplant surgery and ask them to explain them in terms of antibody–antigen reaction. For example: • the possible outcome for a child currently surviving on renal dialysis whose father offers one of his kidneys for transplant; • the possible outcomes for a man on immuno-suppresive drugs after a heart transplant from a non-relative.		

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Describe how bacteria are classified according to features such as:* a. *shape;* b. *nutritional requirements;* c. *respiratory demands.*		
	a. *Draw a diagram of a virus and label it.* b. *What are the distinguishing features of viruses?*		
	Write a brief account of how micro-organisms are grown in bulk.		
	Use the following key words to construct an explanation of gene cloning: ***restriction enzymes / restriction endonucleases*** ***'sticky ends'*** ***DNA ligase*** ***recombinant DNA*** ***plasmids*** ***vectors*** ***viruses / bacteriophages*** ***gene cloning***		
	Make two lists: one showing the advantages of the process of genetic engineering and another showing the ethical and moral concerns about genetic engineering.		
	Produce a flow chart for the commercial/industrial production of single cell protein (SCP).		
	Explain the role of micro-organisms in the wastewater treatment process under the following two sub-headings: a. *aerobic stage by biological fitration;* b. *anaerobic stage of fermentation.*		
	Explain the causes and transmission mechanisms of HIV/AIDS.		
	Explain how the spread of HIV/AIDS may be controlled.		
	Draw a diagram of the life cycle of the HIV-1 virus and explain the stages shown.		
	Hayfever is a problem for many people. Explain what happens in the body when someone is suffering from hayfever.		
	Explain what the possible outcomes are for a man after a heart transplant from a non-relative.		
	Make one list of the ways in which science can help stem the HIV/AIDS pandemic and a second list of problems associated with HIV/AIDS that science cannot resolve.		

GRADE 11A: Chemistry 1

Bonding in more detail

UNIT 11AC.1
9 hours

About this unit

This unit is the first of six units on chemistry for Grade 11 advanced.

The unit is designed to guide your planning and teaching of chemistry lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already know the distribution of mass and charge in atoms and ions up to element 56. They should be able to show how electronic structure explains the pattern of elements in the periodic table and manipulate quantities such as proton number and mass number. They should understand ionic, covalent and metallic bonding and explain the properties of elements and compounds in terms of bond types.

Expectations

By the end of the unit, students know that weak bonds caused by dipole attraction hold particles together and they know of hydrogen bonding and its consequences. They recognise that electron-pair repulsion influences the shapes of molecules, describe dative bonding and know that compounds' physical properties depend on their bonding type. They recognise the significance of s, p, d and f orbitals and hybrids in bonding and molecular shape, and distinguish between σ and π bonds.

Students who progress further differentiate between the different types of dipole interactions. They know that compounds' physical properties depend on their bonding type. They determine the type of bonds formed when simple compounds form.

Resources

The main resources needed for this unit are:

- molecular modelling kit
- long thin balloons
- burettes, charged polythene rods
- card-sort activity on structure and properties
- samples of substances with giant lattice structures
- student copies of the periodic table
- Internet access
- models and animations of biomolecules (e.g. DNA)
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *van der Waals' forces*, *instantaneous dipole*, *induced dipole*, *electronegativity*
- *coordinate* (*dative*) *bond*
- *electron-pair repulsion*
- *lattice*
- *shells*, *subshells*, *orbitals*, *sigma bonds, pi bonds*, *bond hybridisation*

Objectives for the unit

Unit 11AC.1

9 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
3 hours **Intermolecular forces** **1 hour** **Dative bonding** **2 hours** **Structure and properties** **3 hours** **Electron orbitals and hybridisation**			11A.18.1	Know that permanent and induced molecular dipoles can give rise to intermolecular forces (van der Waals' forces), and explain their consequences in terms of physical properties of elements and compounds.	
			11A.18.2	Describe hydrogen bonding, using ammonia and water as simple examples of molecules containing N–H and O–H groups.	
			11A.18.3	Know the importance of hydrogen bonding to the physical properties of substances, particularly ice and water, and to the structures of important organic molecules such as proteins and nucleic acids.	
			11A.18.4	Explain the shapes of simple covalent molecules in terms of electron-pair repulsion (including lone pairs) and know how molecular shape can give rise to permanent dipoles.	
			11A.18.5	Describe coordinate (dative covalent) bonding, as exemplified by the formation of the ammonium and hydroxonium ions and in the structure of carbon monoxide.	
	10A.17.10	Explain the differing physical properties of covalent and ionic compounds in terms of their bonding and be able to deduce the type of bond from information about physical properties.	11A.18.6	Account for the differences in physical properties of substances by reference to different types of bonding: ionic bonding; covalent bonding; hydrogen bonding; other intermolecular interactions; metallic bonding.	
	10A.17.8	Know that some covalent compounds, such as the element carbon and the compound silicon(IV) oxide, form giant molecular structures.	11A.18.7	Describe, in simple terms, the differences between the lattice structures of crystalline solids which are: ionic, as in sodium chloride; simple molecular, as in iodine; giant molecular, as in graphite, diamond or silicon(IV) oxide; hydrogen bonded, as in ice; metallic, as in copper.	
	10A.17.2	Deduce the atomic structure of an atom or ion of any given element up to barium (56) and show how the structures explain the pattern of elements in the periodic table.	11A.18.8	Describe the number and relative energies of the s, p, d and f orbitals for the principal quantum numbers 1, 2, 3 and 4, and show how this leads to the structure of the periodic table.	
			11A.18.9	Describe the shape of the s and p orbitals and their hybrids in atoms such as carbon and oxygen.	
			11A.18.10	Describe covalent bonding in terms of orbital overlap, giving σ (sigma) and π (pi) bonds; explain bond shape and angles in ethane, ethene and benzene in terms of σ and π bonds.	
			11A.18.11	Explain the lack of reactivity of the triple bond (as in nitrogen) in terms of bonding theory.	

Objectives	Possible teaching activities	Notes	School resources
3 hours **Intermolecular forces** Know that permanent and induced molecular dipoles can give rise to intermolecular forces (van der Waals' forces), and explain their consequences in terms of physical properties of elements and compounds. Explain the shapes of simple covalent molecules in terms of electron-pair repulsion (including lone pairs) and know how molecular shape can give rise to permanent dipoles. Describe hydrogen bonding, using ammonia and water as simple examples of molecules containing N–H and O–H groups. Know the importance of hydrogen bonding to the physical properties of substances, particularly ice and water, and to the structures of important organic molecules such as proteins and nucleic acids.	Ask students to think about what holds a liquid such as petrol together. Provide data on the boiling points of the noble gases and straight-chain alkanes and ask students to discuss why the boiling points increase as the atoms or molecules increase in mass. Molecular modelling kits will help to explain the degree of intermolecular forces. Use their ideas to develop the concept of temporary/induced dipoles.	As an extension, you might give boiling points for alkanes of the same molar mass but differing degrees of branching. Enquiry skill 11A.1.1	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Give students a list of electronegativities of common elements. Ask them to work out the polarities of a range of different covalent bonds. Present them with sets of data to demonstrate how molecules with similar molar masses can have very different melting points (e.g. HCl and propane). Tell them to work in small groups to try to account for these differences using their recent work on bond polarities. Ask each group to present their interpretation of one data set to the whole class. Draw out the idea of permanent dipole interactions in a whole class discussion.	These examples need to be carefully selected. Enquiry skill 11A.1.8	
	Students need to appreciate the shapes of simple covalent molecules. A simple visualisation can be carried out using long thin balloons. Give students three balloons each. Tell them to blow one up and twist it in the middle to represent two groups of electrons; this demonstrates a bond angle of 180° and a linear shape. The numbers of groups of electrons can be increased by twisting in more balloons (e.g. four groups will give a tetrahedral shape that can be linked to methane, ammonia and water). For each example, ask students to draw dot and cross diagrams of molecules represented by the given number of electron groups and use these to derive the bond angle and molecular shape. Emphasise the importance of molecular shape on molecular dipoles and how this links to intermolecular forces using the following activity. Tell students to run samples of water, propanone, ethanol, cyclohexane and methylbenzene from burettes into a beaker and to place a charged polythene rod next to the jet. Ask them to make a note of whether the liquid jet is deflected by the rod. Then ask them to draw structures of the molecules and to interpret their results in small discussion groups.	Take care to reinforce that a group of electrons can be a single double or triple covalent bond or a lone pair of electrons. Enquiry skills 11A.4.1, 11A.4.2	
	Present students with line graphs of: • variation in boiling points of the hydrides of group IV, V, VI and VII elements in periods 2–5; • variation in the enthalpy changes of vapourisation of the hydrides of group IV, V, VI and VII elements in periods 2–5. HF, NH_3 and H_2O all have much higher values than would be predicted from the other elements. Ask students to discuss in small groups why this is. Then, as a class, discuss hydrogen bonding, particularly why it is so strong compared with other intermolecular forces and what special conditions are needed for it to arise. Students can then draw diagrams for water and ammonia and explain why ammonia is so soluble in water. You may wish to demonstrate 'the fountain experiment' at this stage.	**Safety**: Concentrated ammonia solution needs to be handled in a fume cupboard.	

Objectives	Possible teaching activities	Notes	School resources
	Allow students to research on the Internet the impact of hydrogen bonding on the structure of ice, the density of ice and the melting point of ice. Tell them to draw up a summary of these properties and to link them to the implications for everyday life (e.g. pipes bursting in winter, ice floating in cold drinks, icebergs). They could also incorporate an account of why the unusually high melting point and density of ice/water are particularly important for life on this planet. Ask students to examine models and animations of biomolecules such as DNA and nucleic acids to identify where hydrogen bonding exists and its importance in overall molecular shape.	**ICT opportunity:** Use of the Internet.	
1 hour **Dative bonding** Describe coordinate (dative covalent) bonding, as exemplified by the formation of the ammonium and hydroxonium ions and in the structure of carbon monoxide.	Brainstorm student understanding of covalent bonding. Give them the formulae of carbon monoxide, ammonium and hydroxonium ions and ask them to draw dot and cross diagrams for each. Students could work in pairs on one example and then report back to the whole class. Use their answers in class discussion to develop the idea of dative bonding.		
2 hours **Structure and properties** Account for the differences in physical properties of substances by reference to different types of bonding: ionic bonding; covalent bonding; hydrogen bonding; other intermolecular interactions; metallic bonding. Describe, in simple terms, the differences between the lattice structures of crystalline solids which are: ionic, as in sodium chloride; simple molecular, as in iodine; giant molecular, as in graphite, diamond or silicon(IV) oxide; hydrogen bonded, as in ice; metallic, as in copper.	Much of this section is revision and consolidation. Provide students with a drop and drag activity or sort cards. Tell them their task is to select an element or compound (e.g. sodium chloride) and match to it the relevant card giving the bonding type and structure. Next get them to add their own cards listing a number of properties relating to that substance (e.g. high melting point). Finally, ask them to pass their work to a partner who has to explain how the property is related to the bonding type.		
	Allow students to download images of giant lattices from the Internet and use these to make a wall display of the different structure types. Alternatively, students could work individually matching descriptions to visual representations of structures using cards.	**ICT opportunity:** Use of the Internet. It would be useful to have a number of models and actual samples in the lab for students to see and touch (e.g. zinc, copper sulfate, ice, iodine).	

Objectives	Possible teaching activities	Notes	School resources
3 hours **Electron orbitals and hybridisation** Describe the number and relative energies of the s, p, d and f orbitals for the principal quantum numbers 1, 2, 3 and 4 and show how this leads to the structure of the periodic table.	Revisit with students their knowledge and understanding of electron configuration from Grade 10. Show the class a plot of atomic number versus first ionisation energy (or, if you have time, get students to prepare their own). Ask why there is not a regular increase in ionisation energy between lithium and neon (and any other examples you care to use). Using the analogy of a filing cabinet, explain that each shell (drawer) is split into subshells (hanging files) and each subshell is further divided into atomic orbitals (folders within the hanging file). Each orbital can hold a maximum of two electrons (two sheets of paper). Describe the principal quantum numbers, the names of the subshells and the number of orbitals associated with each different type of subshell. Finally, show students the relative energy levels for each of the subshells.	Make sure you include information on Hund's rule and Pauli's exclusion principle.	
Describe the shape of the s and p orbitals and their hybrids in atoms such as carbon and oxygen. Describe covalent bonding in terms of orbital overlap, giving σ (sigma) and π (pi) bonds; explain bond shape and angles in ethane, ethene and benzene in terms of σ and π bonds. Explain the lack of reactivity of the triple bond (as in nitrogen) in terms of bonding theory.	Now get students to fill in an orbital (electrons in box) exercise to show the electronic configurations of the first 56 elements. Tell them to shade in one colour all the elements on a periodic table where the highest energy electron is in an s subshell and repeat for p, d and f. This will allow them to appreciate the blocks on the periodic table and what each different period represents. Ask why it is that the electronic configuration of carbon is $1s^2 2s^2 2p^2$ yet it forms four single covalent bonds in methane, two single covalent bonds and one double covalent bond in ethene. Encourage students to download Java applets showing the shapes of s and p orbitals. They can search the Internet for sites showing the hybridisation of orbitals to form sp^3, sp^2 and sp orbitals and the types of bonds they form in ethane, ethene and benzene. Ask students to make molecular energy drawings for N_2 in order to establish the type of bonding present. From this they will see that the system is stable and a lot of energy is needed to break up the molecule, hence N_2 is very stable.	A good site for this is www.chem.ucalgary.ca/courses/351/Carey5th/Ch02/ch2-3.html For detail of bonding in oxygen try www.mpcfaculty.net/mark_bishop/molecular_orbital_theory.htm **ICT opportunity:** Use of the Internet and Java applets.	

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	a. *Explain, why silane (SiH_4) has a lower boiling point than H_2S, which has the same molar mass.* b. *Draw a diagram to show how hydrogen bonds form between H_2SO_4 and H_2O.*		
	Draw dot and cross diagrams for SiH_4, SF_2, $COCl_2$ and HCN. *For each, draw a diagram to illustrate the shape of the molecule and indicate the approximate bond angles.*		
	CO_2 and SiO_2 are both oxides of group IV elements, yet have very different physical properties. Using your knowledge of their structures, explain the differences in the properties given in the table below:		
	Carbon has an electronic configuration of $12^2\ 2s^2\ 2p^2$. It forms four bonds when it reacts. Describe, with diagrams, how the bonding in ethane and ethene occurs.		

	Boiling point/K	**Solubility in water**
CO_2	195	soluble
SiO_2	2503	insoluble

GRADE 11A: Chemistry 2

How much is there?

UNIT 11AC.2
9 hours

About this unit

This unit is the second of six units on chemistry for Grade 11 advanced.

The unit is designed to guide your planning and teaching of chemistry lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For consolidation activities, look at the scheme of work for Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already be able to write balanced molecular and ionic equations for simple reactions. They should be able to explain the macro-properties of the different states of matter in terms of their micro-structure

Expectations

By the end of the unit, most students solve problems using the mole, the Avogadro constant, molar solutions, molar gas volume and the universal gas equation.

Students who progress further solve complex problems using the mole, the Avogadro constant, molar solutions, molar gas volume and the universal gas equation.

Resources

The main resources needed for this unit are:

- two bags of different sized nails (approximately 100 per bag); one set per pair of students
- sealed boiling tubes containing numbers of moles of elements pre-weighed and labelled (e.g. 0.5 mol of lead, 1.0 mol of sulfur).
- copper strips, iodine crystals, fume cupboard, accurate balance(s)
- dilute acids and alkalis, appropriate indicator
- class sets of equipment to demonstrate Charles's law and Boyle's law
- range of problems for students
- student copies of the periodic table

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *reacting mass*, *stoichiometry*, *mole*, *Avogadro constant*, *empirical formula*, *molecular formula*
- *concentration*, *titration*
- *molar volume of a gas*, *ideal gas equation*, *standard temperature and pressure* (*STP*)

Standards for the unit

9 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards	EXTENSION STANDARDS
4 hours **Working with solids** **3 hours** **Working with solutions** **2 hours** **Working with gases**	10A.17.12	Write equations with state symbols for simple reactions, including ionic equations for reactions in aqueous solution, given the formulae of reactants and products.	11A.19.1	Write balanced equations and use them to provide information on reacting masses.	
			11A.19.2	Define a *mole* of a substance in terms of the Avogadro constant and use it in stoichiometric calculations.	
			11A.19.3	Calculate empirical and molecular formulae using combustion data or composition by mass.	
			11A.19.4	Determine concentrations of reactants in solutions through acid–base titrations with appropriate indicators.	
	10A.17.13	Use the kinetic particle theory to explain the main characteristics of the three states of matter and changes between the states: • the basic assumptions of the kinetic theory as applied to an ideal gas …	11A.19.5	Apply the kinetic particle model to an ideal gas and explain, in terms of molecular size and intermolecular forces, how the behaviour of real gases deviates from the ideal model at high pressures and low temperatures.	
			11A.19.6	Define *molar volume* and use it in calculations on the reacting volumes of ideal gases.	
			11A.19.7	Use the general gas equation $PV = nRT$ and the concept of relative molar volume at STP in calculations related to ideal gases.	

Objectives	Possible teaching activities	Notes	School resources
4 hours **Working with solids** Write balanced equations and use them to provide information on reacting masses. Define a *mole* of a substance in terms of the Avogadro constant and use it in stoichiometric calculations. Calculate empirical and molecular formulae using combustion data or composition by mass.	Provide students with word equations representing a range of reactions. Ask them to write balanced formula equations for them. Then get them to work in pairs to mark each other's work and feed back corrections. Revise calculating formula mass by carrying out a class quiz. Set a problem involving reacting masses (e.g. calculate the mass of carbon dioxide produced by heating 15.0 g of limestone) and help students solve it using the teaching approach outlined below. 1 Hold a class discussion on the need to carry out this type of calculation. 2 Check students' appreciation of the conservation of mass by placing a volumetric flask containing a fixed volume of 1 mol dm^{-3} hydrochloric acid and a test-tube containing 0.1 mol dm^{-3} silver nitrate solution on a balance. Take a mass reading and remove from the balance. Mix the two liquids to produce a precipitate. Before putting back on the balance, ask students to vote on whether they think the total mass has decreased, stayed the same or increased. Reweigh and discuss the result. 3 (i) Ask students to write a balanced formula equation: $CaCO_3 \rightarrow CaO + CO_2$ (ii) They should then calculate the molar masses for each reactant and product and write these under each component in the balanced equation. Use this to reinforce conservation of mass: $CaCO_3 \rightarrow CaO + CO_2$ 100 g 56 g 44 g (iii) Ask students which reactants and products are needed for the question and discard data for any others (in this case CaO). Reduce the known mass to 1 g and ratio the unknown mass appropriately: $CaCO_3 \rightarrow CaO + CO_2$ $^{100}/_{100}$ g $^{44}/_{100}$ g 1 g 0.44 g (iv) Take the known mass up to the value given in the question and ratio the unknown mass appropriately: $CaCO_3 \rightarrow CaO + CO_2$ 1 g 0.44 g 1 × 15 g 0.44 × 15 g Answer: 15.0 g limestone produces 6.6 g of carbon dioxide. Give them copies of this as a template to use in future examples. Ask students to work in pairs and give them further examples of increasing complexity (e.g. reactants do not react in a ratio of 1:1, the mass of a reactant needs to be calculated from a given mass of product).	The discussion could include calculating yield/profit in industry, environmental concerns.	Use this column to note your own school's resources, e.g. textbooks, worksheets.

Objectives	Possible teaching activities	Notes	School resources

Give students two bags of different sized nails. Ask them to weigh one nail of each size and calculate the ratio of their masses. Ask them to repeat the exercise but this time weighing five of each, then ten of each, twenty of each, and so on. Tabulate their results and, for each example, calculate the ratio of the masses. In each case, as long as the numbers of each nail are the same, the ratio of their masses will be the same. Refer to atoms and how small they are. Each type of atom has a fixed mass, and these atoms' masses are in a fixed ratio to each other (just like the nails). Since we cannot weigh individual atoms, we need to weigh multiples of them. As long as there are the same numbers of each type of atom, the ratio of their masses will remain unchanged. By having the same large number (6.02×10^{23}, the Avogadro constant) of each, the ratio of masses stays the same. The mass we use in this case is the relative atomic mass in grams and is called the molar mass (g mol–1).

Students can practise calculating the mass of different numbers of moles of different substances, or calculating the number of moles there are in a given mass of a substance. Have different samples of elements weighed out into sealed boiling tubes (e.g. 1 mol of lead, 0.5 mol of sulfur) in order to give visual consolidation. Using the equations balanced by students in the last section, introduce the concept of stoichiometry, by working out how many moles of one substance react with how many moles of another substance in each reaction.

Notes: Enquiry skills 11A.3.1, 11A.3.3

Ask students to place a clean pre-weighed copper strip (15 cm × 1 cm) into a test-tube with approximately 0.3 g iodine crystals in the bottom and warm gently (to prevent iodine vapour escaping) until there is no more iodine vapour left. Tell them to weigh the copper plus copper iodide, scrape the yellow copper iodide from the surface of the copper and reweigh the copper strip, carefully recording all their results. They can then calculate the number of moles of copper and iodine that have reacted and from that calculate the formula of the copper iodide. They can use their results to calculate percentage errors for the measurements they have made.

Consolidate the process of determining the molecular formulae of compounds through sample calculations. At this stage it would be good to give data for compounds formed by direct combination (e.g. $FeCl_3$). Students may find it useful to use the format below to record their calculations.

	Element A	**Element B**
Mass (g)		
Number of moles		
Ratio of A : B		
Formula		

Notes: **Safety:** Heat in a fume cupboard or place a cotton wool plug in the mouth of the test-tube.

Enquiry skill 11A.1.5

Give students the data for benzene (92% C and 8% H) and ask them to calculate the formula for the compound. They will arrive at the formula CH; ask them to draw this compound. This can lead on to a class discussion on empirical formulae. Consolidate the concept using examples in which students are given a range of examples of molecular formulae from which they derive the empirical formulae.

Now give students data from combustion analysis of hydrocarbons so that they can determine the molecular formula/empirical formula of the compound undergoing combustion.

Notes: Enquiry skill 11A.3.2

Objectives	Possible teaching activities	Notes	School resources
3 hours **Working with solutions** Determine concentrations of reactants in solutions through acid–base titrations with appropriate indicators.	Discuss with students why it is necessary to be able to calculate the concentration of a solution (e.g. environmental analysis, pharmaceutical quality control). Ask them to consider an alkaline solution and what they would need to do in order to determine the concentration. They will need to understand what *concentration* means and the appropriate units ($g\,dm^{-3}$, $mol\,dm^{-3}$). Give them short exercises that allow them to practise calculating concentrations of solutions. Demonstrate how to carry out an acid/alkali titration (using a strong acid of known concentration and a strong alkali of unknown concentration). Give students sample graphs showing how pH changes as a titration progresses for strong acid / strong alkali, strong acid / weak alkali, weak acid / strong alkali and weak acid / weak alkali and a chart showing the colour changes for different common indicators. Ask students to use this chart to explain why the selected indicator was used. Take care to show in detail the technique. It may be useful to have a visual record of the process (e.g. on CD-ROM) so students can access this at any time. Allow students time to practise the titration technique individually. Guide them through the calculation to determine the concentration of the alkali.		
	Now give students a sample of 'acid rain' (typically 0.001 $mol\,dm^{-3}$ sulfuric acid) and tell them to work in pairs to plan, carry out and analyse their own results.	Enquiry skills 11A.1.4, 11A.1.5, 11A.4.1	
	Give students a series of practice concentration calculations to carry out. These should be graded in difficulty to suit the needs of individual students.	Enquiry skill 11A.3.2	
2 hours **Working with gases** Apply the kinetic particle model to an ideal gas and explain, in terms of molecular size and intermolecular forces, how the behaviour of real gases deviates from the ideal model at high pressures and low temperatures. Define *molar volume* and use it in calculations on the reacting volumes of ideal gases. Use the general gas equation $PV = nRT$ and the concept of relative molar volume at STP in calculations related to ideal gases.	Give students experimental data on the mass of 1 dm^3 of a number of different gases at 25 °C and 1 atm pressure. Define *standard temperature and pressure* (*STP*). Ask them individually to calculate the volume of 1 mol of each gas. This will lead to developing a definition for the 'molar volume of a gas'. Now give them sample calculations using reacting volumes to carry out. Good contexts include combustion of alkanes and the Haber process.		
	Ask students to carry out practical work to demonstrate Charles's and Boyle's laws and use their conclusions to derive the ideal gas equation $pV = nRT$ (make sure students use kelvin values for temperature). Now give them sample calculations using the ideal gas equation to carry out.	For a diagram and details of class equipment to demonstrate Charles's Law and Boyle's laws, see: chemed.chem.purdue.edu/genchem/topicreview/bp/ch4/gaslaws3.html Enquiry skills 11A.2.1, 11A.2.3	
	Discuss with students the assumptions made (i.e. that molecules of an ideal gas are assumed to occupy negligible volume and exert no forces on each other). Ask students to work in groups of three or four to consider the impact on the value of pV/RT as the pressure increases if the gas is non-ideal. Repeat the exercise to consider the impact on the value of pV/RT as the temperature increases if the gas is non-ideal. Present actual graphical data for students showing the behaviour of a non-ideal gas and discuss how their predictions match real gas behaviour.		

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*In the blast furnace, iron is produced by the reduction of iron(III) oxide to iron by reacting it with carbon monoxide. Carbon dioxide is also produced in the reaction.* a. *How many tonnes of iron oxide are needed to produce 1 tonne of iron?* b. *Assuming iron ore contains 60% iron(III) oxide, what mass of the ore is needed to produce1 tonne of iron?*	Give each student a list of Ar values or a copy of the periodic table.	
	Iron burns in chlorine to produce iron chloride. 5.60 g of iron reacts with 10.65 g of chlorine. *Deduce the equation for the reaction.*		
	Temporary hardness in water is caused by the presence of calcium hydrogencarbonate. This solute can be determined by titration with hydrochloric acid: $Ca(HCO_3)_2 + 2HCl \rightarrow CaCl_2 + 2CO_2 + 2H_2O$ *500 cm^3 of a water sample requires 6.0 cm^3 of 0.25 mol dm^{-3} hydrochloric acid in a titration. What is the concentration of $Ca(HCO_3)_2$ present in the water? Give your answer in mol dm^{-3} and g dm^{-3}.*		
	100 cm^3 of butane undergoes complete combustion. a. *What volume of oxygen is needed for the reaction?* b. *Air is approximately 20% oxygen. What volume of air is needed for the reaction?* c. *What volume of carbon dioxide is formed?*		
	A balloon can hold 1000 cm^3 of air before bursting. The balloon contains 975 cm^3 at 5 °C. Will it burst when it is taken into a room at 27 °C? Show the workings to support your answer.		

GRADE 11A: Chemistry 3

Electrochemistry

UNIT 11AC.3
7 hours

About this unit

This unit is the third of six units on chemistry for Grade 11 advanced.

The unit is designed to guide your planning and teaching of chemistry lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already be able to recognise periodicity in the properties of elements and their compounds, particularly the elements of the first transition series.

Expectations

By the end of the unit, students know that oxidation and reduction reactions are associated with gain or loss of electrons and explain redox reactions in terms of change in oxidation number. They know that transition metals are important redox reagents because they exhibit multiple oxidation states. They understand and use the concepts of redox potential and half-cell potential.

Students who progress further know and understand that oxidation and reduction reactions are associated with gain or loss of electrons and explain complex redox reactions in terms of change in oxidation number.

Resources

The main resources needed for this unit are:

- magnesium ribbon, class sets of equipment for small-scale electrolysis, copper chloride solution
- samples of transition metal compounds
- zinc, copper(II) sulfate, copper, zinc sulfate, silver nitrate
- power packs, graphite electrodes, assorted metal strips, salts of each of the metals, filter paper, potassium nitrate(V), potassium halides
- standard hydrogen electrode and/or simplified diagram
- sodium hydroxide solution, electrolysis cell, graphite rods, voltmeters, small test-tubes
- assorted data (see notes column in the activities section)
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *oxidation*, *reduction*, *redox*, *electron transfer*, *oxidation number*
- *cell potential*, *half-cell*
- *standard electrode potential*, *standard cell potential*
- *dry cell*, *accumulator*
- *faraday*

Standards for the unit

7 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
2 hours **Redox**			11A.23.1	Explain oxidation and reduction in terms of gain or loss of oxygen and in terms of electron transfer.		
			11A.23.2	Explain redox reactions in terms of change in oxidation number.		
3 hours **Electrochemistry**	10A.19.7	Know that the elements of the first transition series (titanium to copper) have similar physical and chemical properties and relate this to their electronic structures.	11A.23.3	Know that variable oxidation number is an important feature of transition metal chemistry and explain it in terms of the elements' electronic structures.	12A.19.10	Explain how the variable oxidation states can result in transition metal ions acting as oxidising and reducing agents. Give examples of transition metal redox systems
1 hour **Applications of electrochemistry**			11A.23.4	Measure cell potentials and relate them to the relative position of the metals in the reactivity series; describe the chemical changes in a cell in terms of half-cell reactions.		
1 hour **Calculations in electrochemistry**			11A.23.5	Define standard electrode potentials relative to the standard hydrogen electrode and describe methods used to measure the standard electrode potentials of metals or non-metals in contact with their ions in aqueous solution. Calculate a standard cell potential by combining two standard electrode potentials.		
			11A.23.6	Know the half-cell reactions of everyday cells, such as the dry cell and the accumulator.		
			11A.23.7	Describe the function of a fuel cell with particular reference to the hydrogen–oxygen cell.		
			11A.23.8	Be aware of the need to recycle modern rechargeable batteries, such as those in computers and cellular telephones, because of the poisonous heavy metals they contain (e.g. mercury and cadmium).		
			11A.23.9	Know and use the concept of the faraday (96 500 coulombs) as a mole of electrons.		

<table>
<tr><th>Objectives</th><th>Possible teaching activities</th><th>Notes</th><th>School resources</th></tr>
<tr>
<td rowspan="2">2 hours

Redox

Explain oxidation and reduction in terms of gain or loss of oxygen and in terms of electron transfer.

Explain redox reactions in terms of change in oxidation number.

Know that variable oxidation number is an important feature of transition metal chemistry and explain it in terms of the elements' electronic structures.</td>
<td>Demonstrate burning magnesium in air. Ask students to write a balanced equation for the reaction and introduce the idea of oxidation being the addition of chemically bonded oxygen. Ask students to write ion equations for the two half reactions.

Introduce the idea of oxidation and reduction in terms of gain or loss of oxygen and in terms of electron transfer. Give students a number of half equations (e.g. those for the electrolysis of $CuCl_2(aq)$) and ask them to determine the species being oxidised and reduced. Ask them to mark each other's answers.

Light a Bunsen burner (or equivalent). Ask students to write a balanced equation for the reaction. They will not be able to write ionic equations for this, so introduce the concept of oxidation numbers and the rules governing assigning oxidation numbers.

Allow students to practise assigning oxidation states with a range of examples of individual atoms, ions and molecules.

Give students a range of equations involving redox reactions and ask them to assign oxidation states to all the species involved. Then ask them to determine which species has been oxidised and which has been reduced.</td>
<td>Use magnesium ribbon.

Safety: Make sure students do not look directly at the burning magnesium. Give them pieces of cobalt glass to look through.

Appropriate data needed.</td>
<td rowspan="2">Use this column to note your own school's resources, e.g. textbooks, worksheets.</td>
</tr>
<tr>
<td>Provide students with a range of samples of transition metal compounds and with a worksheet like the one below to complete for each compound.

<table>
<tr><th colspan="4">Compound:</th></tr>
<tr><th>Symbol of transition metal</th><th>Oxidation state of transition metal</th><th>Colour of the compound</th><th>Electronic configuration of the metal</th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

In class discussion, draw out why the transition metals are able to form a range of oxidation states.</td>
<td>Students will need: samples of transition metal compounds, a blank worksheet for each compound.</td>
</tr>
</table>

Objectives	Possible teaching activities	Notes	School resources
3 hours **Electrochemistry** Measure cell potentials and relate them to the relative position of the metals in the reactivity series; describe the chemical changes in a cell in terms of half-cell reactions. Define standard electrode potentials relative to the standard hydrogen electrode and describe methods used to measure the standard electrode potentials of metals or non-metals in contact with their ions in aqueous solution. Calculate a standard cell potential by combining two standard electrode potentials.	Ask students to place a small piece of zinc into a solution of copper(II) sulfate and a small piece of copper into a solution of zinc sulfate and to observe what happens in each case. Ask them to write half equations for the reaction that occurs (i.e. zinc into a solution of copper(II) sulfate – no reaction occurs in the second scenario). Now ask students to place a small piece of copper into a solution of silver nitrate and to observe what happens. Then ask them to write ion equations for the reaction that occurs. Introduce students to the idea of what happens when a metal ion/metal half-cell is produced. Discuss the reasons why some systems will have a greater degree of ionisation than others, using the examples above.	Students will need: zinc, copper(II) sulfate solution, copper, zinc sulfate solution, silver nitrate solution.	
	Demonstrate how to set up an electrochemical cell using two metal ion/metal half-cells. Explain how they can tell which is the anode and which is the cathode in a cell. Provide students with strips of metals and a salt solution for each metal (e.g. Zn and $ZnSO_4$(aq)). You might choose zinc, iron, nickel and copper. Ask students, in pairs, to design an investigation to determine the order of reactivity of the metals provided by constructing a potential difference chart.	Students will need: power packs, assorted metal strips, salts of each of the metals, filter paper, potassium nitrate(V) Students need to make salt bridges by soaking filter paper in a solution of the potassium nitrate(V). Enquiry skills 11A.1.1–11A.1.4, 11A.3.1, 11A.4.2	
	Get them to discuss the limitations of their findings; this will lead to an understanding of the need for a standard reference electrode. Introduce them to the standard hydrogen electrode and standard conditions.	Show students a standard hydrogen electrode and/or a simplified diagram.	
	If standard hydrogen electrodes are available, get students to make up standard solutions and use them to determine the standard electrode potentials of a number of metal ion/metal half-cells. If no standard hydrogen electrodes are available, ask students to determine the electrode potentials of a number of metal ion/metal half-cells compared with a Cu^{2+}/Cu standard half-cell and adjust appropriately to give E^θ values. Tell them to repeat this process using halogen/halide half-cells with graphite electrodes. Draw out the reasons why the metal/metal ion half-cells have negative E^θ values while those for the halogen/halide half-cells are positive. Ask students to compare their E^θ values against those given in the literature and account for any differences. Ask how they could improve the design of their investigation.	Students will need: power packs, graphite electrodes, assorted metal strips, salts of each of the metals, filter paper, potassium nitrate(V), copper, copper sulfate, potassium halides. Students need to make salt bridges by soaking filter paper in a solution of the potassium nitrate(V). Enquiry skills 11A.1.4–11A.1.6, 11A.1.8, 11A.3.1, 11A.3.3	
	Provide students with data of standard electrode potentials for a range of half-cells. Do a worked example to show how to determine the direction of reaction for each half-cell, and how to write a balanced equation for the reaction and determine the standard cell potential by combining the two relevant standard electrode potentials. Select two half-cells from the data and ask students to: • determine what reactions would occur when two different half-cells are connected together; • write a balanced equation for the reaction; • determine the standard cell potential. Ask students to work in pairs and challenge each other to do the same with a different set of half-cells and check their partner’s answer.	Provide students with appropriate data.	

Objectives	Possible teaching activities	Notes	School resources
1 hour **Applications of electrochemistry** Know the half-cell reactions of everyday cells, such as the dry cell and the accumulator. Describe the function of a fuel cell with particular reference to the hydrogen–oxygen cell. Be aware of the need to recycle modern rechargeable batteries, such as those in computers and cellular telephones, because of the poisonous heavy metals they contain (e.g. mercury and cadmium).	Ask students to work in small groups to research the chemistry and uses of everyday cells (using the Internet and other sources) to produce a poster. Tell them to include the recycling of rechargeable batteries and to research the methods used to do this in Qatar.	**ICT opportunity:** Use of the Internet. Enquiry skills 11A.2.2, 11A.2.4, 11A.2.5, 11A.3.4	
	Ask students to make their own small-scale fuel cell by electrolysing sodium hydroxide solution and collecting the gases formed at the anode and cathode. Then tell them to disconnect the DC supply, connect the graphite electrodes to a high-resistance voltmeter and observe the results. Discuss with students the advantages and disadvantages of the use of such a fuel cell, and how they might research alternative sources of fuel (e.g. methane).	**Safety:** Sodium hydroxide is corrosive. Students will need: power packs, sodium hydroxide solution, electrolysis cell, graphite rods, voltmeters, small test-tubes. Enquiry skills 11A.2.4, 11A.4.1	
1 hour **Calculations in electrochemistry** Know and use the concept of the faraday (96 500 coulombs) as a mole of electrons	Give students the equation for the quantity of electric charge used: Q (C) = I (A) × t (s) Ask students, in pairs, to set up the equipment to carry out electrolysis using copper anode and cathode with copper chloride solution as the electrolyte. Tell them that after a suitable time (about 40 minutes) they should determine the increase in mass of the cathode. This can be used in conjunction with the time taken for the electrolysis and the current to determine the number of coulombs needed to deposit 1 mole of copper. (This approximates to twice the Faraday constant.) Provide students with similar data for the deposition of a range of metals with +1, +2 and +3 charge and ask them to calculate the number of coulombs needed in each case to deposit 1 mole of each metal.	Students will need: power packs, filter paper potassium nitrate(V), copper, copper chloride solution, ammeters. Students need to make salt bridges by soaking filter paper in a solution of the potassium nitrate(V). Enquiry skills 11A.4.1, 11A.4.2, 11A.3.1–11A.3.3	

	Examples of assessment tasks and questions	Notes	School resources

Assessment

Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.

What are the oxidation numbers of

i. *chlorine in HCl, HClO, ClO_3^-, PCl_3, Na_3AlCl_6, $POCl_3$*

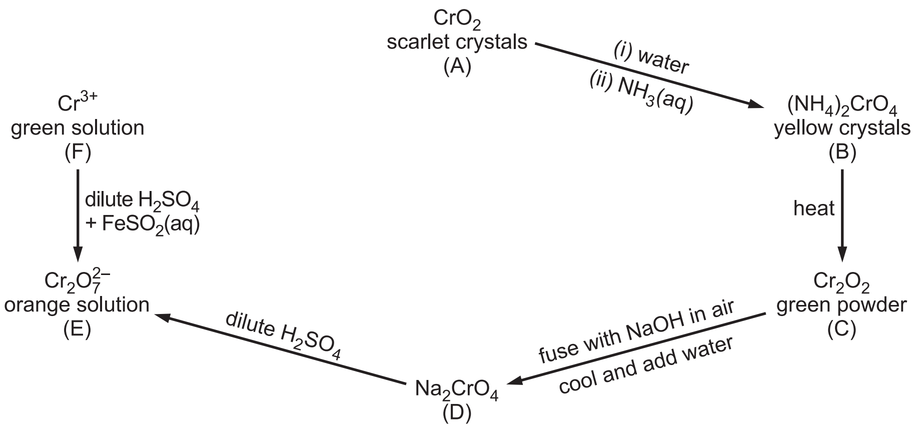
ii. *nitrogen in N_2O, NO, NO_2, NO_3^-, N_2H_4, HCN*

From G. Hill, and J. Holman, 1989, *Chemistry in Context*, 5th edn, Nelson

i. *What is the oxidation number of chromium in each of the substances A–F in the reaction scheme given?*

ii. *Which steps in the scheme involve redox reactions?*

iii. *Write equations or half equations to describe each step in the scheme.*



From G. Hill, and J. Holman, 1989, *Chemistry in Context*, 5th edn, Nelson

Use the data in the electrode potential chart to answer the following questions:

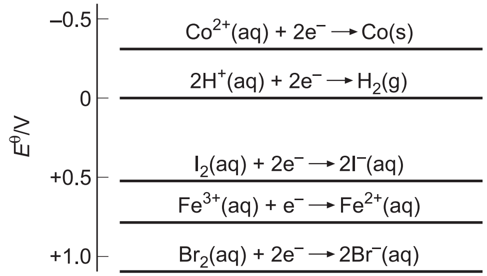
i. *Will cobalt metal react with dilute hydrochloric acid to produce hydrogen gas? Give a reason for your answer.*

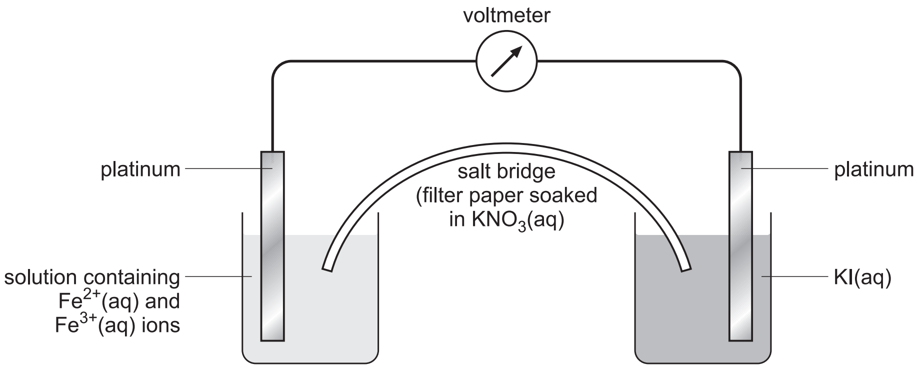
ii. *Predictions of this nature are not always borne out in practice. Suggest two possible reasons for this.*

iii. *Which of the halogens shown in the chart will convert Fe^{2+}(aq) to Fe^{3+}(aq) ion? Write a balanced equation for the reaction you choose.*

iv. *Draw a labelled diagram of the experimental apparatus by which you could measure E^{θ}_{cell} for the reaction you described in part iii.*

From Salters chemistry materials



	Examples of assessment tasks and questions	Notes	School resources
	Look at the apparatus in the diagram. When the circuit is complete, a brown colour appears around the platinum in the right-hand beaker. i. *Write a half equation to summarise the reaction at each of the platinum electrodes.* ii. *In which direction do electrons flow?* iii. *Explain the function of the salt bridge, stating which ions are moving in and out of it in each beaker.*  **Adapted from G. Hill, and J. Holman, 1989, *Chemistry in Context*, 5th edn, Nelson**		
	Write a newspaper article for the general public explaining to them the advantages and disadvantages of using rechargeable batteries. Include information on how the reader can minimise environmental impact.		

GRADE 11A: Chemistry 4

Chemical patterns: part 2

UNIT 11AC.4
6 hours

About this unit

This unit is the fourth of six units on chemistry for Grade 11 advanced.

The unit is designed to guide your planning and teaching of chemistry lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already be able to recognise periodicity in the properties of elements and their compounds, particularly the elements of the first transition series.

Expectations

By the end of the unit, students know the properties of the common compounds of silicon, nitrogen, phosphorus, oxygen and sulfur, and the characteristic properties of the first-row transition elements.

Students who progress further predict the likely oxidation states of a transition element from its electronic configuration. They understand transition metals' redox systems.

Resources

The main resources needed for this unit are:

- class sets of equipment to generate and collect a gas over water
- oxygen cylinder
- Hoffmann voltameter
- pieces of coloured fabric
- gas jar of nitrogen, magnesium ribbon
- ammonia solution, solutions of copper salts, dilute sulfuric acid, a range of ammonium compounds, assortment of alkaline solutions
- model building kits
- samples of silicon, graphite and diamond (or a photograph of diamond)
- ammonium vanadate(V) solution made up in acidic solution, zinc granules; iron(II) chloride solution and iron(III) chloride solution, sodium hydroxide solution; potassium sodium 2,3-dihydroxybutanedioate, hydrogen peroxide solution (20 vol.), cobalt(II) chloride, $CoCl_2{\cdot}6H_2O$
- iron(II) chloride solution, iron(III) chloride solution, sodium hydroxide solution
- potassium sodium 2,3-dihydroxybutanedioate, hydrogen peroxide solution (20 vol.), cobalt(II) chloride, $CoCl_2{\cdot}6H_2O$
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *acid*, *oxidising agent*, *oxidant*, *oxidation state*
- *electronic configuration*
- *catalyst*
- *transition metal*

Standards for the unit

6 hours	SUPPORTING STANDARDS	CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
2 hours **Oxygen and sulfur** **2 hours** **Nitrogen and phosphorus** **1 hour** **Carbon and silicon** **1 hour** **Transition metals**		11A.21.1	Know the main properties and uses of oxygen, and the test for it.	
		11A.21.2	Know that water is a compound of hydrogen and oxygen.	
		11A.21.3	Show an understanding of the properties of hydrogen peroxide as an acid and an oxidising agent and understand the use of peroxides as oxidants in rockets and explosives.	
		11A.21.4	Know that ozone is a form of oxygen formed when oxygen is subjected to electrostatic discharges or high-energy radiation and that it is a powerful oxidising agent.	
		11A.21.5	Know the physiological effects of ozone and recognise that in the lower atmosphere it is a pollutant but that in the upper atmosphere it protects living materials from destructive high-energy radiation.	
		11A.21.6	Compare the physical and chemical properties of sulfur and oxygen and their simple compounds, such as their hydrides.	
		11A.21.7	Know and explain the existence of two oxidation states of sulfur in its common compounds, as typified by its two common oxides and the two acids and series of salts that they form.	
		11A.21.8	Know the importance of sulfur dioxide in the preparation of sulfuric acid and in food preservation.	
		11A.21.9	Know the role of sulfur dioxide in the formation of acid rain and describe the main environmental consequences of acid rain.	
		11A.21.10	Know that nitrogen is an unreactive gas but that it can form nitrides with reactive metals.	
		11A.21.11	Know the test for ammonia, the main properties and uses of its compounds and their reaction with warm alkali.	
		11A.21.12	Know the main properties and uses of nitrates and understand their environmental impact.	
		11A.21.13	Know why nitrogen and phosphorus exhibit two common oxidation states in their compounds and how this leads to two series of compounds.	
		11A.21.14	Recognise the importance of nitrogen and phosphorus to living things.	
		11A.21.15	Compare and contrast the physical and (inorganic) chemical properties of the group IV elements carbon and silicon and their properties.	

6 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
			11A.21.16	Know the industrial importance of silicon and the requirement in many applications that it should be extremely pure.		
			11A.22.1	Know that transition elements typically form more than one stable ion and that they have generally similar physical and chemical properties.		
	10A.19.7	Know that the elements of the first transition series (titanium to copper) have similar physical and chemical properties and relate this to their electronic structures.	11A.22.2	Know the electronic configurations and the typical properties of the first-row transition elements.		
			11A.22.3	State some common uses of some transition elements, including examples of catalysis by transition metals, and relate these uses to their properties.	12A.19.10	Explain how the variable oxidation states can result in transition metal ions acting as oxidising and reducing agents. Give examples of transition metal redox systems.
			11A.22.4	Know that transition metals can form one or more stable ions through the involvement of electrons from the inner (d) orbitals and know that this results in multiple oxidation states.	12A.19.9	Know that in transition metals, d-electrons can be involved in bonding as well as the outer s-electrons, resulting in multiple oxidation states. Predict from its electronic configuration, the likely oxidation states of a transition element.

Objectives	Possible teaching activities	Notes	School resources
2 hours **Oxygen and sulfur** Know the main properties and uses of oxygen, and the test for it. Know that water is a compound of hydrogen and oxygen. Show an understanding of the properties of hydrogen peroxide as an acid and an oxidising agent and understand the use of peroxides as oxidants in rockets and explosives. Know that ozone is a form of oxygen formed when oxygen is subjected to electrostatic discharges or high-energy radiation and that it is a powerful oxidising agent. Know the physiological effects of ozone and recognise that in the lower atmosphere it is a pollutant but that in the upper atmosphere it protects living materials from destructive high-energy radiation. Compare the physical and chemical properties of sulfur and oxygen and their simple compounds, such as their hydrides. **[continued]**	Ask students to demonstrate the need for oxygen in combustion by burning a piece of bread in air, then in a gas jar of nitrogen, then in a gas jar of oxygen. Show students how to burn safely magnesium ribbon, iron filings, sulfur and carbon in air and then ask them to do it for themselves. Tell them to dissolve the products in water and test with universal indicator solution to show the basic nature of metal oxides and the acidic nature of non-metal oxides.	**Safety:** Students must wear safety glasses when heating chemicals. Oxygen cylinders must be properly secured and should only be handled by a teacher. Make sure students do not look directly at burning magnesium. Give them pieces of cobalt glass to look through.	Use this column to note your own school's resources, e.g. textbooks, worksheets
	Ask students to electrolyse acidified water using a Hoffmann voltameter. Tell them to test the two gases collected for oxygen (relighting a glowing splint) and hydrogen (burning with a 'squeaky' pop).	Students will need to use a Hoffmann voltameter.	
	Get students to prepare oxygen gas by the catalytic decomposition of 5 vol. hydrogen peroxide solution, using MnO_2 as a catalyst. Ask them to write balanced equations to show what happens when hydrogen peroxide dissolves in water and relate this to its behaviour as an acid. Demonstrate the effect of hydrogen peroxide solution on pieces of coloured fabrics and samples of hair, to show its bleaching properties. Ask students to work in small discussion groups to examine the structure of hydrogen peroxide (and other peroxides) and try to determine why it is such a good oxidising agent. They can then relate this to the uses of peroxides as oxidants in rockets and explosives.	**Safety:** Class experiments should use concentrations of no more than 5 vol. hydrogen peroxide solution. Students will need glassware to generate oxygen and collect it over water.	
	Ask students to work in small groups to use the Internet or library resources to research the structure of ozone, and how it is produced, and the roles of ozone at tropospheric and stratospheric levels. Tell them to present their findings as a poster.	**ICT opportunity:** Use of Internet.	
	Provide students with samples of oxygen and sulfur, data on their formulae, melting points and boiling points, and an equation for the reaction of H_2S with water. Ask them to work in small groups to explain the differences in these properties. Ask students to prepare sulfur dioxide by burning a small quantity of sulfur in air and dissolving the resultant gas in water to check the pH. Demonstrate the preparation of sulfur trioxide by the contact process using platinised mineral wool as a catalyst. Ask students to draw electron energy level diagrams to explain how sulfur can have a variety of oxidation states and relate these to the formation of sulfur dioxide, sulfur trioxide and sulfuric acid.	**Safety:** Sulfur dioxide should be prepared in small quantities in a well-ventilated room. Sulfur trioxide should be prepared in a fume cupboard. Supply students with samples of oxygen and sulfur and appropriate data.	
	Ask students to work in small groups to use the Internet or library resources to research the uses of sulfur dioxide, the role of sulfur dioxide in the formation of acid rain, and the environmental impact of acid rain. Tell each student to prepare clear notes on one small section of the research and then share these with the rest of their group.	**ICT opportunity:** Use of Internet. Enquiry skills 11A.1.1–11A.1.5, 11A.2.2	

Objectives	Possible teaching activities	Notes	School resources
[continued] Know and explain the existence of two oxidation states of sulfur in its common compounds, as typified by its two common oxides and the two acids and series of salts that they form. Know the importance of sulfur dioxide in the preparation of sulfuric acid and in food preservation. Know the role of sulfur dioxide in the formation of acid rain and describe the main environmental consequences of acid rain.	Ask students use their findings about the impact of acid rain on the environment to develop a focused research question, make predictions, and design, carry out and evaluate an investigation related to this issue. For example, they could investigate the impact of different concentrations of sulfur dioxide on plant growth, using cress in sealed containers.		
2 hours **Nitrogen and phosphorus** Know that nitrogen is an unreactive gas but that it can form nitrides with reactive metals. Know the test for ammonia, the main properties and uses of its compounds and their reaction with warm alkali. Know the main properties and uses of nitrates and understand their environmental impact. Know why nitrogen and phosphorus exhibit two common oxidation states in their compounds and how this leads to two series of compounds. Recognise the importance of nitrogen and phosphorus to living things.	Ask students to draw a 'dot and cross' diagram of N_2. Provide them with relevant bond enthalpy data and ask them to use this to explain the relative unreactivity of nitrogen. Demonstrate the burning of magnesium in nitrogen and use this to lead to a class discussion on the formation of nitrides. Ask students to draw dot and cross diagrams to show the structure of the nitride (N^{3-}) ion.		
	Get students to test ammonia solution with damp red litmus paper for the presence of ammonia gas. Ask students to use the Internet or library resources to research the main uses of common ammonium compounds (e.g. ammonium sulfate and ammonium nitrate) and then tabulate their results. Set up a circus of reactions for students to carry out, such as: • adding dilute ammonia solution dropwise to a small volume of dilute sulfuric acid and universal indicator in a test-tube; • observing the reaction of ammonia solution with solutions of copper salts; • gently heating ammonium salts and testing the product with damp red litmus paper; • gently heating ammonium compounds with different alkalis and testing the product with damp red litmus paper. Generate equations for the reactions in a class discussion.	Students will need: red litmus paper, ammonia solution, solutions of copper salts, dilute sulfuric acid, a range of ammonium compounds, an assortment of alkaline solutions. **ICT opportunity:** Use of Internet. Enquiry skill 11A.4.1	
	Ask students to obtain data on the world production and use of nitrogenous fertilisers from the Internet and to make graphical displays showing changes in use over time and differences between continents. Then ask them to research the role of nitrates in eutrophication and to use their findings to produce posters encouraging the responsible use of fertilisers.	**ICT opportunity:** Use of Internet. Use of Excel or comparable spreadsheet package. Enquiry skill 11A.1.6	

Objectives	Possible teaching activities	Notes	School resources
	Ask students to consider how nitrogen and phosphorus are able to form different oxidation states when given their electronic configurations. Ask them to search the literature to find examples of compounds of nitrogen and phosphorus and classify them relative to the oxidation state of the nitrogen or phosphorus.	Students will need a range of chemistry reference books. Enquiry skill 11A.1.8	
	Divide the class in two. Tell one half of the class to use the Internet or library resources to research the importance of phosphorus in living things and the other half to research the importance of nitrogen in living things. Ask each group to produce a PowerPoint presentation and give a short presentation to the whole class on their findings. Ask each group to produce a handout for the rest of the class.	**ICT opportunity:** Use of Internet. Use of PowerPoint and a data projector	
1 hour **Carbon and silicon** Compare and contrast the physical and (inorganic) chemical properties of the group IV elements carbon and silicon and their properties. Know the industrial importance of silicon and the requirement in many applications that it should be extremely pure.	Allow students to examine samples of silicon, graphite and diamond (or a photograph of a diamond). Then ask them to build molecular models to represent all three. Tell them to use these models to interpret data relating to their physical properties (e.g. melting and boiling points, electrical conductivity, solubility in water). Provide information on zone refining and ask students to explain in their own words what the process is and why it is necessary. Tell students to make pyramidal shapes from card and attach them together to simulate bonding in silicates. Peer teaching in small groups will allow them to consolidate their understanding of what is occurring. Tell students to study the similarities and differences between the chemical reactions of carbon and silicon, and to consider the physical and chemical differences between their oxides in terms of their different structures.	Students will need: model building kits, samples of silicon, graphite and diamond (or a photograph of a diamond), information on zone refining.	

Objectives	Possible teaching activities	Notes	School resources
1 hour **Transition metals** Know that transition elements typically form more than one stable ion and that they have generally similar physical and chemical properties. Know the electronic configurations and the typical properties of the first-row transition elements. State some common uses of some transition elements, including examples of catalysis by transition metals, and relate these uses to their properties. Know that transition metals can form one or more stable ions through the involvement of electrons from the inner (d) orbitals and know that this results in multiple oxidation states.	Refer back to the work done in Unit 11AC.1 and use these ideas to help students write detailed electronic configurations for atoms of the first row of the d block (Sc to Zn). Take special care to highlight copper and chromium. Also use the work to reinforce the fact that the transition metals have similar chemical and physical properties. Provide students with samples of a range of compounds of the elements above (with their formulae). Ask students to determine the oxidation states of the transition metal in each compound. This allows them to compile a chart of the most common oxidation states of the metals. Ask students to work out the electronic configuration for each of the oxidation states identified. Class discussion should lead to an appreciation of the fact that transition metals can form one or more stable ions through the involvement of electrons from the inner (d) orbitals, resulting in multiple oxidation states. Explain to students how to carry out practical work to observe the reduction of the VO_3^- ion through a series of oxidation states (as observed by the colour changes) to V^{2+} by adding zinc granules to a solution of ammonium vanadate(V). The change from one oxidation state of a metal to another is a redox reaction. Students can therefore consider the relative stability of different oxidation states of a given transition metal by looking at standard electrode potentials for these. Tell students to prepare iron(II) hydroxide and iron(III) hydroxide and account for the change of colour of iron(II) hydroxide on exposure to air. Ask them to write out the electronic configurations of the metal ions involved.	**Safety:** Ammonium vanadate(V) is toxic and should only be handled by students in solution, when it is classified as an irritant. Cobalt chloride solid is toxic. Gloves and eye protection should be worn when handling it. The hydrogen peroxide solution is an irritant. The mixture froths as the reaction progresses, so place it in a spill tray and stand clear of the reaction. Students will need: ammonium vanadate(V) solution made up in acidic solution, zinc granules; iron(II) chloride solution and iron(III) chloride solution, sodium hydroxide solution; potassium sodium 2,3-dihydroxybutanedioate, hydrogen peroxide solution (20 vol.), cobalt(II)chloride, $CoCl_2{\cdot}6H_2O$ Enquiry skill 11A.1.6	
	Ask students to use the Internet or library resources to research the uses of transition metals as catalysts, paying particular attention to any processes currently being used in Qatar. Tell them to carry out and observe the reaction of the 2,3-dihydroxybutanedioate anion with hydrogen peroxide, both in the presence and in the absence of cobalt(II) chloride. Encourage them discuss their observations in small groups. The colour changes during the reaction will give clues as to the nature of the reaction occurring.	**ICT opportunity:** Use of Internet.	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Give an account of the role of sulfur dioxide in the environment. Give suggestions on how any negative environmental impact can be reduced.*	Enquiry skill 11A.2.4	
	Describe and explain the differences in physical properties of carbon dioxide and silicon(IV) oxide.		
	a. *Write the electronic configuration for each of the following:* i. Cu^{2+} ii. Fe^{3+} iii. Ni^{2+} iv. V^{3+} b. *Explain why* Cu^{2+} *behaves as a typical transition metal but* Cu^{+} *does not.*		

GRADE 11A: Chemistry 5

Organic chemistry

UNIT 11AC.5
15 hours

About this unit

This unit is the fifth of six units on chemistry for Grade 11 advanced.

The unit is designed to guide your planning and teaching of chemistry lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 9.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already know that carbon forms covalent compounds with four bonds and that life is based on structures of carbon atoms.

Expectations

By the end of the unit, students have an understanding of the general chemistry of alkanes, alkenes, halogenoalkanes, alcohols, alcohols, aldhehydes, ketones, carboxylic acids, esters, acyl chlorides, amines and nitriles, and they recognise the relative unreactivity of the arene ring. They know that the main sources of organic compounds are fossil fuels and living materials. They understand the importance of alkanes as fuels.

Students who progress further understand the mechanisms of electrophilic substitution and know the fundamental chemistry of arenes and substituted arenes.

Resources

The main resources needed for this unit are:

- 'ball and stick' molecular model kits (e.g. Molymod)
- lists of names and structures of a variety of organic compounds
- names and structures of a variety of organic compounds on cards
- sample alkanes to burn; data on alkane melting points and boiling points
- hexane, bromine, tin foil
- 2-methylpropan-2-ol and concentrated hydrochloric acid, balance, $NaHCO_3$, anhydrous sodium sulfate, distillation equipment (class set)
- ethanol, sodium dichromate(VII), tin lids, distillation apparatus, concentrated sulfuric acid, Tollens' reagent, Fehling's solution, sodium carbonate, glacial ethanoic acid, pumice stone, glassware to carry out a dehydration and collect gaseous products over water, bromine water
- 2,4-dinitrophenylhydrazine, ethanal, propanone, triiodomethane
- Dreschel bottles, 0.1 $mol\,dm^{-3}$ sodium hydroxide solution, sodium metal
- pentanol, glacial ethanoic acid
- benzene, methylbenzene, cyclohexene, dilute potassium manganate(VII) solution
- phenol
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *alkanes*, *alkenes*, *halogenoalkanes*, *alcohols*, *aldhehydes*, *ketones*, *carboxylic acids*, *esters*, *acyl chlorides*, *amines*, *nitriles*
- *electrophiles*, *nucleophiles*, *substitution*, *addition*, *elimination*, *condensation*, *oxidation*
- *polymerisation*, *monomer*, *polymer*, *repeating unit*
- *structural isomerism*, *geometric isomerism*, *cis-*, *trans-*, *stereochemistry*
- *catalytic cracking*, *gas-to-liquid refining*
- *arene*, *aliphatic*

Standards for the unit

Unit 11AC.5

15 hours

4 hours
Alkanes and alkenes

1 hour
Halogenoalkanes

5 hours
Esters and their chemistry

4 hours
Arenes

1 hour
The organic chemical industry

	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
		11A.24.1	Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: • alkanes and alkenes; • halogenoalkanes; • alcohols; • aldhehydes and ketones; • carboxylic acids, esters and acyl chlorides; • amines, nitriles …	12A.23.1	Interpret and use the nomenclature and structural formulae of the following classes of compound: • arenes; • halogenoarenes; • phenols; • aromatic aldehydes and ketones; • aromatic carboxylic acids, esters and acyl chlorides; • aromatic amines, nitriles, amides and amino acids.
		11A.24.2	Describe the chemistry of alkanes as exemplified by their combustion, by substitution of hydrogen by chlorine and by bromine, and by their general unreactivity towards electrophiles and nucleophiles.		
9.16.5	Know what chemical reactions take place when fuels burn.	11A.24.3	Know that the main use of alkanes is as fuels and that the size of the molecule determines what kind of fuel it is and how it is used.		
		11A.24.4	Describe the chemistry of alkenes as the chemistry of the double bond, exemplified by addition and polymerisation.	12A.22.4	Describe the mechanisms of electrophilic addition in alkenes and nucleophilic substitution in compounds such as halogenoalkanes
		11A.24.5	Illustrate structural and geometric isomerism in alkanes and alkenes.	12A.22.2	Describe the restricted rotation and the resulting stereochemistry of multiple bonds in terms of σ (sigma) and π (pi) bonds.
		11A.24.6	Describe the stereochemistry of alkanes and alkenes and related molecules.		
		11A.24.7	Know that petroleum and natural gas are sources of organic compounds and describe the processes of catalytic cracking and gas-to-liquid refining.		
9.14.1	Know that materials such as wood, wool and cotton, that are derived from living things, have molecular structures that consist of a skeleton of carbon atoms with atoms of a small number of other elements joined to them.	11A.24.8	Know that many organic compounds are made from plant and animal material.		
		11A.24.9	Describe the chemistry of halogenoalkanes as exemplified by substitution reactions and the elimination of hydrogen halide to form an alkene.	12A.22.4	Describe the mechanisms of electrophilic addition in alkenes and nucleophilic substitution in compounds such as halogenoalkanes.
		11A.24.10	Know some of the important applications of halogenoalkanes.		

15 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
		11A.24.11	Describe the chemistry of alcohols as exemplified by ethanol, including combustion, substitution reactions, reaction with sodium, oxidation to carbonyl compounds and acids, dehydration, ester formation and its commercial production.		
		11A.24.12	Classify alcohols as primary, secondary and tertiary, and describe the formation of aldehydes and ketones by oxidation of the corresponding alcohol by acidified dichromate.		
		11A.24.13	Describe the chemistry of the carbonyl group as exemplified by aldehydes and ketones.	12A.22.6	Describe the chemistry of the carbonyl group in terms of nucleophilic substitution and show how its reactivity depends on the electronegativity of the group or groups attached to it.
		11A.24.14	Describe the formation of carboxylic acids and their reactions to form esters and salts.		
		11A.24.15	Describe the characteristic structure of esters and know that they can be hydrolysed to the alcohol and acid.		
		11A.24.16	Know the main commercial uses of esters in perfumes and flavourings.		
		11A.24.17	Interpret and use the nomenclature and structural formulae of the following classes of compound: • arenes; • halogenoarenes; • phenols.		
		11A.24.18	Describe the chemistry of arenes (such as benzene and methylbenzene) and show an understanding of the relative unreactivity of the aromatic ring compared with an isolated double bond; know that the chemistry of side chains is similar to that of aliphatic compounds.	12A.23.3	Describe the chemistry of arenes (such as benzene and methylbenzene), as exemplified by substitution reactions with electrophiles, nitration and oxidation of the side chain.
				12A.23.4	Understand the mechanism of electrophilic substitution in arenes and the effect of the delocalisation of electrons in arenes in such reactions.
		11A.24.19	Know the chemistry of phenol, as exemplified by its reactions with bases and sodium, and know of its common use as a mild disinfectant.	12A.23.5	Know the chemistry of phenol, as exemplified by its reactions with bases and sodium and by electrophilic substitution in the aromatic ring.
		11A.24.20	Compare the preparation and properties of bromobenzene with bromoethane to show the effect of the benzene ring.		
		11A.24.21	Show an understanding of the broad issues relating to social benefits and environmental costs associated with the organic chemical industry.		

Objectives	Possible teaching activities	Notes	School resources
4 hours **Alkanes and alkenes** Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: • alkanes and alkenes; … Describe the chemistry of alkanes as exemplified by their combustion, by substitution of hydrogen by chlorine and by bromine, and by their general unreactivity towards electrophiles and nucleophiles Know that the main use of alkanes is as fuels and that the size of the molecule determines what kind of fuel it is and how it is used. Describe the chemistry of alkenes as the chemistry of the double bond, exemplified by addition and polymerisation Illustrate structural and geometric isomerism in alkanes and alkenes Describe the stereochemistry of alkanes and alkenes and related molecules **[continued]**	In a teacher-led session, outline the main rules for naming straight-chain and branched alkanes. Introduce students to structural formulae and skeletal formulae. Arrange students into pairs and give them a list of names of a variety of alkanes. Ask them to build models of these using 'ball and stick' model kits. To consolidate, give them a number of skeletal and structural formulae of alkanes to name; get them to mark their partner's responses. Repeat the process by giving them names of alkanes and asking them to produce the structural and/or skeletal formulae.		Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Provide students with samples of alkanes to burn (e.g. methane gas, propane, stove paraffin, octane oil based candles). Ask them to write balanced equations for complete and incomplete combustion. Give students the melting and boiling points for alkanes C1–C20 and ask them to plot graphs of the data. Ask them to suggest uses for a range of different alkanes (e.g. C20, C5, C2) taking into account their melting and boiling points.	**Safety:** Take care with flammable materials. Enquiry skill 11A.1.8	
	Dispense a few drops of bromine into three test-tubes of hexane. Cover one completely in tin foil, half cover a second in tin foil and leave the third uncovered. Plug the mouth of each test-tube with cotton wool and leave in the sunlight for approximately 30 minutes. The greater the exposure to sunlight, the more rapid the decolourisation of the mixture. Follow this with a teacher-led class discussion on substitution reactions and an appreciation that similar reactions occur with chlorine. At this stage, give student definitions of *electrophile* and *nucleophile* coupled with examples of each. Give students the electronegativity values for carbon and hydrogen and ask them to explain why alkanes are generally unreactive towards them.	**Safety:** Students must not handle bromine. Use appropriate safety precautions (gloves, goggles, fume cupboard).	
	In a teacher-led session, outline the main rules for naming straight-chain and branched alkenes. Arrange students into pairs and give them a list of names of a variety of alkenes. Ask them to build models of them using 'ball and stick' model kits. To consolidate, give them a number of skeletal and structural formulae of alkenes to name; get them to mark their partner's responses. Repeat the process by giving them names of alkenes and asking them to produce the structural and/or skeletal formulae.		
	Describe addition reactions (e.g. the addition of bromine to ethane) in a whole class session. Ask students to use their textbook, the library or the Internet to research the conditions needed for and products formed from a variety of addition reactions to the ethane double bond (e.g. the addition of HBr, H_2, Cl_2, H_2O).	**ICT opportunity:** Use of the Internet.	
	Ask each student to use 'ball and stick' models to produce an ethane molecule. Line these all up next to each other and join them into one unsaturated long chain to demonstrate the process of addition polymerisation. Then show the whole class the convention used to write this down, incorporating key terms such as *monomer*, *polymer* and *addition polymerisation* as well as how to systematically name the addition polymer.		

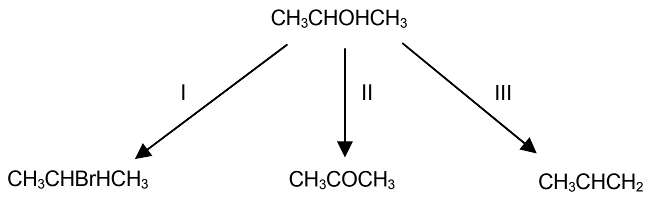
Objectives	Possible teaching activities	Notes	School resources
[continued] Know that petroleum and natural gas are sources of organic compounds and describe the processes of catalytic cracking and gas-to-liquid refining. Know that many organic compounds are made from plant and animal material	Arrange students into small groups and give each group the name of a monomer (and its structure if needed). Ask each group to produce a number of monomer molecules, link them together to produce the appropriate polymer, write an equation for the reaction, name the polymer and give a list of uses for the polymer. Then ask groups present their work to the whole class.	Enquiry skill 11A.3.3	
	Use model building kits to guide students through a series of examples of structural isomers of alkanes and geometric isomerism in alkenes. Use molecular kits to illustrate molecular shapes.		
	Ask students to use their textbook, the library or the Internet to research the gas to liquid process in Qatar and catalytic cracking. Tell them to use their findings to draw flow charts summarising the processes.	**ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.6, 11A.1.8	
	Provide students with a list of organic compounds. Ask them to use the library or the Internet to research the origins of these compounds and draw up a summary table.	**ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.6, 11A.1.8, 11A.3.4	
1 hour **Halogenoalkanes** Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: … • halogenoalkanes; … • amines … Describe the chemistry of halogenoalkanes as exemplified by substitution reactions and the elimination of hydrogen halide to form an alkene. Know some of the important applications of halogenoalkanes	In a teacher-led session, outline the main rules for naming halogenoalkanes. Arrange students into pairs and give them a list of names of a variety of halogenoalkanes. Ask them to build models of them using 'ball and stick' model kits. To consolidate, give them a number of skeletal and structural formulae of halogenoalkanes to name; get them to mark their partner's responses. Repeat the process by giving them names of halogenoalkanes and asking them to produce the structural and/or skeletal formulae. Get students, in pairs, to prepare 2-chloro-2-methylpropane from 2-methylpropan-2-ol and concentrated hydrochloric acid, followed by neutralization, drying and distillation to purify. A teacher-led discussion will lead to an appreciation of the nature of the reaction. Ask students to use their textbook, the library or the Internet to research the reactions of bromoethane and classify the reactions into substitution or elimination reactions. Use the example of the substitution of halogenoalkanes by ammonia to identify the functional group *amine*. In a teacher-led session, outline the main rules for naming amines. Arrange students into pairs and give them a list of names of a variety of amines. Ask them to build models of them using 'ball and stick' model kits. To consolidate, give them a number of skeletal and structural formulae of amines to name; get them to mark their partner's responses. Repeat the process by giving them names of amines and asking them to produce the structural and/or skeletal formulae.	**Safety:** 2-chloro-2-methylpropane and 2-methylpropan-2-ol are flammable. Concentrated hydrochloric acid is corrosive. **ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.6, 11A.1.8	
	Ask students to use their textbook, the library or the Internet to research the uses of halogenoalkanes and produce posters of their findings.	**ICT opportunity:** Use of the Internet.	

Objectives	Possible teaching activities	Notes	School resources
5 hours **Esters and their chemistry** Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: … • alcohols; • aldhehydes and ketones; • carboxylic acids, esters and acyl chlorides • … nitriles … Describe the chemistry of alcohols as exemplified by ethanol, including combustion, substitution reactions, reaction with sodium, oxidation to carbonyl compounds and acids, dehydration, ester formation and its commercial production. Classify alcohols as primary, secondary and tertiary, and describe the formation of aldehydes and ketones by oxidation of the corresponding alcohol by acidified dichromate. Describe the chemistry of the carbonyl group as exemplified by aldehydes and ketones. Describe the formation of carboxylic acids and their reactions to form esters and salts. Describe the characteristic structure of esters and know that they can be hydrolysed to the alcohol and acid. Know the main commercial uses of esters in perfumes and flavourings.	Whenever you introduce a new category of organic compound, go through the process given in previous sections to ensure students are happy with the nomenclature of that type of compound. In a teacher-led session, classify a range of alcohols as *primary*, *secondary* or *tertiary*. Let students, in pairs, investigate the chemistry of alcohols by using ethanol in a circus of experiments, including: • igniting a few drops on a tin lid; • reacting with sodium and allowing the resultant mixture to evaporate; • mild oxidation with acidified sodium dichromate, distilling out the resultant aldehyde and testing with Fehling's solution and Tollens' reagent; • further oxidation with excess acidified sodium dichromate under reflux and testing the resultant carboxylic acid with sodium carbonate; • esterification by warming ethanol with glacial ethanoic acid; • dehydration by passing over heated pumice stone, collecting the product over water and testing the gaseous product with bromine water. Ask small groups to report their findings and interpretation of one experiment to the class. Consolidate each example by asking students to predict the results for different alcohols. Fill in any gaps by asking appropriate questions. Add examples of substitution reactions and relate these back to the substitution reactions of halogenoalkanes. Ask students to use their textbook, the library or the Internet to research the preparation of ethanol from petroleum and from sugars by the action of ethanol. Ask them to work in small groups to discuss the economics and sustainability of each process.	**Safety:** Sodium needs to be handled with care. Ethanol vapour is flammable. Tollens' reagent becomes explosive when dry. Fehling's solution is corrosive. Sodium dichromate(VI) is extremely dangerous and can damage the skin. Concentrated sulfuric acid is corrosive. Bromine water is harmful. When carrying out the dehydration always install a trap to avoid suckback. Enquiry skill 11A.4.1 **ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.6, 11A.1.8, 11A.2.4, 11A.2.5	
	Let students, in pairs, investigate the reactions of aldehydes and ketones using ethanal and propanone. Use a similar approach to that used with the alcohols (i.e. a circus of experiments followed by reporting back and class discussion). Experiments could include: • the addition of 2,4-dinitrophenylhydrazine (condensation reaction); • testing with Fehling's solution and Tollens' reagent; • reacting with triiodomethane.	**Safety:** Ethanal and propanone are irritants to eyes, skin and lungs and are highly flammable. 2,4-dinitrophenylhydrazine is toxic. Sodium hydroxide is corrosive (at concentrations of $0.1\,mol\,dm^{-3}$ or above)	
	Tell students, working individually, to draw air through a sample of ethanol and assay for ethanoic acid by titration with sodium hydroxide solution at regular intervals to determine the degree of oxidation to ethanoic acid. Revise with the whole class the oxidation of ethanol to ethanal to ethanoic acid as seen in the previous section of this unit. Let students, working individually, produce the sodium salt of ethanoic acid by neutralising a carboxylic acid with sodium hydroxide solution and evaporating the product to dryness. Ask students to use their textbook, the library or the Internet to research the production of propanoic acid from propanenitrile.	Enquiry skill 11A.4.1 **ICT opportunity:** Use of the Internet.	
	In a teacher-led session, introduce the concept of *esterification* using carboxylic acids or acyl chlorides with alcohols. Arrange students into pairs and give them sets of cards showing the structures of different carboxylic acids, acyl chlorides and alcohols. Tell each pair to select one alcohol card and one	Prepare suitable sets of cards.	

Objectives	Possible teaching activities	Notes	School resources
	acid or acyl chloride card; explain that one student has to name the two reagents and the other has to write out the structure of the products of esterification and then name the resultant ester. A point is given for each correct answer. The process is repeated with all the cards, and the winner is the student with the most correct answers. Let students, working individually, carry out an esterification by warming pentanol with glacial ethanoic acid in the presence of a few drops of concentrated sulfuric acid. Reverse the card activity above. Give pairs of students sets of cards showing the structures of different esters. Tell each pair to select one card; explain that one student has to name the ester and the other has to write out the structure of the products of hydrolysis of the ester. A point is given for each correct answer. The process is repeated with all the cards, and the winner is the student with the most correct answers. Ask students to use their textbook, the library or the Internet to research the main uses for esters and produce visual representations of usage.	**Safety:** Pentanol is flammable. Glacial ethanoic acid is corrosive. Enquiry skills 11A.3.1–11A.3.3 **ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.8, 11A.3.4	
4 hours **Arenes** Interpret and use the nomenclature and structural formulae of the following classes of compound: • arenes; • halogenoarenes; • phenols. Describe the chemistry of arenes (such as benzene and methylbenzene) and show an understanding of the relative unreactivity of the aromatic ring compared with an isolated double bond; know that the chemistry of side chains is similar to that of aliphatic compounds. Know the chemistry of phenol, as exemplified by its reactions with bases and sodium, and know of its common use as a mild disinfectant. Compare the preparation and properties of bromobenzene with bromoethane to show the effect of the benzene ring.	Organise students into pairs to compare the reactions of benzene, methylbenzene and cyclohexene with hot dilute potassium manganate(VII) solution. Discuss the results as a whole class and lead the discussion on to the relative unreactivity of the aromatic ring when compared with double bonds in isolation. You may wish to introduce data to support this (e.g. the enthalpy of hydrogenation for cyclohexane and benzene) and ask students to calculate the degree to which benzene is more stable than might be expected. Ask students to work individually to determine the pH of a solution of phenol and compare this with the pH of ethanol. Tell them to add a little sodium hydroxide solution to a stock phenol solution and observe its solubility. They can then add a few drops of concentrated hydrochloric acid and observe. Tell them to add a small piece of sodium to a solution of phenol in dry ethanol and compare this reaction with that of sodium in dry ethanol only. At each stage, encourage students to try to work out what is happening and write equations for any reactions. Complete the session with a whole class discussion and summary. Ask students to use their textbook, the library or the Internet to research the preparation of bromobenzene and its reactions. Tell them to tabulate these reactions and compare them with their findings for the reaction of bromoethane (see halogenoalkanes section above). Make sure they are aware that the bromobenzene is largely unreactive towards the reagents that react readily with bromoethane. Draw out the reasons for this in a whole class discussion.	**Safety:** Benzene is a carcinogen. Methylbenzene and cyclohexene are flammable. Concentrated hydrochloric acid is corrosive. Sodium is dangerous to handle. Enquiry skill 11A.4.1 **ICT opportunity:** Use of the Internet.	

Objectives	Possible teaching activities	Notes	School resources
1 hour **The organic chemical industry** Show an understanding of the broad issues relating to social benefits and environmental costs associated with the organic chemical industry.	Divide the class into three groups. Ask each group to use the library or the Internet to research one of the topics below. Then get them to present their findings to the whole class and hold a question and answer session. • The social benefits brought about by the simple drug aspirin. • The consequences of the explosion in the Union Carbide factory at Bhopal, India. • Issues raised by the release into the environment of potentially harmful chemicals, such as DDT or CFCs.	**ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.8, 11A.2.2, 11A.2.4, 11A.2.5	

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Ethene reacts readily with chlorine, forming A ($C_2H_4Cl_2$).* a. i. *Draw the displayed formula of A.* ii. *Draw the displayed formula of a structural isomer of A.* b. *Some alkenes display cis–trans isomerism.* i. *Draw and label a pair of cis–trans isomers.* ii. *Explain the origin of cis–trans isomerism.* c. *Describe how you would show that ethane contains a double bond.* **O&C 1997, specimen, in T. Lister and J. Renshaw, 2000, *Understanding Chemistry for Advanced Level*, 3rd edn, Stanley Thornes, p.277**		
	There are four structural isomers of molecular formula C_4H_9Br. The structures of two of them are given below. *(1) $CH_2Br–CH_2–CH_2–CH_3$ (2) $CH_3–CHBr–CH_2–CH_3$* a. i. *Draw the remaining two isomers.* ii. *Give the name of isomer (2).* b. *All four structural isomers of C_4H_9Br undergo similar reactions with ammonia.* i. *Give the name of the mechanism involved in these reactions.* ii. *Draw the structural formula of the product formed by the reaction of isomer (1) with ammonia.* c. *The elimination of HBr from isomer (1) produces two structural isomers, compounds A and B.* i. *Give the reagent and conditions required for this reaction.* ii. *Give the structural formula of the two isomers A and B, formed by the elimination of HBr from isomer (1).* **Adapted from AEB 1998, in T. Lister and J. Renshaw, 2000, *Understanding Chemistry for Advanced Level*, 3rd edn, Stanley Thornes, p.294**		

	Examples of assessment tasks and questions	Notes	School resources
	Three different reactions of propan-2-ol are shown below  a. *For each of the reactions I, II and III give suitable reagents and conditions.* b. *If 2-methylpropan-2-ol was used as a starting material in a instead of propan-2ol, identify the organic products, if any, of reactions I, II and III. You should indicate if no reaction occurs.* **London (Nuffield) 1998, part question, in T. Lister and J. Renshaw, 2000, *Understanding Chemistry for Advanced Level*, 3rd edn, Stanley Thornes, p.318**		
	Research a chemical synthesis carried out on an industrial scale. Write a report summarising the social benefits and environmental costs associated with the process you have identified.		
	a. *Name and draw the full structures of one ketone A and one aldehyde B, each with the molecular formula* $C_5H_{10}0$. b. *Describe a chemical test which would enable you to differentiate between samples of A and B. State the observations you would expect to make for each sample involved and explain the chemistry involved.* c. *Give an equation for the reaction of aldehydes B with HCN.* **Adapted from Oxford 1996, in T. Lister and J. Renshaw, 2000, *Understanding Chemistry for Advanced Level*, 3rd edn, Stanley Thornes, p.551**		

GRADE 11A: Chemistry 6

Making and using chemicals

UNIT 11AC.6
11 hours

About this unit

This unit is the sixth of six units on chemistry for Grade 11 advanced.

The unit is designed to guide your planning and teaching of chemistry lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and earlier units in Grade 11A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already know the properties of the common compounds of nitrogen and sulfur. They should have an understanding of the general chemistry of alkenes and esters.

Expectations

By the end of the unit, students know the processes for manufacturing ammonia, nitric acid and sulfuric acid, and the chemistry behind the limestone industry. They know how to make soaps from fats, and how soaps and detergents solubilise oily stains. They know the characteristic structures of natural and artificial addition and condensation polymers.

Students who progress further know that economic considerations determine what commercial processes commonly exist and where, and that economic advantages of such processes must be balanced against environmental threats. They know how addition and condensation polymers are formed and how their properties can be modified by additives.

Resources

The main resources needed for this unit are:

- video clips of the Haber and contact processes
- demonstration equipment for the synthesis of sulfur trioxide
- fume cupboard
- tin lids, Bunsen burners, limestone or solid calcium carbonate
- student whiteboards
- phenylethene, di(dodecanoyl) peroxide, water bath (50 °C), methylbenzene, bromine water
- decanedioyl dichloride (5% in cyclohexane), 1,6-diaminohexane (5% solution in sodium carbonate solution)
- fume cupboard
- molecular modelling kits (e.g. Molymod)
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *oxidation*
- *Haber process*, *contact process*
- *lime*, *quicklime*, *slaked lime*
- *amide*, *amino acid*
- *macromolecule*, *repeating units*, *condensation polymers*, *addition polymers*
- *long-chain fatty acids*, *unsaturated*
- *esterification*, *saponification*, *solubilise*

Standards for the unit

Unit 11AC.6

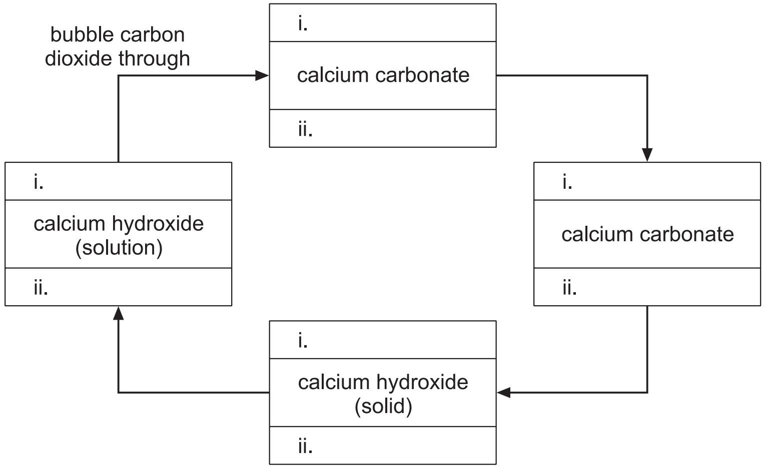
11 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS	
3 hours **Haber process and ammonia**			11A.20.1	Know the essential details of the Haber process for making ammonia from nitrogen.		
	11A.21.12	Know the main properties and uses of nitrates and understand their environmental impact.	11A.20.2	Know the essential details of the commercial oxidation of ammonia to nitric acid and of the main commercial uses of nitric acid.		
2 hours **Contact process and sulfur**	11A.21.11	Know the test for ammonia, the main properties and uses of its compounds and their reaction with warm alkali.	11A.20.3	Understand the industrial importance of ammonia and nitrogen compounds derived from ammonia and nitric acid.		
2 hours **Limestone and cement**	11A.21.7	Know and explain the existence of two oxidation states of sulfur in its common compounds, as typified by its two common oxides and the two acids and series of salts that they form.	11A.20.4	Know that the Qatar natural gas field is also a source of sulfur and that this has consequences for the processes that exploit the gas.	12A.18.4	Show an understanding of the balance that often has to be made between the economic advantages that industrial processes bring to Qatar and the environmental threat that they pose.
2 hours **Natural and synthetic polymers**	11A.21.8	Know the importance of sulfur dioxide in the preparation of sulfuric acid and in food preservation	11A.20.5	Know the essential details of the contact process for manufacturing sulfuric acid and understand the industrial importance of sulfuric acid.		
2 hours **Soaps**			11A.20.6	Know that limestone is a source of many important agricultural and industrial chemicals and describe the conversion of limestone into quicklime and slaked lime.		
			11A.20.7	Describe the manufacture of cement and know how changes at the molecular level that take place during the setting of concrete give it its strength and durability.		
			11A.24.1	Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: … • … amides and amino acids.		
	11A.24.4	Describe the chemistry of alkenes as the chemistry of the double bond, exemplified by addition and polymerisation.	11A.25.1	Know that a polymer is a macromolecule containing repeating units and recognise the difference between condensation and addition polymers.		
			11A.25.2	Describe the manufacture and uses of synthetic addition polymers as exemplified by polythene and PVC, and of condensation polymers such as nylon and polyesters.	12A.24.7	Know that the properties of polymers can be modified by the use of additives.

11 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
	11A.24.8	Know that many organic compounds are made from plant and animal material.	11A.25.3	Know that living things produce many natural condensation polymers, such as proteins from amino acids, starch and cellulose from glucose, and DNA from nucleic acids.	12A.24.1	Know that proteins are formed from combinations of 20 different amino acids through peptide bonds and that they have a variety of functions in living things. Know that they can be broken down by hydrolysis into their constituent amino acids, which can be separated by electrophoresis and ion-exchange chromatography
					12A.24.5	Describe the structural features of monosaccharides and know that they form polysaccharides such as starch and cellulose.
	11A.24.15	Describe the characteristic structure of esters and know that they can be hydrolysed to the alcohol and acid.	11A.25.4	Know that fats and oils are natural esters formed by the alcohol glycerol with long-chain fatty acids, and understand the meaning of the term *unsaturated* when applied to these esters.		
			11A.25.5	Show how the typical structural features of soaps and detergents can explain how they can readily solubilise oily stains.		

Objectives	Possible teaching activities	Notes	School resources
3 hours **Haber process and ammonia** Know the essential details of the Haber process for making ammonia from nitrogen. Know the essential details of the commercial oxidation of ammonia to nitric acid and of the main commercial uses of nitric acid. Understand the industrial importance of ammonia and nitrogen compounds derived from ammonia and nitric acid.	Show students a video of the manufacture of ammonia from nitrogen. Ask each student to produce a detailed flow chart for the process. Ask students, in pairs, to use their textbook, the library or the Internet to research the history of the development of the Haber process and to use the information they find to produce a poster.	**ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.8, 11A.3.4	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Ask students, in pairs, to use their textbook, the library or the Internet to research the synthesis of nitric acid from ammonia. Ask them to produce an interactive electronic flow chart, illustrated with images from the Internet (e.g. a 'drag and drop' activity, or fill in the missing boxes). The class as a whole can then use these flow charts to consolidate their learning.	**ICT opportunity:** Use of the Internet and software to make an interactive flow chart. Enquiry skills 11A.1.8, 11A.3.4	
	Ask students to prepare a booklet summarising the industrial uses of ammonia and nitric acid. Tell them to represent graphically, using statistics, the growth in worldwide production and uses of nitrogenous fertilisers since the Haber process was developed.	Enquiry skills 11A.2.1, 11A.3.4	
2 hours **Contact process and sulfur** Know that the Qatar natural gas field is also a source of sulfur and that this has consequences for the processes that exploit the gas. Know the essential details of the contact process for manufacturing sulfuric acid and understand the industrial importance of sulfuric acid.	Get students to obtain statistics on the sulfur content of Qatar gas as part of an industrial visit and to find out how desulfurisation takes place and what is done with the sulfur extracted. Ask students, working in small groups, to use this data to produce a public information leaflet to raise awareness about desulfurisation.	**Visit opportunity:** Visit a petrochemical plant.	
	Show students a video describing the contact process for manufacturing sulfuric acid. Ask them, working in groups of three or four, to use this to produce a PowerPoint presentation describing the contact process. Put these presentations on the school intranet. Then provide a series of structured notes for students to answer individually, using the PowerPoint presentations. Demonstrate the synthesis of sulfur trioxide by the catalytic oxidation of sulfur dioxide.	**ICT opportunity:** Use of PowerPoint and the school intranet. Prepare structured notes for students. **Safety:** Carry out synthesis of sulfur trioxide in a fume cupboard.	

Objectives	Possible teaching activities	Notes	School resources
2 hours **Limestone and cement** Know that limestone is a source of many important agricultural and industrial chemicals and describe the conversion of limestone into quicklime and slaked lime. Describe the manufacture of cement and know how changes at the molecular level that take place during the setting of concrete give it its strength and durability.	Ask students to carry out the following activity in pairs. Place small pieces of solid limestone (or calcium carbonate) on a tin lid and heat with two Bunsen burners. After approximately 30 minutes, the solid crumbles. When cool, transfer a small portion of the solid into a 1 cm depth of water in a test-tube. Then test the solution with universal indicator solution. Record all observations. When students have finished the activity, relate their observations to the conversion of limestone into quicklime and slaked lime and provide balanced equations for each reaction. Ask students, individually, to use their textbook, the library or the Internet to research the production of cement and produce an annotated flow chart for the processes involved. Then describe to the whole class the chemical changes that occur during the setting of concrete. Ask students, in small groups, to use this information to design and carry out experiments to investigate how altering the composition of concrete changes the strength and durability of the resultant concrete.	Students will need tin lids, Bunsen burners, limestone or solid calcium carbonate, test-tubes, universal indicator solution. **Safety:** Take care, there is a highly exothermic reaction when the solid is put in the water. Enquiry skills 11A.4.1, 11A.4.2 **ICT opportunity:** Use of the Internet. Students will need cement, gravel, sand, small moulds to set the concrete in (e.g. yoghurt pots). Enquiry skills 11A.1.1–11A.1.5, 11A.1.8, 11A.3.1–11A.3.4	
2 hours **Natural and synthetic polymers** Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: … • … amides and amino acids. Know that a polymer is a macromolecule containing repeating units and recognise the difference between condensation and addition polymers. Describe the manufacture and uses of synthetic addition polymers as exemplified by polythene and PVC, and of condensation polymers such as nylon and polyesters. Know that living things produce many natural condensation polymers, such as proteins from amino acids, starch and cellulose from glucose, and DNA from nucleic acids.	Give pairs of students a list of names of a variety of amides and ask them to build models of them using 'ball and stick' model kits. To consolidate, give them a number of skeletal and structural formulae of amides and ask all students to write down their names; get them to mark their partner's responses. Repeat the process by giving them names of amides and ask them to produce the structural and/or skeletal formulae. Encourage the pairs to build models of amino acids to consolidate their understanding of the nature of their structure. Revise the section earlier this year on polymerisation of alkenes using student whiteboards. Ask questions and tell students to write an answer quickly on a small whiteboard, which they hold up for you to see. Use this to guide you in how much detail is needed on addition polymerisation. Ask students to make an addition polymer, polystyrene (poly(phenylethene)), by warming styrene in the presence of di(dodecanoyl) peroxide in a water bath. Tell them to observe the change in viscosity and, when solid, to dissolve a small quantity in methylbenzene and test with bromine water. Ask them to compare this with the reaction of phenylethene with bromine water. Also ask them to make a nylon by reacting decanedioyl dichloride with 1,6-diaminohexane and drawing out the nylon polymer formed at the interface using tweezers. Get them to work in pairs to build models (using Molymod kits or similar) of reactants for both polymerisation reactions. Using the models, they can show what happens during the polymerisation and name the product/s in each case. Clarify the differences between addition and condensation polymers in a class discussion. Ask students, in small groups, to use the library or the Internet to research the commercial manufacture and uses of one polymer from a selection including poly(ethane), PVC, nylon and polyesters. Ask each group to produce a handout summarising their findings for the rest of the class. Provide students with models and 3D applets of naturally occurring polymers. Ask each student to produce a summary noting the features that are related to their function.	**Safety:** Both reactions should be carried out in the fume cupboard wearing gloves and goggles at all times. Enquiry skills 11A.4.1, 11A.4.2 **ICT opportunity:** Use of the Internet. Enquiry skill 11A.3.4 **ICT opportunity:** Use of Java applets. Enquiry skill 11A.3.4	

Objectives	Possible teaching activities	Notes	School resources
2 hours **Soaps** Know that fats and oils are natural esters formed by the alcohol glycerol with long-chain fatty acids, and understand the meaning of the term *unsaturated* when applied to these esters. Show how the typical structural features of soaps and detergents can explain how they can readily solubilise oily stains.	Write the structure of glycerol on the board or OHP. Ask students to write down the structures of the product(s) if this molecule were refluxed with ethanoic acid in the presence of a few drops of concentrated sulfuric acid. Ask them to ring and identify all the functional groups involved. Lead them to identify the product as a *triester*. Give students structures for a range of saturated and unsaturated fatty acids and ask them each to build them using molecular model kits (e.g. palmitic acid, stearic acid, oleic acid). Bring the class together and 'esterify' a range of these acids with glycerol to produce an oil and a fat. Ask students to identify the differences between the two. Then ask them to write out equations for the reaction of triesters with sodium hydroxide to produce mixtures of sodium salts of fatty acids. Explain that these are the basic components of soaps.		
	Ask students to use the library or the Internet to find out about soaps and then write a short article for a homemaker to explain why soaps are good at removing greasy stains from fabrics.	**ICT opportunity:** Use of the Internet.	
	Show the whole class how soaps form a scum with hard water. Ask students to use the library or the Internet to research the alternative to soaps – detergents. Ask them to produce a public information poster showing the advantages and disadvantages of using detergents.	Enquiry skill 11A.3.4	

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*a. Describe in outline the manufacture of one of the following industrial chemicals:* *i. sulfuric acid;* *ii. nitric acid;* *iii. ammonia.* *b. Discuss the chemical principles which determine the optimum operating conditions for the process you describe.* *c. For the substance you have chosen, mention two large-scale uses.* **From G. Hill and J. Holman, 1989, *Chemistry in Context*, 3rd edn, Nelson, p. 370**		
	Ammonia is manufactured by the Haber process, in which nitrogen reacts with hydrogen according to the equation below: $N_2 + 3H_2 \rightleftharpoons 2NH_3$ *a. What is the meaning of the symbol* $\rightleftharpoons$ *?* *b. Name and give a use for one compound manufactured on a large scale from ammonia.* *c. Why is iron used in the Haber process and what effect does it have?*		
	a. Complete the diagram below by writing in *i. the common names;* *ii. the chemical formulae.* *b. Write beside each arrow how the change would be carried out. One example is given.*  		

	Examples of assessment tasks and questions	Notes	School resources
	Draw the structures of the polymers formed from the following pairs of monomers showing two repeating units. a. *HO—CH_2CH_2—OH and HOOC—CH_2—COOH* b. *H_2N—CH_2CH_2—NH_2 and HOOC—CH_2CH_2—COOH* **From G. Burton, 2000, Salters Advanced Chemistry, *Chemical Ideas*, 2nd edn, Heinemann, p.116**		
	Write an account describing how soaps and detergents function as cleaning agents. Give the advantages and disadvantages of both.		

GRADE 11A: Physics 1

Forces and movement

UNIT 11AP.1
10 hours

About this unit

This unit is the first of seven units on physics for Grade 11 advanced.

The unit is designed to guide your planning and teaching of physics lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already be able to derive and use equations for uniformly accelerated linear motion. They should know that a force can cause a deformation or a velocity change. They should be able to combine and resolve forces, and calculate the moment of a force. They should understand the meaning of centre of gravity.

Expectations

By the end of the unit, students state Newton's laws of motion and use them to solve problems of motion in two dimensions. They distinguish between mass and weight, know that momentum is conserved during collisions and apply the knowledge to collisions and explosions in one dimension. They determine the centre of gravity of a lamina and apply the principle of moments to real problems.

Students who progress further understand the relationship between an applied force and the resulting momentum change. They distinguish between inertial and gravitational mass.

Resources

The main resources needed for this unit are:

- ball-bearing and tracks for Galileo's demonstration
- ticker-timers, trolleys and runways
- light gates or other motion sensors
- elastic cords

and/or

- 100 g sets of hanger masses, inextensible cords and pulleys
- dynamics trolley(s) with spring-loaded plunger
- dynamics trolley(s) with Velcro attached
- pairs of bar magnets
- balloons
- strong rope (for tug of war)
- thick card cut into irregular shapes (approximately 30 cm wide)
- six-sided nut; long and short spanners to fit nut
- thick card, elastic bands and pins to make a model arm
- bathroom scales

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- terms relating to Newton's laws of motion: *velocity, acceleration, force, equilibrium, Newtonian pair, mass, momentum, conservation*
- terms relating to mass, weight and gravity: *inertial mass, gravitational mass, weight*
- terms relating to the principle of moments: *moment, couple, torque, equilibrium, centre of gravity, lever, fulcrum*

Standards for the unit

10 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
3 hours **Newton's first and second laws of motion**	10A.26.2	Derive, from the definitions of velocity and acceleration, equations that represent uniformly accelerated motion in a straight line and use them to solve problems relating to the motion of objects under uniform acceleration.	11A.26.1	State Newton's laws of motion and apply them to real situations.	11A.27.1	Define work and apply the concept of work as the product of a force and displacement in the direction of the force.
1 hour **Newton's third law of motion**	10A.26.3	Know that a force acting on an object can cause deformation or velocity change.	11A.26.2	Know that linear momentum is the product of mass and velocity, and that a momentum change on a body is equal to the force causing it. Understand and use the relationship $F = ma$.		
2 hours **Momentum**			11A.26.3	Distinguish between inertial and gravitational mass.		
			11A.26.4	Distinguish between mass and weight.		
2 hours **Mass, weight and gravity**			11A.26.5	Know the principle of conservation of momentum and apply it to elastic and inelastic collisions and explosions involving two bodies in one dimension.		
	7.16.7	Know that the centre of gravity of an object is the point through which its weight appears to act.	11A.26.6	Know that the weight of a body may be taken as acting at a single point known as its centre of gravity.		
2 hours **The principle of moments**	10A.26.4	Identify forces acting on a body, determine resultants, resolve forces into components and use the vector triangle to represent forces in equilibrium.	11A.26.7	Describe and apply the moment of a force and the torque of a couple, and apply the principle of moments to a system in equilibrium.		
	9.19.2	Know that the turning effect of a force is called its *moment* and calculate the moment of a given force.	11A.26.8	List and explain applications of the principle of moments to engineering systems and to the muscles of the human body.		

Objectives	Possible teaching activities	Notes	School resources
3 hours **Newton's first and second laws of motion** State Newton's laws of motion and apply them to real situations. … Understand and use the relationship $F = ma$.	**Newton's first law of motion** Display or hand out pictures of stationary and moving objects. Ask students to identify the force(s) acting and to say whether they are in equilibrium. Use students' comments to review their knowledge of forces and motion from earlier work where they learned that: • if an object is at rest, any forces must be in equilibrium (zero resultant); • a change of velocity (speed and/or direction) requires the action of a force. Ask students what happens to an object on which no forces act after it is set in motion. They will probably say that it comes to rest.	Suitable examples include: • a falling stone; • a book on a table; • a car setting off from a traffic light; • a boxer falling against the ropes; • a tennis or golf ball being hit.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Show and discuss Galileo's demonstration. Establish that, *in the absence of friction*, a ball-bearing released near the top of the steep side climbs to the same height on the other side regardless of gradient. If the second side were horizontal, the ball-bearing would continue at constant velocity for ever. Discuss what happens to spacecraft in 'deep space' if their motors are switched off (they continue to move at constant velocity – hence space probes can travel long distances with very little expenditure of fuel.)	Galileo's demonstration needs three V-shaped tracks on which a ball-bearing can roll freely. One track is symmetrical, the other two each have one steep side and one longer side with a shallower gradient.	
	Sum up these observations with a statement of Newton's first law of motion: • if no resultant force acts on an object, it will remain at rest or will continue to move at constant velocity. Establish that the corollary is also true: • if an object is moving at constant velocity, then there must be no resultant force acting. Students will probably object to the second statement; in their experience, motion at constant speed requires a force (e.g. cycling at steady speed on level ground requires effort from the rider). Emphasise that a key word is *resultant*. In many everyday examples there are frictional and viscous forces as well as a driving force. The individual forces may be large, but if they combine to give a resultant of zero the velocity remains constant. Ask students to suggest other examples of motion at constant velocity, and then to identify and comment on the forces acting.	You might want to give students the traditional form of Newton's first law: • a body continues in a state of rest or uniform motion until acted upon by a force. However, it is important that students understand the underlying physics rather than merely reciting a form of words, so encourage them to state this important result in various different ways and to discuss its consequences.	

Objectives	Possible teaching activities	Notes	School resources
	Newton's second law of motion Arrange for students to use ticker-timers and trolleys to explore the relationship between a non-zero resultant force and the acceleration it produces. Discuss with students the need to set up a friction-compensated runway and demonstrate how it is done. Show them how to produce a constant force acting on the trolley. Students should then work in pairs or small groups to obtain their own results for different forces acting on trolleys of different mass. If time is short, arrange for each pair or small group to use a different force and mass, then share results between the whole class. The results can be displayed and analysed most effectively if the tapes are cut into 0.1 s lengths and pasted side-by-side to make a chart showing how velocity changes with time. The gradient of the chart indicates acceleration. Collect the results on the board or OHP, or in a wall display. Discuss the outcomes of students' explorations. Establish that: • a constant force produces a constant acceleration; • the greater the force acting on a given mass, the greater the acceleration; • the greater the mass subject to a given force, the smaller the acceleration. Show that these results can all be described by the equation $F = ma$, where F is the *resultant* force acting.	Friction-compensation: slope the runway so that a trolley at rest remains so until given a very gentle nudge, after which it slowly rolls down the slope at constant velocity (as judged by eye). A constant force can be produced by: • stretching an elastic cord to a constant length using a marker on the trolley as a guide; • attaching the trolley to a falling mass via an inextensible cord passed over a pulley clamped to the far end of the runway. Enquiry skills 11A.1.1, 11A.1.3	
	Introduce Newton's second law of motion, which relates the *change of motion* to the resultant force acting. For constant mass, this is summarised as $F = ma$. Discuss with students the relationship between Newton's first and second laws: the first is a special case of the second with $F = 0$ and $a = 0$. On the board or OHP, show how $F = ma$ is used to define the SI unit of force: the units m, kg and s are already defined as SI base units and the unit of force, the newton (N), is chosen so that $1\,N = 1\,kg\,m\,s^{-2}$. Provide plenty of examples for students to practise rearranging and using $F = ma$ and the relevant SI units in calculations.	A more complete algebraic statement of Newton's second law relates force to rate of change of momentum. This version encompasses the situation in which mass varies and is covered later in this unit. This activity also relates to Standard 10A.21.1.	
1 hour **Newton's third law of motion** State Newton's laws of motion and apply them to real situations. … Understand and use the relationship $F = ma$.	**Newton's third law of motion** Demonstrate several examples of pairs of objects exerting forces on one another. Challenge students to arrange the objects so that only one of a pair experiences a force: it cannot be done. Discuss the nature of the forces that the objects exert on one another. They are always of the same type (e.g. both magnetic, or both electrostatic, or both involve the tension in a rope or the compression of a spring). Use spring-loaded trolleys to demonstrate the magnitudes of the forces. Discuss with students what happens. Two trolleys of equal mass both acquire the same speed when pushed apart by a spring, so they must have had the same acceleration and hence must have experienced the same force. If one trolley has twice the mass it acquires half the speed, so must have undergone half the acceleration as they were being pushed apart; from Newton's second law this implies that the two forces were equal.	Suitable examples include: • bar magnets arranged so that they either repel or attract one another; • a spring-loaded dynamics trolley placed in contact with another, then release the spring; • two students having a tug of war; • two inflated balloons suspended close together, one or both charged electrostatically by friction.	

Objectives	Possible teaching activities	Notes	School resources
	All these results can be summed up in Newton's third law of motion: • all forces arise from the interaction of two objects, the two forces exerted during interaction are of the same nature, they each act on a different object and they are equal in magnitude and opposite in direction. In many situations it can be difficult to identify the Newtonian pairs of forces because: • if the two interacting objects are of very different mass, the effect on the larger mass can be difficult to detect; • in many situations there is more than one pair of forces. As an example, discuss the forces acting when an object (e.g. a stone) falls freely. Students might argue that there is only one force: the force of Earth's gravity on the stone. It is not obvious that the stone attracts the Earth gravitationally with an equal force: the very large mass of the Earth means its upward acceleration (as deduced using Newton's second law) is so small as to be unnoticeable. On the board or OHP draw a large diagram of an object resting on a table which rests on the Earth (not to scale!). Ask students to identify the forces involving the book. One pair is the gravitational interaction between book and Earth – book attracts Earth and Earth attracts book. Represent this pair by two coloured arrows – one from the book pointing downwards and another of equal length pointing upwards from the centre of the Earth. There is also the interaction between book and table – book pushes down on table and table pushes up on book. Draw two arrows in another colour to represent this second pair.	Newton's third law is conventionally stated as: • to every action there is an equal and opposite reaction. You might want to tell students this form of the law, but do bear in mind that it is unhelpful and misleading because: • the term 'action' is not nowadays synonymous with force; • it implies that the 'reaction' occurs after, and as a result of, the 'action' rather than both being part of a single simultaneous interaction; • it does not make clear that the 'action' and 'reaction' always involve two objects. As with Newton's first law, understanding the physics is much more important than learning a particular form of words.	
	Divide the class into small groups and ask each group to analyse a different example in which forces are acting. Give each group a sheet of A3 paper and some coloured pens to record their ideas. Then display all the diagrams and discuss each in turn.	Keep the examples simple: this is not an easy task!	
2 hours **Momentum** Know that linear momentum is the product of mass and velocity, and that a momentum change on a body is equal to the force causing it. Understand and use the relationship $F = ma$.	**Momentum in collisions and explosions** Give each pair or small group of students a horizontal runway, up to four dynamics trolleys and some means of measuring speed. Ask them to predict then investigate the relationships between the speeds of the trolleys in each of the following situations. 1 Two trolleys are initially at rest and are then pushed apart by releasing a spring-loaded plunger. 2 One trolley collides with another that is initially at rest so that they stick and move off together. 3 One trolley collides with another of equal mass that is initially at rest and they bounce apart. In each of situations 1 and 2, use trolleys of both equal and unequal mass. If time is short, this activity could be demonstrated.	At least one trolley should have a spring-loaded plunger. At least two should have Velcro strips attached so that they stick on colliding. Speed can be measured with ticker-timers, light gates or other motion sensors. Measurements need only be approximate. Increase the masses of the trolleys by stacking two or three together.	

Objectives	Possible teaching activities	Notes	School resources
	Many students will be able to make 'common sense' predictions along the lines of 'if two equal masses spring apart they will move at the same speed', 'if two unequal masses spring apart the more massive one will move more slowly (e.g. if it has twice the mass it will have half the speed)', 'if you double the moving mass, the speed halves'. They should find that these predictions correctly describe what happens. Use students' 'common sense' knowledge to introduce momentum and its conservation. In all the situations explored above, the sum of (mass × velocity) remains constant. Remind students that velocity is a vector, so if two objects move in opposite directions, their velocities have opposite signs. Introduce momentum $p = mv$ as a quantity that is useful because it is conserved in collisions and explosions. Establish that momentum is a vector, so in the case of an explosion from rest the total momentum is zero before and after. Discuss the SI units of momentum and show how they are derived from its definition.	Encourage students to use 'common sense' to make their predictions rather than trying to apply any physical laws. It might be useful to introduce the terms *elastic* and *inelastic* as applied to collisions. However, as kinetic energy is not introduced quantitatively until a later unit, a loose definition will have to suffice; if objects bounce apart, the collision is elastic but, if they stick together, it is inelastic. Enquiry skills 11A.1.1, 11A.1.2 This activity also relates to Standards 10A.21.1 and 10A.21.4.	
	Force and momentum change Ask students to comment on the forces objects exert on one another as they collide or spring apart. They should know from earlier work on Newton's third law of motion that the forces are equal and opposite. Drawing on students' earlier work, discuss the effect of these forces on the individual objects. Establish that, if a force F acts for a time interval t on a mass m, then $F = m(v - u)/t$ so $Ft = m(v - u) = mv - mu$ so force × time interval = change of momentum Ask students what will happen if two equal and opposite forces act for a given time interval (the resulting changes of momentum must also be equal and opposite). Newton's second and third laws of motion therefore lead inevitably to the principle of conservation of momentum: • in the absence of any net external force, the total momentum of any interacting objects remains constant. If time permits, divide students into groups and give each a different picture that illustrates momentum conservation. Ask each group to write a short explanation of what is happening. No equations should be used and each explanation should include the term *momentum* and refer to its *conservation*. Display the pictures and explanations on the wall.		
	Provide plenty of examples for students to practise applying the principle of momentum conservation to algebraic and numerical calculations. Point out that the statement relating force and time interval to the resulting change of momentum is a more complete statement of Newton's second law of motion than $F = ma$. It can be applied to situations where the mass does not remain constant. Provide examples of calculations using this form of Newton's second law.	Suitable examples requiring explanation in terms of momentum conservation include: • a person stepping out of a small boat (the boat moves back as the person moves forward); • a rocket expelling exhaust gases (and thus moving in the opposite direction); • a rifle producing recoil when fired; • the toy known as Newton's cradle; • a snooker shot in which the cue ball hits a stationary ball head-on; • a traffic accident involving a head-on collision between two vehicles.	

Objectives	Possible teaching activities	Notes	School resources
2 hours **Mass, weight and gravity** Distinguish between inertial and gravitational mass. Distinguish between mass and weight.	**Mass and weight** Tell students to imagine they are designing a space mission to 'deep space' far from Earth (or any other planet). During the voyage, the astronaut's masses need to be measured to keep a check on their health. Ask students what problems this might pose. Ask whether it would be possible to use apparatus such as a spring balance, top-pan balance or beam balance to find a person's mass. By suitable questioning and comments, lead them to realise that such methods rely on the person exerting a gravity-dependent force and that in 'deep space' this force will be zero. If necessary, show the mechanism inside a top-pan balance. Review Grade 10 work in which students measured gravitational acceleration and remind them that the gravitational acceleration close to Earth's surface is $g = 9.8\,\mathrm{m\,s^{-2}}$. Define the term *weight* $W = mg$ and emphasise that weight is a force and hence a vector, whereas mass is a scalar. Provide a few examples for quick calculations of weight (e.g. find the weight of a 70 kg person). Discuss the possibility of a person's or an object's weight or mass varying. Establish that weight depends on the local gravity, whereas mass is a property of the object itself. Provide further examples for calculation, some involving the weight of objects in locations other than on Earth's surface.		
	Divide students into small groups. Ask each group to discuss how they would measure someone's mass in weightless conditions. If time permits, also ask them to prepare to demonstrate their best idea to the rest of the class, using items available in the laboratory to show their method on a small scale (they could be asked to determine a mass of a few hundred grams). Encourage students to be imaginative so that different groups make different suggestions. Initially, do not give students any hints about methods. If a group gets stuck, ask them to think of situations they have seen in recent lessons where mass affected an object's motion. Hold a reporting-back session and ask for comments from the rest of the class on whether each suggestion is likely to work.	There is no one right approach or even a best method, but any method that involves measuring the force involved in changing the object's velocity (speed and/or direction of motion) is likely to be successful, as are methods that measure the time and/or the distance over which a given force produces a given effect on the motion. Methods involving attaching the object to a spring and timing the period of oscillation will work provided they do not rely on the object's weight to extend the spring. Enquiry skills 11A.1.4, 11A.1.5	
	Inertial and gravitational mass It might be appropriate to discuss the distinction between inertial and gravitational mass with some students. This is a bit subtle and is best approached from a standpoint of expecting them to be different. Start by demonstrating and discussing the behaviour of magnets, or of electrically charged objects. Such objects have magnetic or electrical properties that determine the forces they exert on one another. Introduce the term *inertia* as, loosely, 'resistance to motion'. Methods for finding mass in weightless conditions all involve inertia. So we can define *inertial mass* m_I using familiar expressions such as $F = m_I a$ and $p = m_I v$.		

Objectives	Possible teaching activities	Notes	School resources
	Ask students what connection, if any, there is between the (inertial) mass of an object and the magnetic or electrical force it can exert, and establish that there is no particular connection. Then ask what determines the size of gravitational force that objects exert on one another (e.g. what determines an object's weight). Call this property *gravitational mass* m_G and write $W = m_G g$ and note that m_G is equivalent to magnetism or electric charge in that it is the 'source' of a force rather than a measure of inertia. Now ask what connection there might be between m_I and m_G. The fact that all experimental measurements of inertial and gravitational mass yield the same result is a remarkable one – though students are so accustomed to taking it for granted they might not appreciate its significance.		
2 hours **The principle of moments** Know the principle of conservation of momentum and apply it to elastic and inelastic collisions and explosions involving two bodies in one dimension. Know that the weight of a body may be taken as acting at a single point known as its centre of gravity. Describe and apply the moment of a force and the torque of a couple, and apply the principle of moments to a system in equilibrium. List and explain applications of the principle of moments to engineering systems and to the muscles of the human body.	**Forces and moments** Show a metre ruler suspended at its mid point with hanger masses suspended from each side so that the ruler balances. Then challenge students to predict arrangements of masses that will balance the ruler. When they have written down their predictions they should work with apparatus in pairs to test each prediction in turn. Discuss students' success with the challenge and hence review earlier work. Emphasise that the masses are exerting a force (i.e. weight) and that, unless these forces act through the suspension point, they produce a turning effect (show an unbalanced ruler). Use students' own results to review the meaning of *moment of a force* and to establish the principle of moments for a system in equilibrium. Establish the SI units of the moment of a force (i.e. N m). Define the terms *torque* and *couple* and, on the board or OHP, use diagrams and numerical examples to show that the torque of a couple is the same about any point and is equal to the magnitude of one force multiplied by the perpendicular distance between their lines of action. Provide plenty of examples of algebraic and numerical calculations in which students calculate moments and apply the principle of moments to systems in equilibrium.	With classes that are likely to recall earlier work on moments, the initial arrangement can have several masses at different positions on each side. However, with some classes a simpler arrangement would be advisable (e.g. 200 g at 40 cm from the centre, balanced by 400 g at 20 cm from the centre). For the challenge, list about five combinations of masses and distances. Some should be simple (e.g. 400 g at 30 cm from the centre, to be balanced by 300 g on the other side). Some can be more complicated (e.g. if one side has 400 g at 10 cm from the centre and 400 g at 30 cm from centre, how can 700 g be arranged on the other side?). Enquiry skills 11A.1.1–11A.1.3	

Objectives	Possible teaching activities	Notes	School resources
	Lever mechanisms Set up a circus of activities that involve using levers and measuring turning effects. These should include examples relating to engineering applications and to the muscles in the human body. Ask students to work in pairs and to visit each station in turn. Provide a printed worksheet that tells students what to do at each station.	Suitable activities include: • measure the force applied at the end of a long and a short spanner to turn a six-sided nut and calculate the torque in each case; • make and explain a model arm showing the two lever mechanisms using elastic bands as muscles; • take appropriate measurements to calculate the force in the Achilles tendon when standing on the ball of the foot and by an arm muscle when lifting a mass; • position two students either side of a part-opened door; tell one to push about 10 cm from the hinge and tell the other to push close to the open edge; • measure the force and hence calculate the torque needed to lever the lid from a paint can using a screwdriver.	
	Centre of gravity Suspend a balanced metre ruler (see above) from a spring-balance forcemeter so that students can observe that the weight of the whole ruler system is equal to the sum of the weights of the hanger masses plus ruler. Review work from previous grades and establish the meaning of *centre of gravity*. Hold an object, such as a can of cola, so that one edge rests on the bench. Ask students to use the terms *centre of gravity* and *moment* to describe what will happen next. Establish that, if the centre of gravity does not lie vertically above the point of contact, there will be a turning effect. Discuss how the position of the centre of gravity determines whether the object will fall over or whether it will return to an upright position. Discuss other examples where this is important (e.g. the effect of a vehicle's centre of gravity on its road-holding ability).	Use actual objects or pictures displayed on a screen or wall to illustrate situations in which the position of centre of gravity is important for determining stability or otherwise. Suitable examples include: • a child's 'wobbly man' toy that is impossible to tip over; • a tower crane on a building site; • a desk lamp with a heavy base.	
	Give each pair of students an irregular lamina cut from thick card and ask them to devise a method of locating its centre of gravity. Allow students to request other items of apparatus. When students have devised a successful method, they should be asked to explain, in terms of moments and centre of gravity, why it works.	Various methods are possible. Students might try balancing the lamina on the point of a pencil and noting the position of the support. A tried and tested method is as follows. Suspend the lamina so that it hangs freely from one point. Draw a vertical line that passes through the suspension point. Repeat with a different suspension point. The centre of gravity is where the lines cross. Repeat with a third suspension point to verify the result.	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*A cyclist pedals hard as she accelerates from rest along a horizontal road, then pedals more gently to keep moving at steady speed. She stops pedalling and gradually comes to rest. Explain how her motion illustrates Newton's first and second laws of motion.*		
	An average resultant force of 200 N acts on a tennis ball while it is contact with a racket. The ball's mass is 0.055 kg. What is its acceleration during the contact time?		
	Draw a diagram to show the horizontal and vertical forces acting as a sprinter pushes off from a starting-block. Identify the Newtonian pairs of forces involving the sprinter.		
	A fire hose expels water at high velocity. Explain why the person holding it feels a force.		
	A railway coach of mass 90 tonnes travelling at 50 m s^{-1} collides with a coach of mass 20 tonnes travelling in the same direction at 30 m s^{-1}. The coaches join and move along together. How fast do they travel?		
	An astronaut boarding a spacecraft on Earth finds that his mass is 85 kg. The gravitational acceleration on Earth is 9.8 m s^{-2}. He lands on the Moon, where the acceleration due to gravity is 1.6 m s^{-2}. What is his weight on Earth? What is his mass on the Moon? What is his weight on the Moon?		
	A student hangs masses from a ruler suspended from its mid point. On one side she hangs 200 g at 30 cm from the mid point and 400 g at 10 cm from the mid point. On the other side she hangs 100 g at 40 cm from the mid point and 500 g at 10 cm from the mid point. Calculate the moments of the forces involved. Explain what will happen to the ruler when she stops holding it. (The weight of 100 g is approximately 1 N.)		

GRADE 11A: Physics 2

Work, energy and power

UNIT 11AP.2
7 hours

About this unit

This unit is the second of seven units on physics for Grade 11 advanced.

The unit is designed to guide your planning and teaching of physics lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For consolidation activities, look at the scheme of work for Grade 11A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already be able to state and use Newton's laws of motion. They should know and use the joule as the SI units of energy. They should know that energy can be transferred and transformed but that the total amount of energy is conserved. They should be able to define potential difference and the volt, and be able to solve problems relating to current and energy transfers in electric circuits.

Expectations

By the end of the unit, students know that there are many interconvertible forms of energy and perform calculations using expressions for kinetic energy and potential energy, work and power.

Students who progress further use a force–displacement graph to determine work done on a body when the force is not constant. They calculate efficiencies relating energy input to useful energy output.

Resources

The main resources needed for this unit are:

- demonstrations, pictures and video clips illustrating work being done
- simple examples of energy transducers (e.g. a lamp lit from a battery; a mass suspended from a spring so that it bounces up and down; a wind-up toy; a solar-powered calculator; a bell or buzzer powered by a battery; a piezo-electric lighter)
- poster tube, about 0.7 m long, with rubber bungs to fit each end
- lead shot
- motion sensor, freeze-frame video or multiflash photography apparatus
- information about Qatar power stations and/or other industries that involve the dispersal of waste heat
- electric motor to run from low-voltage DC supply

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *work*, *kinetic energy*, *potential energy*, *conservation of energy*, *transducer*, *efficiency*, *power*

Standards for the unit

7 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
1 hour **Work**	8.16.6	Know and use the joule as the unit of energy.	11A.27.1	Define work and apply the concept of work as the product of a force and displacement in the direction of the force.	12A..27.6	Calculate work done by a gas expanding against a constant external pressure using $W = p\Delta V$.
	11A.26.1	State Newton's laws of motion and apply them to real situations.				
3 hours **Kinetic and potential energy**	8.16.1	Classify common forms of energy as either kinetic or potential energy.	11A.27.2	Define kinetic and potential energy. Give examples of different forms of energy and their interconversion by transducers of various kinds, and classify them as potential or kinetic. Describe the principle of energy conservation and apply it to simple examples.	12A.27.3	Recognise that the first law of thermodynamics is a statement of the principle of conservation of energy.
	8.16.3	Know that during energy transformations energy is converted from one form to others but that the total energy remains the same.	11A.27.3	Recall, derive and apply the formulae $E_k = \frac{1}{2}mv^2$ and $E_p = mgh$.	12A.25.6	Derive and use expressions relating the kinetic, potential and total energy of an orbiting satellite.
1 hour **Power** **2 hours** **Efficiency and energy loss**	8.16.4	Know that heat is produced in all energy transformations ...	11A.27.4	Know that in practical systems energy loss, particularly in the form of waste heat, always occurs and use the concept of efficiency to solve problems. Calculate conversion efficiencies relating energy input to useful energy output.	11A.28.6	Define ... and use the concepts of specific heat capacity and specific latent heat.
	10A.31.2	Define potential difference and the volt. Solve problems using the relationships $V = W/Q$, $P = VI$, $P = I^2R$.	11A.27.5	Define power as the rate of doing work or converting energy and solve problems using $P = W/t$.		

Objectives	Possible teaching activities	Notes	School resources
1 hour **Work** Define work and apply the concept of work as the product of a force and displacement in the direction of the force.	**Mechanical work** Ask each student to write one sentence containing the word *work* and read it to the rest of the class. Some will use *work* to describe moving something with a force, but others will not. Explain that, in physics, *work* has a specific meaning: define $W = Fx$, where W is work done when a force F produces a displacement x along its own direction. Explain the derivation of the SI unit of work, the joule (J): 1 J = 1 N m. Establish that the work done is related to the energy supplied, hence energy and work are measured in the same units. Discuss the scalar nature of work. The amount of work done is related to the amount of energy input required and does not depend on the direction of the force or displacement. Point out to students with a strong mathematics background that work is the scalar product ('dot product') of force and displacement vectors.	This activity also relates to Standards 10A.25.1, 10A.25.4.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Show students a variety of demonstrations, pictures and video clips involving work and talk through each in turn with the whole class. Some should involve students making a measurement (e.g. the force needed to lift an object) – ask one or more students to come to the front of the class to make the measurements. Some should require students to deduce, or estimate, reasonable values for the force and/or displacement involved. In each case, ask students to calculate the work done. Provide plenty of examples of algebraic and numerical calculations involving the work done by a constant force for students to work through.	Suitable examples for measurement include: • the force needed to lift an orange; • the force needed to lift a bag of books; • the force needed to push a chair along the floor; • the force needed to open a door. In each case, specify the distance the object should be moved. Suitable pictures or video clips include: • a crane on a building site lifting a load; • a bulldozer pushing earth; • a weight-lifter.	
	Varying force For some students it will be appropriate to examine situations in which the force is not constant. On the board or OHP, show a graph of force against displacement for a situation in which the force is constant. Show that the area under the horizontal straight line is numerically equal to the work done. Explain that the area under a force–displacement graph is *always* equal to the work done, regardless of whether the graph is horizontal; this method can be used to find the work done in situations where the force is not constant. Show how this can be done by (1) finding the 'area' (in joules) of one graph-paper square then (2) counting or estimating the total number of such squares under the line of the graph. Give each pair of students a rubber band and a forcemeter and ask them to generate a force–displacement graph and hence find the work done in stretching the rubber to four times its original length. Provide a few examples of force–displacement graphs for situations in which the force varies. Tell students to work on these in small groups to deduce the work done.	Include a graph for a spring that obeys Hooke's law (straight line through the origin). Students can show that, to reach a displacement x, $W = {}^{1}/_{2}Fx$.	

<table>
<tr><th>Objectives</th><th>Possible teaching activities</th><th>Notes</th><th>School resources</th></tr>
<tr><td rowspan="2">3 hours

Kinetic and potential energy

Define kinetic and potential energy. Give examples of different forms of energy and their interconversion by transducers of various kinds, and classify them as potential or kinetic. Describe the principle of energy conservation and apply it to simple examples.

Recall, derive and apply the formulae $E_k = \frac{1}{2}mv^2$ and $E_p = mgh$.</td>
<td>Transducers

Set up a circus of activities with each illustrating an energy conversion. Tell students, in pairs, to visit each one in turn and use their knowledge of earlier work to identify and record the energy transformations involved.

Talk through students' observations with the whole class. Establish that all forms of energy can be described as either kinetic (something is moving) or potential (energy is stored so that there is the possibility of producing motion). Point out that the gravitational, elastic, magnetic and chemical energy can all be classed as potential energy.

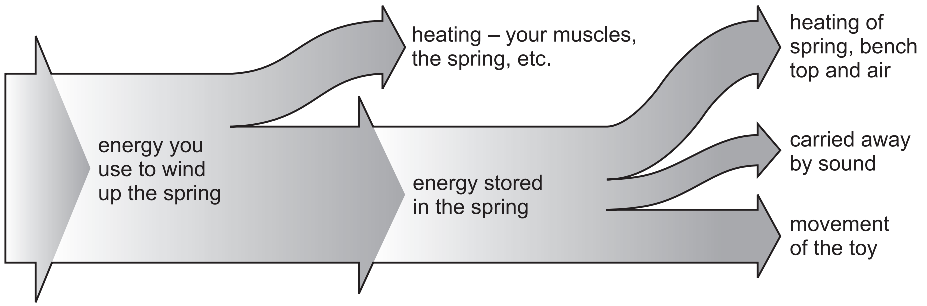
Introduce and define the term transducer. Ask students to suggest examples of transducers designed to perform particular energy conversions.</td>
<td>Suitable examples of energy conversion include:
• a lamp lit from a battery;
• a mass suspended from a spring so that it bounces up and down;
• a wind-up toy;
• a solar-powered calculator;
• a bell or buzzer powered by a battery;
• a piezo-electric lighter.

Suitable examples of transducers include:
• a car engine (chemical to kinetic);
• a stretched spring (elastic to kinetic);
• a kettle (electrical to heat).</td>
<td></td></tr>
<tr><td>Calculating energy

In earlier grades, students will have met the notion that energy is conserved. Remind them of this important law of nature and point out that, in order for any statement about conservation to be meaningful, we need some way of measuring energy. Explain that energy is related to work, which gives us a way to define and measure energy.

On the board or OHP, show how to derive an expression for the work done, and hence for the increase in gravitational potential energy E_p, when an object mass m is lifted (which requires a force mg) through a height h. Then use equations for motion at constant acceleration to show that when a constant force accelerates an object mass m from rest, the work done is equal to $\frac{1}{2}mv^2$, where v is the final velocity. Identify this as an expression for the object's kinetic energy E_k.

Introduce students to Sankey diagrams (see the diagram below for a wind-up toy), which are a useful way to display information about energy transformations. The total width of the diagram remains constant throughout any process (representing energy conservation) and the widths of the constituent arrows represent the proportions of different forms of energy.



Ask students to sketch Sankey diagrams for some of the transducers they studied in the previous activity. These will not be quantitative, but should indicate the likely relative proportions of the forms of energy involved.</td>
<td>Example Sankey diagram showing energy transformations in a wind-up toy.

Source: adapted from Science Focus, The Salters Approach: 2 Looking into Science, Heinemann Educational, p.27. © 1993 University of York Science Education Group.</td>
<td></td></tr>
</table>

Objectives	Possible teaching activities	Notes	School resources
	Measuring energy Divide the class into pairs or small groups and tell each to carry out one of the following activities (or another activity that enables energy conversion to be measured), and to draw a quantitative Sankey diagram for the process. Then ask them to present their results to the rest of the class. 1 Falling object. Drop an object of mass *m* through a height *h*. Use freeze-frame video, multiflash photography or a motion sensor to determine its speed *v* immediately before impact. Compare the calculated values of *mgh* and $\frac{1}{2}mv^2$. 2 Lead shot. Put a measured mass *m* of lead shot (about 100 g) in a plastic cup. Record its temperature. Seal one end of a 0.7 m long poster tube firmly with a rubber bung. Pour in the lead shot. Seal the other end of the tube firmly. Invert the tube 20 times in succession. Pour the lead shot into the cup and record its temperature. Find the total distance through which the shot has fallen (20 × the length of the tube) and hence calculate the total loss in gravitational energy. Find the rise in temperature and use the specific heat capacity of lead (c = 130 J kg^{-1} °C^{-1}) to calculate the increase in heat energy. 3 Catapult. Fix a rubber band so that it acts as a catapult to propel a vehicle along an airtrack or a dynamics trolley along a friction-compensated runway. Use a motion sensor or ticker-tape to record the speed *v* of a vehicle, mass *m*, after it has been set in motion by the catapult stretched through a measured distance. Use a forcemeter to plot a force–extension curve for the catapult and hence determine the elastic energy stored. Compare this with the vehicle's kinetic energy. Establish the key points arising from these activities in a whole-class discussion: • the energy measured after the transformation is always equal to or less than that measured before; • any discrepancy can be accounted for by uncertainties in measurement and/or by loss in the form of heat (activity 2 illustrates that a relatively large change in potential energy gives rise to a relatively small rise in temperature; in practice, energy lost as heat can often go unnoticed). Any difference between initial and final energy can be used to deduce the width of the 'heat' component of the Sankey diagram. Point out that, in theoretical calculations, energy losses as heat are often ignored as they are difficult to quantify. Provide plenty of examples that allow students to practise algebraic and numerical calculations involving energy conservation and transformation.	This activity also relates to Standards 10A.25.2, 10A.25.3. Enquiry skills 11A.1.1, 11A.1.4, 11A.3.3, 11A.4.1 If students have not already met the concept of specific heat capacity, either introduce it here or omit this example.	

Objectives	Possible teaching activities	Notes	School resources
1 hour **Power** Define power as the rate of doing work or converting energy and solve problems using $P = W/t$.	**Power** By means of a few quick-fire questions, build on students' own experiences to introduce the scientific meaning of *power*. For example; two cars drive up a slope, one reaches the top in 10 s and the other takes 20 s – which is the more powerful? Two cranes are unloading cargo from a ship, one can lift 10 tonnes through 10 m in 30 s and the other can move the same load through the same distance in only 20 s – which is the more powerful? Define power P as the rate of doing work or converting energy: $P = W/t$. Remind students of the SI unit of power: $1\ \text{W} = 1\ \text{J s}^{-1}$. Point out that the same relationship and units are used in calculations of electrical power. Ask students to work alone or in pairs to determine the power of a muscle system. A variety of methods can be used, and different students might carry out different measurements. If they have access to a gym, students can use the equipment there to make relevant measurements. Provide plenty of examples that allow students to practise algebraic and numerical calculations involving energy and power.	**Safety:** When asking students to measure their own muscle power, first check whether any student has health problems that would make this activity unsafe. Suitable muscle power activities include: • Weight-lifting. Record the time taken to lift a measured mass through a measured distance ten times. • Climbing steps. Record the time taken to run up a flight of steps. Measure body mass and the vertical height of the stairs. • Press-ups. Record the time to perform five press-ups. Measure body mass. Estimate the position of the centre of gravity and hence find the height through which the body mass is lifted.	
2 hours **Efficiency and energy loss** Know that in practical systems energy loss, particularly in the form of waste heat, always occurs and use the concept of efficiency to solve problems. Calculate conversion efficiencies relating energy input to useful energy output.	**Waste heat** If possible, arrange a class visit to a local industry where waste heat needs to be dispersed, such as a power station. Otherwise, use the Internet and/or other sources of information to gather information about such industries in Qatar. Present the information to students using whichever visual media are available and appropriate (e.g. video, PowerPoint, posters). Emphasise that in all industrial processes, and other practical systems, there is always some energy loss, generally in the form of waste heat. In order to reduce costs and save fuel, this waste can be reduced to some extent by good design and engineering but can never be eliminated completely. Discuss methods used to disperse the waste heat (e.g. cooling towers). Sometimes the waste heat can become a useful by-product of the process (e.g. in combined-heat-and-power stations where it is used for space and water heating).	**Visit opportunity:** Doha power station.	
	Efficiency Define the efficiency of a process as $\frac{\text{useful energy (or power) output}}{\text{total energy (or power) input}}$ and establish that this can be expressed as a fraction or a percentage. Relate this to Sankey diagrams: if such a diagram is drawn quantitatively, the efficiency is equal to the ratio of the widths of arrows representing the useful output and the total input. Ask students, in small groups, to determine the efficiency of an electric motor lifting a load. Tell them to connect the motor to an ammeter and voltmeter in order to find the input power. They should record the time taken to lift a known mass through a measured distance and hence calculate the output power. They should observe that the motor gets warm due to energy wasted as heat. Provide plenty of examples that allow students to practise algebraic and numerical calculations involving efficiency, energy and power.	You will need an electric motor that runs from a low-voltage DC supply. If not enough apparatus is available, this activity can be done as a student-assisted demonstration. Adjust the input to the motor so that the load is lifted quite slowly.	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*A crane lifts 1 tonne of concrete through a height of 25 m. How much work does it do? (1 kg has a weight of 9.81 N.)*		
	Which has the greater kinetic energy: an athlete, mass 72 kg, sprinting at 9.5 m s^{-1}, or a bullet, mass 15 g, moving at 560 m s^{-1}?		
	A student finds that a stretched rubber band stores 3.5 J of energy. She uses it to propel an object of mass 0.025 kg vertically upwards. What will be the initial speed of the object? How high can it travel before coming momentarily to rest?		
	A lift in a building raises a mass of 1500 kg through 30 m in 1 minute. What must be the minimum output power of the motor?		
	A student of mass 65 kg climbs to the top of a building 30 m high. If the efficiency of his muscles is 20%, how much energy does he need to obtain from food in order to do this?		

GRADE 11A: Physics 3

Thermal physics

UNIT 11AP.3
10 hours

About this unit

This unit is the third of seven units on physics for Grade 11 advanced.

The unit is designed to guide your planning and teaching of physics lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For consolidation activities, look at the scheme of work for Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already be able to use the Celsius scale of temperature. They should know that heat can be transferred by conduction, convection and radiation, and be able to explain how convection currents are caused. The should know that the joule is the SI unit of energy, and that the amount of heat energy in an object depends on the mass of the object and what it is made of as well as how hot it is.

Expectations

By the end of the unit, students define and measure temperature and know how thermal energy moves from place to place. They know that heat is transferred by conduction, convection and radiation and can give examples of each. They know that some substances are better conductors than others, that convection currents are the basis of weather patterns and that some surfaces radiate and absorb heat better than others. They use the concepts of specific heat capacity and specific latent heat to calculate heat transferred to bodies.

Students who progress further explain the concepts of specific heat capacity and specific latent heat in terms of the kinetic particle model and understand the importance of the unusually large specific heat capacity of water.

Resources

The main resources needed for this unit are:

- freezing mixture of ice and salt
- apparatus to make alcohol-in-glass thermometer
- ethanol coloured with dye
- model domestic water system
- apparatus to demonstrate thermal conductivity of metal rod
- samples of building materials used for thermal insulation
- thermometer with blackened bulb
- Leslie's cube
- converging lens and/or concave mirror
- dry sand
- joulemeters
- 1 kg blocks of metal (aluminium, steel) manufactured for use with low-power electrical heaters
- hexadecanol (or other solid with well-defined melting point below 100 °C)
- copper calorimeter
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- terms relating to temperature: *thermometer*, *temperature scale*, *calibrate*
- terms relating to heat transfer: *thermal equilibrium*, *heat*, *conduction*, *convection*, *radiation*, *infrared*, *convection current*, *vacuum*
- terms relating to heating and cooling: *specific heat capacity*, *specific latent heat*

Standards for the unit

10 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
2 hours **Temperature** **4 hours** **Heat transfer** **4 hours** **Heating and cooling**	8.17.1	Know that temperature is a measure of how hot something is and the common unit of temperature is the degree Celsius.	11A.28.1	Define temperature and explain how a temperature scale is constructed. Know how different types of thermometer work and list their advantages and disadvantages.	
			11A.28.2	Recognise that thermal energy is transferred from a region of higher temperature to a region of lower temperature and that regions of equal temperature are in thermal equilibrium.	
	8.17.3	Know that heat is transferred by conduction, convection and radiation and cite everyday examples of each.	11A.28.3	Know that heat is transferred by conduction, convection and radiation; explain conduction and convection in terms of particle movement.	
	10A.27.1	Describe the kinetic particle model for solids, liquids and gases, and relate the difference in the structures and densities of solids, liquids and gases to the spacing, ordering and motion of particles.			
	8.17.5	Explain the cause of convection currents in air and water.	11A.28.4	Know the causes of convection currents in air and water and understand how these can affect climate and weather.	
	8.17.6	Show how convection currents in air cause weather features.			
	8.17.8	Know that heat can be radiated through a vacuum and that this is how the heat from the Sun reaches the Earth.	11A.28.5	Know that heat can be radiated through a vacuum and that this is how the heat from the Sun reaches Earth.	
	8.16.6	Know and use the joule as the unit of energy.	11A.28.6	Define, explain in terms of the kinetic particle model and use the concepts of specific heat capacity and specific latent heat. Offer explanations for the relative magnitudes of these quantities and for differences between materials.	
	8.17.2	Know that the amount of heat energy in an object depends on the mass of the object and what it is made of as well as how hot it is.			
	11A.27.4	Know that in practical systems energy loss, particularly in the form of waste heat, always occurs and use the concept of efficiency to solve problems. Calculate conversion efficiencies relating energy input to useful energy output.			
			11A.28.7	Show an understanding of the importance of the unusually large value of the specific latent heat and the specific heat capacity of water, in terms of heat regulation in the body and the impact of the oceans on climate.	

Objectives	Possible teaching activities	Notes	School resources
2 hours **Temperature** Define temperature and explain how a temperature scale is constructed. Know how different types of thermometer work and list their advantages and disadvantages.	**Measuring temperature** Divide the class into groups and set each the task of using the Internet to find out how one type of thermometer works. Hold a reporting-back session in which students explain the operation of various types of thermometer to the rest of the class. Discuss the advantages and disadvantages of each. If available, demonstrate examples of each type of thermometer. You might also wish to show and discuss a constant-volume gas thermometer. Establish that all thermometers involve some physical parameter that changes with temperature, and that the changes must be reproducible and must be easily measured and displayed.	**ICT opportunity:** Use of the Internet. Suitable examples include: • liquid-in-glass (mercury and alcohol); • electrical resistance; • thermocouple; • liquid crystal; • bimetallic. (*Note:* 'digital thermometer' refers to the mode of display rather than the underlying mechanism which usually involves electrical resistance.)	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Calibration Divide the class into pairs or small groups and give each the apparatus necessary to make a liquid-in-glass thermometer. Establish that the liquid will rise further up the tube if the flask is warmed. Ask students how they would calibrate their apparatus (i.e. mark a scale on the tube) to make a thermometer without using another ready-calibrated thermometer. By careful questioning and comment, establish the following procedure for devising a temperature scale and calibrating a thermometer: • define two 'fixed points' that can be reproduced independently (e.g. melting and freezing of pure water at atmospheric pressure); • assign values to these on a temperature scale (e.g. 0° and 100° on the Celsius scale); • mark the height of liquid (or other measurable property) at each of these two points; • divide the scale between these marks and extrapolate beyond them. Tell students to calibrate their own apparatus. Show them how to place the flask safely into a beaker of boiling water and provide access to a freezing mixture of ice and salt. Then ask students to use their calibrated thermometers to measure room temperature and compare their results with one another and with those from a commercially produced instrument.	**Safety:** Take care using boiling water and other hot objects. Apparatus: small glass flask, stopper, long narrow open-ended glass tube and more than enough coloured ethanol to fill the flask. Show students how to fill the flask and insert the stopper so that the liquid rises up the tube. You might want to tell students about the absolute (Kelvin) temperature scale. Explain that this has just one defined fixed point (absolute zero) but the unit of temperature change (the kelvin) is defined to be exactly the same as the Celsius degree. Enquiry skills 11A.4.1, 11A.4.2	

Objectives	Possible teaching activities	Notes	School resources
4 hours **Heat transfer** Recognise that thermal energy is transferred from a region of higher temperature to a region of lower temperature and that regions of equal temperature are in thermal equilibrium. Know that heat is transferred by conduction, convection and radiation; explain conduction and convection in terms of particle movement. Know the causes of convection currents in air and water and understand how these can affect climate and weather. Know that heat can be radiated through a vacuum and that this is how the heat from the Sun reaches Earth.	**Conduction and convection** Divide the class into small groups and give each a briefing sheet on one aspect of heat transfer by conduction or convection. Each group has the task of: • preparing and presenting a demonstration to the rest of the class; • explaining their results in terms of the kinetic particle model. To help with the first part of the task, students will need to review work from Grade 8. For the second part, they will need to review work from Grade 10 in which it was established that the random motion of particles becomes more vigorous as temperature increases, that heating causes expansion and that a substance will float if immersed in a fluid (gas or liquid) of greater density. During the presentations, ensure that students are familiar with key terms (such as *convection current*) and are using them correctly. After all groups have made their presentations, introduce the term *thermal equilibrium*. Establish that heat transfer will occur only between regions of different temperature and that regions at the same temperature are said to be in thermal equilibrium (i.e. no net heat transfer can occur). Discuss this in terms of the kinetic particle model: if two objects are in thermal equilibrium, their particles have the same (average) kinetic energy. Set students a challenge: working in pairs or individually, they should devise and carry out an investigation into the insulating properties of materials used for thermal insulation in buildings. Tell them that they should first plan their investigations. You might want them to produce written plans for approval before proceeding. Plans should indicate the apparatus required, the method to be used and how relevant variables will be controlled. They should also include a prediction: which material do students think will be the best insulator, and why. Students should produce written reports that include a clear statement of results and conclusions, and an evaluation of the method used.	Prepare briefing sheets outlining suitable tasks, such as: • show convection currents in water using a crystal of potassium manganate(VII) and in air using a paper spiral; • demonstrate and explain a model domestic water system; • show thermal conduction along a metal rod (fix thumb-tacks to the rod with wax, heat one end of the rod in a Bunsen flame); • demonstrate and discuss everyday examples of good and poor thermal conductors; • devise a demonstration to show that, while water readily allows heat transfer by convection, it is a poor thermal conductor. Enquiry skills 11A.1.4, 11A.4.1, 11A.4.2 As far as resources and safety permit, allow students a free choice of apparatus and approach. Enquiry skills 11A.1.1–11A.1.5	
	Radiation Set up a circus of activities to illustrate heat transfer by radiation. Tell students, in pairs, to visit each in turn and use the apparatus to help them answer questions including the following: • What is the source of the radiation? • How is the radiation detected? • What evidence is there that the radiation travels in straight lines? • What types of surfaces are good at emitting, absorbing or reflecting the radiation? • Which materials absorb the radiation and which let it pass through easily? Ensure that students have addressed the questions posed during the circus. Check that they know that a vacuum is an absence of any material substance. Introduce the term *infrared radiation* and establish that it is closely related to visible light. Display images from the Internet to show that even objects that are very cold by everyday standards emit radiation. (Look for images of buildings and other objects obtained using thermal imaging cameras and/or images of cold astronomical objects made with infrared-sensitive telescopes.)	Suitable examples include: • Herschel's experiment (sunlight passes through a prism to produce a visible spectrum; a thermometer with a blackened bulb detects 'heat' radiation beyond the red); • Leslie's cube (a metal cube with different surfaces, filled with hot water; radiation is 'felt' by holding a hand a few centimetres from each face; a matt black face emits most radiation and shiny silver least); • a lens or curved mirror that can focus solar radiation onto a match head. Enquiry skills 11A.1.1, 11A.4.1. 11A.4.2	

Objectives	Possible teaching activities	Notes	School resources
	Climate and weather Use examples of climate and weather to sum up and apply what students have learned about heat transfer. Begin with a whole-class session to establish some key principles: • Earth is heated by solar radiation travelling through a vacuum; • solar radiation is more intense and undergoes less atmospheric absorption at low latitudes; • Earth's atmosphere is transparent to visible and some other radiation but absorbs much infrared radiation; • radiation is readily absorbed by dark rock but is reflected from light-coloured surfaces and water. Tell students to form small groups and assign to each one example of a weather- or climate-related phenomenon. Their task is to use the Internet and other information sources to find out about its importance and to produce a large colourful wall poster explaining the phenomenon in terms of heat transfer. They should include an acknowledgment of the sources consulted.	Suitable examples include: • El Niño events; • the origin of tropical storms; • land and sea breezes; • the greenhouse effect and possible global warming. You might wish to defer this activity until after students have studied heating and cooling and know of the anomalously high specific heat capacity of water. **ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.6, 11A.1.8, 11A.2.2, 11A.3.4	
4 hours **Heating and cooling** Define, explain in terms of the kinetic particle model and use the concepts of specific heat capacity and specific latent heat. Offer explanations for the relative magnitudes of these quantities and for differences between materials. Show an understanding of the importance of the unusually large value of the specific latent heat and the specific heat capacity of water, in terms of heat regulation in the body and the impact of the oceans on climate.	**Specific heat capacity** Place two identical metal cans on the front bench. Put a measured mass of water at room temperature in one and an equal mass of dry sand in the other. Measure and record the temperature of each. Ask students each to write down their own prediction, with reasons, of what will happen when both containers are heated for the same period of time over an equally strong Bunsen flame. Ask students to indicate by a show of hands who thinks the temperature rises will be the same, who thinks the water will get hotter and who thinks the sand will get hotter, then ask a few students to give the reasons for their predictions. Heat both containers for a few minutes then stir and measure their temperatures. The sand will be noticeable hotter than the water. Discuss how the relationship between heat input, mass and temperature rise depends also upon the nature of the substance. Introduce the term *specific heat capacity* and establish the relationship $Q = mc\theta$, where Q is heat input (or output), m mass, c specific heat capacity and θ the *change* in temperature.	Make sure that the water and sand have both been allowed to reach room temperature beforehand. Adjust the Bunsen flames so that both are of similar size and intensity. Some students may predict equal temperature rises because the masses are equal. Some may predict that the water will get hotter on the grounds that sand, being solid, is 'more difficult' to heat. Some may predict that the sand gets hotter as it occupies a smaller volume. Enquiry skill 11A.1.2	
	Review work from Grade 8 to establish the joule as the SI unit of energy. Ask students to derive the SI units of c and establish that these are $J\,kg^{-1}\,°C^{-1}$. Provide plenty of algebraic and numerical examples of calculations involving specific heat capacity.	This also relates to Standard 10A.25.1.	
	Demonstrate how the heat output from a small electrical heater can be recorded using a joulemeter, and how such a heater can be used to heat a specially designed metal block. Ask students to suggest how this apparatus can be used to determine the specific heat capacity of a metal. Discuss the need to insulate the apparatus to reduce heat loss and the need to ensure even distribution of heat (if using a poor conductor, it must be able to be stirred). Ask students to work in pairs to determine the specific heat capacity of a solid or a liquid. Ask them each to write their final result on the OHP or board. Discuss any similarities and differences with the whole class.	Suitable substances include: • various metals (use specially designed 1 kg blocks); • water; • paraffin; • dry sand.	

Objectives	Possible teaching activities	Notes	School resources
	Students who have used the same substance will not all get exactly the same result. Discuss the accuracy and precision of the measurements and any sources of systematic error such as heat loss. Point out that, in theoretical calculations, it is customary to ignore heat loss as it is difficult to quantify. If time permits, ask students to determine specific heat by a 'method of mixtures'. For example, ensure that a copper calorimeter of known mass is initially at room temperature. Insulate it to prevent heat loss. Heat a known mass of water and record its temperature. Pour the hot water into the calorimeter, stir and record the new temperature. Given that water has $c = 4.2 \times 10^3\,\mathrm{J\,kg^{-1}\,°C^{-1}}$, calculate *c* for copper.	If using liquid or sand, ensure that the heater is fully immersed and stir before measuring temperature. Ideally, more than one pair of students should determine *c* for each substance. If you have the relevant apparatus, it would be appropriate to demonstrate and discuss a continuous flow method for determining specific heat capacity. This work also relates to Standards 10A.25.2, 10A.25.3. Enquiry skills 11A.1.1, 11A.1.3, 11A.1.5, 11A.4.1, 11A.4.2	
	It should be apparent from the previous activity that different substances have different values of *c*. In particular, water has a much higher specific heat capacity than other substances. Ask students to suggest explanations, in terms of the kinetic particle model, for substances having different specific heat capacities. Establish, by questioning and by example calculations, that a high value of *c* means that a large input or output of energy results in only a small temperature change. Discuss with students situations where the high specific heat capacity of water is particularly important, including the following. • The human body contains a high proportion of water. This helps to maintain a near-constant body temperature despite changes in surrounding air temperature, and this constant temperature in turn helps to maintain correct functioning of the biochemical processes within the body. • The oceans have a moderating effect on climate and weather. Inland locations experience a far greater seasonal and day–night temperature variation than those close to the sea. As an illustrative example, use the following to compare the effects of solar heating of land and ocean. At sea level, solar radiation provides about $700\,\mathrm{J\,m^{-2}\,s^{-1}}$. Water has $c = 4.2 \times 10^3\,\mathrm{J\,kg^{-1}\,°C^{-1}}$ and density $\rho = 1 \times 10^3\,\mathrm{kg\,m^{-3}}$. Sand and rock typically have $c = 8 \times 10^2\,\mathrm{J\,kg^{-1}\,°C^{-1}}$ and density $\rho = 2.5 \times 10^3\,\mathrm{kg\,m^{-3}}$. Assuming all the incoming energy is absorbed evenly throughout the top metre of land or water, calculate the rise in temperature after 5 hours of solar heating. It would be useful to discuss with students the likely validity of the assumptions made.	You will need to decide how much detail in terms of particles is appropriate for your students. This will be determined in part by their knowledge of chemistry. One major reason for differences in *c* is simply the masses of the particles (atoms or molecules). Most metals have very similar heat capacities *per atom* (or per mole): at any given temperature, all atoms have, on average, the same kinetic energy regardless of their mass. A metal such as lead, with high atomic mass, has a much lower *c* than one, such as aluminium, with low atomic mass, simply because 1 kg of lead contains fewer atoms than 1 kg of aluminium. A similar argument applies to the heat capacities of monatomic gases. Substances whose molecules can rotate and vibrate have higher specific heat capacities than those made from single atoms, since energy must be supplied to increase the vibrational and rotational motion as well as the translational kinetic energy. Water has a particularly high *c* because (a) its molecules have low mass, so there are more per kilogram than in substances with more massive particles, and (b) there are weak bonds between the molecules, and energy is associated with the stretching and twisting of these as well as the interatomic bonds within molecules.	

Objectives	Possible teaching activities	Notes	School resources
	Changing state Give each pair of students a test-tube containing a low-melting-point solid, a thermometer and a stop-clock. Show how the tube can be heated by supporting it in a clamp and immersing into a beaker of water heated by a Bunsen burner. Tell students to heat their samples until they melt then continue to heat for a further minute or so. They should then stop heating and remove the beaker of water so that the sample in the tube can cool freely with the thermometer inserted. Tell them to record the temperature at regular intervals (e.g. every 20 s) and plot a graph of temperature against time. They will notice that after a while the temperature ceases to fall, even though it is well above room temperature. Encourage them to observe that the sample is still emitting heat (which can be detected by holding a hand a few centimetres from the tube) and that the sample is in the process of solidifying. Discuss the results and ask students to suggest explanations in terms of kinetic particle theory. Establish that melting requires an input of energy to enable the particles to move freely; their potential energy, though not their kinetic energy, must increase. Solidification requires that this energy be emitted. Explain that energy associated with a change of state at constant temperature is known as *latent heat* and introduce the term *specific latent heat*. Point out that melting and vaporisation both involve a change of state, and hence both involve latent heat, so it is important to distinguish *latent heat of melting* from *latent heat of vaporisation*. You might wish also to point out that *fusion* is often used synonymously with *melting*. Discuss the SI units of latent heat and establish that they are $J\,kg^{-1}$.	This work also relates to Standard 10A.25.1. **Safety:** Use a non-carcinogenic low-melting-point substance (e.g. use hexadecanol *not* naphthalene).	
	Demonstrate the following experimental method for determining the specific latent heat of melting of ice: • place crushed ice in a large filter-funnel so that it completely covers a small electric heater; • place a measuring cylinder under the funnel to collect water; • using a joulemeter to record the energy input, heat the ice until it is partially melted. Then ask pairs of students to carry this out for themselves and compare their results with those obtained by other pairs. They should state any assumptions they have made and consider the accuracy and precision of their measurements. Divide students into small groups and challenge them to design a method for determining the specific latent heat of vaporisation of a liquid. Check that their plans are safe and feasible, then provide suitable apparatus so that they can carry out their procedures. Ask students to compare their experimental values for the specific latent heats of melting and vaporisation of water and to suggest explanations for their very different values: vaporisation involves a large volume change so energy is needed, loosely speaking, to push the surrounding air out of the way. Provide plenty of examples of numerical and algebraic calculations using latent heat.	This work also relates to Standards 10A.25.2, 10A.25.3. Enquiry skills 11A.1.1, 11A.1.5	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Draw a labelled series of sketch diagrams to explain heat conduction along a metal rod in terms of particle motion.*		
	Explain why rooms at the top of a building without heating or air-conditioning are often warmer than those near the bottom. Include the following terms in your answer: ***density****,* ***convection****,* ***current****,* ***expand****.*		
	A student says 'I've seen pictures of the Sun that show convection currents near its surface, so heat from the Sun must reach Earth by convection.' Explain whether or not the student is right about the way energy travels to Earth from the Sun.		
	A silver spoon, with mass 50 g and at a temperature 20 °C, falls into a cup containing 300 g of tea at 80 °C. Silver has specific heat capacity $c = 232\ \mathrm{J\,kg^{-1}\,°C^{-1}}$ *and water has* $c = 4.2 \times 10^3\ \mathrm{J\,kg^{-1}\,°C^{-1}}$*. By making suitable assumptions, calculate the resulting temperature of the tea.*		
	An electric heater supplies energy at a rate of 2000 $\mathrm{J\,s^{-1}}$*. How long does it take to raise the temperature of 500 kg of water from 25 °C to boiling point and then to vaporise 50 g of the water? (Water has specific heat capacity* $c = 4.2 \times 10^3\ \mathrm{J\,kg^{-1}\,°C^{-1}}$ *and specific latent heat of vaporisation* $l = 2.3 \times 10^6\ \mathrm{J\,kg^{-1}}$*.)*		

GRADE 11A: Physics 4

Properties of waves

UNIT 11AP.4
9 hours

About this unit

This unit is the fourth of seven units on physics for Grade 11 advanced.

The unit is designed to guide your planning and teaching of physics lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already be able to distinguish between transverse and longitudinal waves and be able to describe the properties of a wave using appropriate technical vocabulary. They should be able to explain the geometry of refraction, calculate the refractive index of a medium and interpret it in terms of change in the velocity of light. They should be able to describe electric and magnetic fields as fields of force.

Expectations

By the end of the unit, students explain refraction, diffraction and interference of waves and apply the explanation to water waves, sound waves and electromagnetic waves. They know that the electromagnetic spectrum consists of electromagnetic radiation of varying frequency but with the same velocity in a vacuum and describe the properties and applications of the main parts of the spectrum.

Students who progress further explain the operation of a diffraction grating and solve problems relating to interference phenomena. They explain the Doppler effect in terms of wave motion, and understand the phenomena of coherence and the polarisation of transverses waves.

Resources

The main resources needed for this unit are:

- ripple tanks
- ray boxes
- rectangular blocks of transparent material (e.g. glass, transparent rigid plastic)
- microwave generator and receiver
- ultrasound generator and receiver
- polarising filters
- overhead projector (OHP)
- large Iceland spar crystal
- liquid crystal display (e.g. in a calculator)
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *reflection*, *refraction*, *refractive index*, *velocity*, *wavelength*
- *diffraction*, *superposition*, *constructive interference*, *destructive interference*, *diffraction grating*, *coherence*, *phase*, *antiphase*
- *beats*
- *Doppler effect*
- *polarisation*
- *electromagnetic spectrum*, *free space*

Standards for the unit

Unit 11AP.4

9 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS	
1 hour **Reflection and refraction** **4 hours** **Diffraction and superposition** **1 hour** **Doppler effect** **1 hour** **Polarisation** **2 hours** **Electromagnetic spectrum**	10A.28.3	Know and use the terms *crest*, *trough*, *compression*, *rarefaction*, *displacement*, *amplitude*, *phase difference*, *period*, *frequency*, *wavelength* and *velocity*, and perform calculations using the relationships between velocity, frequency and wavelength.	11A.29.1	Know what happens to waves when they are reflected and refracted; explain diffraction, superposition and constructive and destructive interference in terms of wave motion.		
	10A.29.1	Know that light travels in straight lines and can be reflected by plane surfaces ...				
	10A.29.2	Know that light is refracted as it passes from one medium to another. Explain the geometry of refraction, calculate the refractive index of a medium and interpret it in terms of change in the velocity of light.	11A.29.2	Explain refraction of light and water waves in terms of waves, know that the velocity of waves changes during refraction and relate this to refractive index.		
			11A.29.3	Use a diffraction grating to show diffraction and the production of visible spectra and to solve problems relating to interference phenomena using the relationships $\lambda = ax/D$ and $d \sin\theta = n\lambda$.		
			11A.29.4	Explain the Doppler effect in terms of wave motion and give examples from sound and light.		
	10A.28.2	... distinguish between transverse and longitudinal waves.	11A.29.5	Explain the phenomena of coherence and polarisation of transverse waves and describe applications of both.		
	10A.30.3	Describe an electric field as an example of a field of force ...	11A.29.6	Explain electromagnetic radiation in terms of oscillating electric and magnetic fields and know that all electromagnetic waves travel with the same velocity in free space. Describe the main characteristics and applications of the different parts of the electromagnetic spectrum and give examples of the reflection, refraction and interference of electromagnetic waves.	12A.30.2	Know about the particulate nature of electromagnetic radiation; recall and use the formula $E = hf$.
	10A.30.5	Describe a magnetic field as an example of a field of force ...				

Objectives	Possible teaching activities	Notes	School resources
1 hour **Reflection and refraction** Know what happens to waves when they are reflected and refracted ... Explain refraction of light and water waves in terms of waves, know that the velocity of waves changes during refraction and relate this to refractive index.	**Reflection** Perform a sequence of short demonstrations to remind students about the reflection of waves. These could include: • using a ripple tank to show reflection of plane and circular wave pulses at a straight barrier; • reflection of microwaves and/or ultrasound at a plane surface; • reflection of a light ray at a plane mirror. Hand out copies of diagrams of these demonstrations for students to complete.	Throughout this unit, ensure that students are familiar with relevant terminology from earlier units relating to waves (e.g. *wavelength*, *frequency*, *period*, *amplitude*). Prepare student worksheets. Check that completed diagrams show there is no change of wavelength on reflection and that light rays, and lines drawn at right-angles to wavefronts, obey the law of reflection.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Refraction Present a series of demonstrations relating to refraction. Suitable demonstrations include: • refraction of plane waves in a ripple tank; • refraction of a light ray by a rectangular glass block; • getting a line of students to act as a wavefront and to walk across a boundary between areas representing high-speed and low-speed regions; • a Java applet showing waves refracting at a plane boundary. Ensure that students know that refraction involves a change of speed and direction.	The third demonstration involves about six students walking side by side with regular steps of a constant length (they will need to practise this). They should walk towards a chalk line on the floor marking a boundary between two regions, and as each one crosses the boundary he or she should reduce speed by halving the length of their steps. If the 'wavefront' crosses the boundary at an angle, it will change direction. **ICT opportunity:** Use of Java applets. Enquiry skill 11A.3.4	
	Refractive index Use large labelled diagrams on the board or OHP to remind students of Snell's law of refraction. Establish the definition of refractive index expressed both in terms of wave velocities in two media and in terms of the angles of incidence and refraction. Ask students to work in pairs using ray-boxes to determine the refractive index of a variety of media (e.g. glass, transparent rigid plastic) and hence calculate the speed of light in each. Tell them to consider uncertainties in measurement and say how these affect their results and calculations. Provide plenty of numerical and algebraic examples that allow students to practise using Snell's law.	**Mathematics:** A knowledge of the trigonometry of right-angled triangles is required. Enquiry skills 11A.3.2, 11A.3.3	

Objectives	Possible teaching activities	Notes	School resources
4 hours **Diffraction and superposition** ... explain diffraction, superposition and constructive and destructive interference in terms of wave motion.	**Superposition** Ask students to work in small groups using a rope to explore what happens when two wave pulses meet. Introduce the term *superposition*. Get two students to hold one end of the rope each and tell them both to send a single pulse. Tell the rest of the group to observe carefully what happens when the pulses superpose. Then get them to use pulses of varying size, and to see what happens when both pulses begin at the top or bottom of the rope, and when one begins at the top and the other at the bottom. Ask students to record their observations using diagrams. Introduce the terms *constructive superposition* and *destructive superposition*.	Instead of a rope, students could use a Slinky spring or a long piece of rubber tubing. Make sure students' diagrams show pulses superposing algebraically as they meet and then continuing unaffected.	
Use a diffraction grating to show diffraction and the production of visible spectra and to solve problems relating to interference phenomena using the relationships $\lambda = ax/D$ and $d \sin\theta = n\lambda$. Explain the phenomena of coherence ... and describe applications ... ... give examples of the reflection, refraction and interference of electromagnetic waves.	**Diffraction** Present several demonstrations illustrating diffraction. Suitable examples include: • a ripple tank in which plane waves travel towards a barrier with a gap of adjustable width; • a ripple tank in which plane waves travel towards a small obstacle; • a narrow vertical slit mounted in the path of a laser beam; • a microwave and/or ultrasound transmitter and receiver, with a narrow gap formed from two metal plates interrupting the beam. Ask students to record their observations using notes and diagrams. Introduce the term *diffraction*. Establish that waves are diffracted when they encounter a gap or obstacle, and that diffraction is most pronounced when the gap or obstacle is comparable in size to the wavelength. Discuss some everyday examples of diffraction, such as: • sound waves can easily be heard through a gap (such as an open door) even if the source is not in line with the detector; • water waves on the sea are observed to be diffracted by obstacles such as breakwaters and harbour walls; • broadcast radio waves can be detected even if there are obstacles (such as buildings) between the transmitter and receiver.	**Safety:** Follow safety guidelines when using lasers and ensure that the laser is positioned so that it is impossible for students to look into the beam.	
	Interference Set up two loudspeakers driven by a single signal generator in a large open space (e.g. a playground or hall). Adjust the separation of the speakers and the frequency of the signal so that there are clear regions of constructive and destructive interference. Invite students first to walk across the space, then to stand in a position where they have heard a loud sound; this should reveal clear bands of loud sound radiating from the speakers. Ask students to suggest explanations for this finding in terms of superposition and diffraction. Introduce the term *interference*. Establish that there are regions of constructive and destructive interference, and that positions of maximum loudness correspond to waves from the two speakers arriving in phase, while positions of minimum loudness arise when waves are in antiphase.		

Objectives	Possible teaching activities	Notes	School resources
	Set up a circus of activities illustrating interference between two wave sources. Tell small groups of students to visit each in turn and record their observations using notes and diagrams. Suitable examples include: • two sets of circular waves in a ripple tank; • microwaves and/or ultrasound diffracted through two parallel slits; • a pair of parallel slits mounted in the path of a laser beam; • Java applets that show how the interference pattern depends on slit separation and wavelength. Introduce the term *coherence* and establish that, in order to produce a steady interference pattern, there must be a constant phase relationship between two sources. Explain that, in practice, this is often best achieved by splitting a single beam of radiation. Use large labelled diagrams on the board or OHP to explain the relationship between *phase difference* and *path difference*. Provide examples of calculations in which students relate phase difference to path difference and hence to features of an interference pattern.	**Safety:** Follow safety guidelines when using lasers and ensure that the laser is positioned so that it is impossible for students to look into the beam. **ICT opportunity:** Use of Java applets. Enquiry skills 11A.1.1, 11A.4.1, 11A.4.2	
	Discuss how measurements on interference patterns can be used to determine the wavelength of radiation. Ask students to work in pairs or small groups to determine the wavelength of microwave or ultrasound radiation. They should use a double-slit arrangement and locate positions of maximum and minimum intensity. By measuring the distance from such locations to each of the slits, they will obtain a set of data from which wavelength can be deduced. Ask them to consider how this basic technique might be refined to obtain more accurate results.	Enquiry skills 11A.1.1, 11A.1.3, 11A.1.5, 11A.3.3 This activity also relates to Standard 10A.25.2.	
	Show more advanced students the derivation of the formula for double-slit interference, making the small-angle approximation where necessary. Then ask them to make measurements on the diffraction pattern produced when a laser beam shines through a pair of slits onto a distant screen, and hence calculate the wavelength of the light. Provide students with examples of numerical and algebraic calculations that allow them to practise using the double-slit formula.	**Mathematics:** A knowledge of angles expressed in radians, and the small angle approximation, is required. **Safety:** Follow safety guidelines when using lasers and ensure that the laser is positioned so that it is impossible for students to look into the beam.	
	Diffraction grating Use a laser to demonstrate diffraction and interference produce by sets of two, three, four and more narrow slits. Establish that, in each case, bright spots correspond to waves from all slits arriving in phase. Introduce the term *diffraction grating*. Get students to use Java applets to explore the relationship between slit spacing, wavelength and the angles at which bright beams emerge from a grating. Shine light from an incandescent source first through a single slit to produce a narrow beam and then through a diffraction grating. Use an infrared detector to show the presence of invisible 'heat' radiation with a longer wavelength than red light.	**Safety:** Follow safety guidelines when using lasers and ensure that the laser is positioned so that it is impossible for students to look into the beam. **ICT opportunity:** Use of Java applets.	

Objectives	Possible teaching activities	Notes	School resources
	Show more advanced students the derivation of the diffraction grating formula and discuss how the spacing, *d*, and wavelength, λ, limit the maximum available diffraction order, *n*, since sin θ cannot exceed 1. Explain how plotting a graph of sin θ against diffraction order, *n*, for monochromatic light yields a straight-line graph whose gradient enables wavelength to be determined. Ask students to work in pairs to use a grating spectrometer to determine the wavelengths of different colours of visible light. Explain to some advanced students how the sharpness of the diffraction maxima depends on the total number of slits in the beam, and how the amount of light diffracted through large angles depends on the width of the individual slits. Provide students with examples of numerical and algebraic calculations that allow them to practise using the diffraction grating formula.	Enquiry skills 11A.1.1, 11A.1.3, 11A.4.1	
	Beats If any students in the class play stringed instruments such as guitar or violin, ask them to bring their instruments into class. Ask them to demonstrate what happens when two strings sound almost, but not quite, the same note. (Use one 'open' string and place a finger on another string to achieve almost the same note.) If the two notes are close in pitch, it should be possible to hear clear fluctuations in intensity: beats. Demonstrate beats using speakers driven by two signal generators set to slightly different frequencies, or a tuning fork with plastic modelling clay stuck to one prong to reduce its frequency of vibration slightly. Ask students to explain beats. They should be able to suggest explanations in terms of superposition of two sets of waves that gradually come in and out of phase. Some students might be able to derive an expression of the beat frequency as the difference between the two superposed frequencies.		
1 hour **Doppler effect** Explain the Doppler effect in terms of wave motion and give examples from sound and light.	**Doppler effect** Ask students to imitate the sound of a motorbike driving past at high speed. They will almost certainly make a sound that decreases abruptly in pitch, and identify the higher pitch with the approaching vehicle and the lower pitch with the vehicle receding. Explain that this change in received frequency is a consequence of the Doppler effect. Use large diagrams on the board or OHP and/or Java applets to show how the waves from an approaching object are reduced in wavelength and hence rise in frequency, while waves from a receding object have an increased wavelength and reduced frequency. Similarly, explain how an observer moving relative to a stationary source detects an increased or reduced frequency.	 **ICT opportunity:** Use of Java applets.	

Objectives	Possible teaching activities	Notes	School resources
	Show how to derive formulae for the change of frequency in each case, and show that if the speed, u, of source or detector is much less than the wave speed, v, then $\Delta f/f = u/v$, where f is the emitted frequency and Δf is the difference between emitted and detected frequencies. Point out that the analysis applies to all types of waves, including sound and light and other types of electromagnetic radiation. (With some students you might wish to mention that a full analysis of the Doppler effect for electromagnetic waves requires relativity, but that when the speeds involved are low compared with the speed of light, the classical and relativistic analyses give the same results.) Discuss the double frequency shift that occurs when radiation is reflected from a moving target. Discuss uses of the Doppler effect, including the mechanism of radar speed traps, medical uses (e.g. blood flow measurement) and the determination of velocities of astronomical objects. Ask students to work in pairs using appropriate software to analyse recordings of engine noise or horns as obtained when a vehicle moves past a stationary microphone and hence determine the speed of the vehicle. Provide students with examples of numerical and algebraic calculations involving the Doppler effect.	**Safety:** If students make their own recordings of vehicle noise, ensure that they do not distract drivers, and that they themselves are in no danger from traffic **ICT opportunity:** Use of appropriate software to analyse sound recordings. Enquiry skills 11A.1.1, 11A.4.1, 11A.4.2	
1 hour **Polarisation** Explain the phenomena of ... polarisation of transverse waves and describe applications ... Explain electromagnetic radiation in terms of oscillating electric and magnetic fields ...	**Polarisation** Set up a circus of activities relating to polarisation of light. Tell pairs of students to visit each in turn and record their observations. Suitable examples for observation include: • a small lamp viewed through a single polarising filter then through two such filters held so that one can be rotated relative to the other; • light scattered from a polished bench-top through a single polarising filter; • double refraction by a large Iceland spar crystal; • light transmitted and scattered from a torch shining through a large tank of water to which a few drops of milk have been added; • a liquid crystal display whose upper polarising filter can be removed and rotated; • a beaker of concentrated sugar solution placed on an OHP with one polarising filter below and one above the beaker. Explain the phenomenon of polarisation in terms of vibrations being confined to one plane. Show transverse waves on a rope or a length of rubber tubing to illustrate the difference between polarised and unpolarised waves. Establish that only transverse waves can be polarised: sound waves, being longitudinal, cannot be polarised. Explain that polarising filters work by absorbing vibrations in one plane and that only components of vibration at right-angles to this plane are transmitted.		

Objectives	Possible teaching activities	Notes	School resources
	Show that microwaves are plane polarised in the generator: a grid of parallel wires held vertically absorbs the radiation, but with the wires horizontal the radiation passes through. With the aid of a large diagram displayed on the board or OHP, explain that microwaves consist of oscillating electric and magnetic fields at right-angles to one another and to the direction of wave travel. A microwave generator produces waves in which an electric field oscillates vertically, and the waves are readily absorbed when the field causes free electrons (e.g. in metal wires) to oscillate. If time permits, you might want to discuss some of the introductory examples from the circus in more details (e.g. the operation of liquid crystal displays, the production of polarised light by Iceland spar crystals).	The grid of parallel wires provided with most laboratory microwave kits is *not* a diffraction grating. It is a polarising filter. A grating must have slits whose separation is *greater* than the 3 cm wavelength of the radiation.	
2 hours **Electromagnetic spectrum** Explain electromagnetic radiation in terms of oscillating electric and magnetic fields and know that all electromagnetic waves travel with the same velocity in free space. Describe the main characteristics and applications of the different parts of the electromagnetic spectrum ...	Introduce this topic by giving a short presentation to the class on electromagnetic radiation. You should introduce the main categories and emphasise their common characteristics: • all travel at the same speed in a vacuum ('free space'); • all can undergo reflection, refraction diffraction and superposition; • all can be plane polarised; • all consist of oscillating electric and magnetic fields. Do not go into details of the discovery, production or uses of the radiation. Divide the class into groups and allocate each group to one region of the spectrum. Tell each group to use the Internet and other resources to research their own region and produce a large colourful poster to communicate their findings. They should address the following questions: • What is the approximate wavelength and frequency range of this type of electromagnetic radiation? • When and how was this type of radiation first discovered? • How have ideas about its nature changed over time? • How is the radiation produced? • What are some examples of this type of radiation in use? • Are there any hazards associated with this type of radiation? Hold a presentation session in which each group gives a brief oral introduction to their research and their poster. Posters should then be displayed and students allowed time to visit and discuss one another's work.	Make sure students are familiar with conventions for expressing very large and small numbers using scientific notation and SI prefixes. **ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.8, 11A.2.1, 11A.3.4	

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*A light ray enters a glass block at an angle of incidence 35°. The refractive index of the glass is 1.55. Calculate the angle of refraction and hence draw a diagram showing the path of the ray.*		
	A student uses a microwave generator and a probe that can detect microwaves from any direction. She places a metal screen about 0.5 m from the generator and notices that, as she moves the probe around, the detected signal fluctuates in strength. She moves the probe from the generator along a line at right-angles to the screen and finds that the distance between adjacent maxima is 1.4 cm. a. *Explain why the detected signal varies in intensity. Include the following terms in your answer:* ***superposition***, ***phase***, ***path difference***, ***wavelength***. b. *What is the wavelength of the microwaves?*		
	A student uses a diffraction grating with 600 lines per mm to measure the wavelength of red light emitted by hydrogen atoms. He finds the first and second orders of diffraction at 23.2° and 51.9° to the straight-through beam. a. *What is the wavelength of the light?* b. *Explain why he was unable to find a third-order beam.*		
	An astronomer identifies a pattern of light from a distant galaxy as coming from hydrogen atoms. He knows that the wavelength of this light in the laboratory is 486 nm, and the light he detects from the galaxy has wavelength 498 nm. Given that the speed of light is $3.00 \times 10^8\ m\ s^{-1}$, *calculate the speed of the galaxy and say whether it is approaching or receding.*		
	A student wearing Polaroid™ sunglasses notices that they reduce the amount of glare from light scattered by roads and other horizontal surfaces. Explain what can be deduced from this observation about the nature of the scattered light.		
	A cloud of interstellar gas emits a lot of electromagnetic radiation in the frequency range 1–10 GHz. What is the corresponding range of wavelengths? In what region of the electromagnetic spectrum is this radiation?		

GRADE 11A: Physics 5

Electronic devices

UNIT 11AP.5
6 hours

About this unit

This unit is the fifth of seven units on physics for Grade 11 advanced.

The unit is designed to guide your planning and teaching of physics lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For consolidation activities, look at the scheme of work for Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already know that current is a flow of charged particles, and that the resistance of some materials, particularly semiconductors, can change markedly in response to external conditions.

Expectations

By the end of the unit, students use capacitors in real circuits and use thermistors, diodes, transistors and light-dependent resistors as potential dividers to drive gates in logic circuits. They know how astable and bistable switches can be used in memory circuits.

Students who progress further understand and use relay switches. They design and make simple delayed-action switching circuits, and design and build devices that use combinations of logic gates.

Resources

The main resources needed for this unit are:

- electrolytic capacitor cut open to reveal its construction
- sets of components for constructing circuits
- cathode-ray oscilloscope (CRO)
- logic gates
- astable and bistable modules

Key vocabulary and technical terms

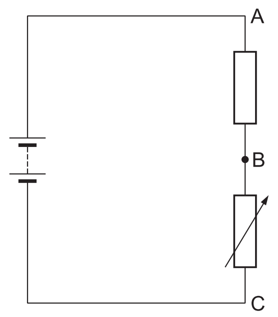
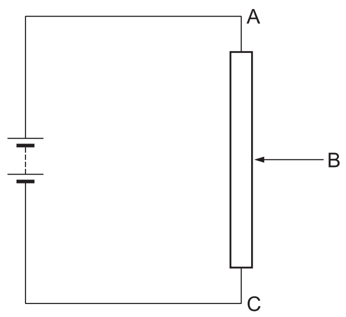
Students should understand, use and spell correctly:

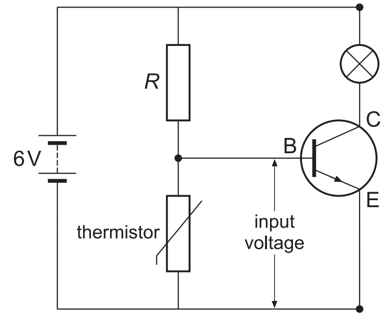
- *potential divider*, *potentiometer*, *rheostat*
- *sensor, thermistor*, *light-dependent resistor*, *diode*, *transistor*, *capacitor*, *relay*
- *analogue signal*, *digital signal*
- *logic gate*, *truth table*
- *astable*, *bistable*

Standards for the unit

Unit 11AP.5

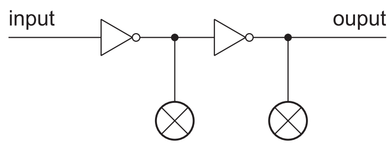
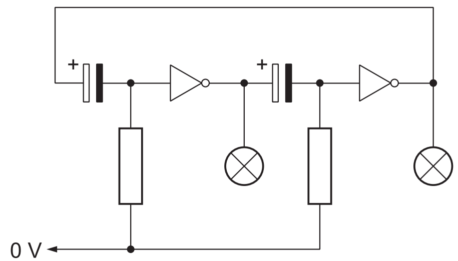
6 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards	EXTENSION STANDARDS
3 hours **Potential dividers and variable resistors** **1 hour** **Capacitors** **2 hours** **Logic gates and switches**	10A.30.2	Know that ... opposite charges attract but like charges repel each other.	11A.30.1	Demonstrate an understanding of the construction of capacitors and their use in electrical circuits.	
	10A.30.1	Distinguish between conductors, semiconductors and insulators with reference to moving electrons or ions; know how the properties of semiconductors can be influenced by the presence of small quantities of impurities.	11A.30.2	Explain the variation in resistance shown by devices such as the potentiometer, the diode, the light-dependent resistor, the transistor and the thermistor; use these resistors as potential dividers in practical circuits.	
	9.21.7	Know that the resistance of a wire depends on its diameter, length and the material from which it is made.			
			11A.30.3	Use logic gates in practical circuits (AND, OR, NAND, NOR) and determine truth tables for the gates, individually and in combination.	
			11A.30.4	Understand and use bistable and astable switches and know how these can constitute memory circuits.	

Objectives	Possible teaching activities	Notes	School resources
3 hours **Potential dividers and variable resistors** Explain the variation in resistance shown by devices such as the potentiometer, the diode, the light-dependent resistor, the transistor and the thermistor; use these resistors as potential dividers in practical circuits.	**Potential divider** Provide each pair of students with a ready-assembled circuit and a worksheet for the following activity. Connect a thermistor (NTC type) in series with a fixed resistor and a battery. Connect a lamp in parallel with the thermistor. Ask students to observe and try to explain what happens to the lamp as the thermistor is placed in a beaker of iced water or warm water (as the thermistor gets warmer, its resistance falls, the pd across thermistor and lamp also falls so the lamp glows less brightly). They should recall their work from earlier units to explain the changing resistance in terms of mobile charged particles. Ask students how the circuit might be modified so that the lamp glows *more* brightly as the thermistor gets warmer (the lamp should be connected in parallel with the fixed resistor). With the aid of a large clear diagram displayed on the board or OHP, explain the operation of the circuit and introduce the term *potential divider*. Establish that the total pd across the two resistors remains constant and equal to the terminal pd of the battery. Remind students by suitable questioning that, in the absence of the lamp, the current is the same in both resistors, hence the pds across them are in the ratio of their resistances.	Prepare suitable circuits and student worksheets. Note that the terminal pd of the battery only remains constant if the circuit resistance is much greater than the internal resistance of the battery. Choose components that ensure this will be the case. Enquiry skill 11A.4.1	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Potentiometer and rheostat Show students the first circuit on the right made with a long wire and flying lead. Introduce the term *potentiometer*. (You might want to point out that, as implied by the name, the circuit can be used to measure pd: the pd between the fixed and moveable contact is proportional to the length of wire between them.) Give each pair of students a small wire-wound potentiometer and point out that the three terminals correspond to the two fixed and one movable contact in the circuit you have demonstrated. Give students the two circuit diagrams on the right and ask them to construct each one in turn, using the potentiometer and other components. Introduce (or remind students of) the term *rheostat* (adjustable resistor). Ensure that students realise how to connect the potentiometer into a circuit so that it functions as a rheostat (use terminal B and either A or C). Students should be able to draw on earlier work to explain the changing resistance between the central and outer terminal in terms of the different lengths of wire included in the circuit. Tell students to use high-resistance (digital) voltmeters to measure the pds between pairs of points A, B and C within each circuit and to list the similarities and differences between the two circuits. (Both are potential dividers. In each, the pd between A and C remains constant and equal to the terminal pd of the battery. In the first, the total resistance remains constant, whereas in the second circuit the total resistance can be changed.)	  Enquiry skill 11A.4.1	

Objectives	Possible teaching activities	Notes	School resources
	Transistor and relay Refer to the thermistor circuit used earlier. Point out that it forms the basis of a useful device and ask students to think of examples of electrical devices that are controlled by temperature (i.e. that contain thermostats). Examples might include refrigerators, air-conditioning units, electric cookers, heaters. Ask students how the thermistor circuit might need to be modified in order to make a practical thermostat (it should be able to switch a device on and off, rather than giving a continuously varying output). Introduce the terms *analogue* and *digital* and establish that digital devices involve signals that can only be either 'on' or 'off' whereas analogue devices involve continuous variation. Demonstrate the circuit shown on the right and give students a handout containing its circuit diagram. Explain that the *transistor* can act as a switch. When the input voltage (between base and emitter) is below a certain threshold value, the resistance between collector and emitter is high, but when the input is above the threshold, the collector–emitter resistance becomes very low.	 Enquiry skills 11A.4.1, 11A.4.2	
	Then ask students, working in pairs, to assemble and use the circuit and to explain its operation. If they need help with the explanation, provide a handout containing the following paragraph with some key words deleted (shown in bold below) and ask students to decide how to fill the gaps. The thermistor and *R* form a potential divider. The pd across the thermistor forms the input to the transistor between B and E. When the thermistor is warm, its resistance is **low**, the pd across it is **small**, so the input to the transistor is small, giving the transistor a very **high** resistance between C and E. The pd across the lamp is **small** and there is little current in that part of the circuit so the lamp **does not light**. When the thermistor is cold, its resistance is **high**, the BE input voltage is **high**, the CE resistance is **low** and the lamp **lights**. Ask advanced students to explain the operation of the transistor in terms of mobile charge carriers across the junctions between n-type and p-type semiconductors. Refer to the thermistor/transistor circuit used earlier. Introduce the term *transducer* and point out that the circuit can only operate a low-power transducer such as an indicator lamp, whereas in many practical applications an output device such as a heater or a motor requires a large current and/or voltage. Explain how a low-power circuit can use a *relay* to switch another circuit on or off.	Prepare suitable handouts.	
	Sensor circuits Show students a variety of components that can be used in *sensor* circuits: these should include a light-dependent resistor (LDR), diode, light-emitting diode (LED) and pressure sensor. Provide a handout showing the conventional circuit symbol for each component and a brief note of how it performs. Tell students that their task will be to design, build and use an electronic control circuit that responds to external changes by switching on or off a device such as a motor or a heater. They should base their circuit design on the thermistor/transistor circuit used earlier.	Prepare a suitable handout. Enquiry skills 11A.1.1, 11A.1.3–11A.1.5, 11A.3.4, 11A.4.1, 11A.4.2	

Objectives	Possible teaching activities	Notes	School resources
	Students should work in pairs on this task. Ideally, give each pair a different task; either allow them to choose, or allocate tasks according to students' abilities and interests. Suitable tasks include the following: • a device that operates a heater when the temperature falls below freezing; • a device that switches on a fan when the temperature rises above a certain value; • a lamp that switches on in the dark; • a burglar alarm that sounds when a door is opened; • a device that operates a motor to close a blind at dawn and open it at night-fall. Ask students to draw a circuit diagram first. When you have checked that the diagrams are acceptable, let them build and test their circuits. Ask them to produce a one-page summary of their work, including a circuit diagram and a brief account of its operation. When all the tasks are complete, get students to arrange their circuits in a display around the lab, accompanied by the summaries, forming a circus. Students should then work in pairs to visit at least two stations other than their own and explore the operation of the circuits.		
1 hour **Capacitors** Demonstrate an understanding of the construction of capacitors and their use in electrical circuits.	**Storing charge** Give each pair of students a large *capacitor*, a selection of resistors, ammeter, voltmeter, battery, LED and connecting wires. Tell them that their task is to find out as much as they can about the behaviour of the capacitor in a circuit. If using electrolytic capacitors, instruct students how to connect them with the correct polarity, but otherwise let them connect the components in whatever ways they wish. Discuss students' observations with the whole class and, where necessary, carry out demonstrations to illustrate points that some students might have missed. Establish the following points: • there is a brief flow of current (i.e. movement of charge) when a capacitor is first connected but no steady current; • the capacitor can store small amounts of charge; • when a charged capacitor is connected to a resistor, there is a brief flow of current as it discharges; • a resistor connected in series with a capacitor slows down the movement of charge as it charges or discharges (the current is reduced but flows for slightly longer). Introduce the conventional circuit symbol for a capacitor and relate the symbol to its construction. Open up a capacitor and show students how it is constructed from two metal foils separated by an insulating layer. Set up two large parallel metal plates and connect them to a battery through a microammeter. Establish that electrons flow so that one plate acquires a negative charge while the other loses electrons to acquire a positive charge. Introduce *capacitance* as, loosely, a measure of the amount of charge that a capacitor can store and point out that most circuit capacitors are labelled with their values in microfarads (μF) or picofarads (pF).	Enquiry skills 11A.1.1, 11A.1.3, 11A.4.1	

Objectives	Possible teaching activities	Notes	School resources
	Capacitors in circuits Use a cathode-ray oscilloscope (CRO) to show how the pd across a capacitor varies as it is charged or discharged through a resistor. Either use a storage oscilloscope to display the trace from a single charge or discharge, or use a signal generator with a square-wave input to show a sequence of charge/discharges. (Choose the capacitor and resistor so that *RC* is about one-fifth of the period of the oscillation so that an almost complete charge and discharge can be displayed.) Discuss with students how the charge or discharge of a capacitor might be exploited in a delayed-action switching circuit. More advanced students might be able to suggest how the transistor circuits used earlier could be adapted to perform this function (discharge the capacitor through a resistor that is connected across the input to a transistor so that when the pd falls below a threshold value, the transistor's emitter–collector resistance abruptly changes). Provide each pair of students with a circuit diagram for a simple delayed-action switching circuit along with the necessary components. Ask them to build and test the circuit and to explore how using different capacitances and resistances controls the delay time (increasing *R* and/or *C* increases the delay time).	Enquiry skills 11A.4.1, 11A.4.2 Prepare a suitable handout.	
2 hours **Logic gates and switches** Use logic gates in practical circuits (AND, OR, NAND, NOR) and determine truth tables for the gates, individually and in combination. Understand and use bistable and astable switches and know how these can constitute memory circuits.	**Logic gates** Refer to the simple transistor switching circuit used earlier. Point out to students that it acts as an *inverter* – a high pd across the transistor BE input results in a low pd across any output device connected in series with the transistor collector and emitter, and vice versa. Tell students that inverters are often manufactured as pre-assembled modules either on 'chips' or as larger devices, and explain that an inverter is a simple example of a device known as a *logic gate*. It takes a 'high' input (usually represented as '1') and gives a 'low' output (represented as '0'), and vice versa. It is sometimes known as a NOT gate, as its output is high when the input is *not* high. Explain that logic gates are widely used in processing digital (i.e. on/off) signals and that most have at least two inputs and produce a single output. Introduce the symbols for AND, OR, NOR, NAND and NOT gates. Point out that the gates must always be connected to a power supply, although by convention these connections are not included in the symbols. Demonstrate the operation of the OR gate and show how its performance can be summarised in a *truth table*. Then ask students, in pairs, to use pre-assembled logic gates and determine their individual truth tables.		
	Combining logic gates Show students how the output from one logic gate can be used as the input for another (e.g. connecting a NOT gate to the output of an AND gate produces a NAND gate) and that more complex logic circuits can thus be produced. Provide a handout with diagrams showing several different combinations of logic gates. Ask students first to deduce the truth tables for each combination and then, in pairs, to use circuit design software to explore the operation of each combination.	Provide a suitable handout. **ICT opportunity:** Use of circuit design software.	

Objectives	Possible teaching activities	Notes	School resources
	Tell the pairs of students that their task is now to design and make a practical control circuit using logic gates and sensor circuits such as those they explored earlier in this unit. Tell them first to draw a diagram showing how they intend to connect gates together, then to test their design using a circuit design software package before finally assembling their circuit using apparatus. Either allocate students to particular tasks according to their abilities or allow them to choose. Suitable tasks include the following: • an intruder alarm that sounds a buzzer when a door is opened and a light switched on; • an automatic irrigation system that switches on when it is dark but not raining; • a seatbelt warning light that switches on if a person is sitting in a car seat and the belt is not fastened.	Enquiry skills 11A.1.2, 11A.4.2	
	Astable and bistable circuits Display the diagrams on the right on the board or OHP. Ask students to predict how the circuits will behave, and then, in pairs, to assemble and use them. In the second circuit, they should explore how to control the frequency at which the lamps alternately flash on and off (increasing the resistance and/or capacitance reduces the frequency). Tell students that they have made first a *bistable* circuit (it remains in one of two states unless disturbed) and secondly an *astable* circuit (i.e. one that has no steady output but continuously switches between two states). Point out that both bistable and astable circuits act as switches: they switch an output alternately on or off. Discuss uses of bistable and astable switches. Point out that bistables are used in memory circuits as they retain a record of their most recent input, and astables can be used to produce a continuous stream of pulses for a DC input. Show students how to set up an array of switches to count events. Set students, in pairs or individually, one or more tasks involving switching circuits to work on. (The tasks are more manageable if students can have access to pre-assembled astable and bistable modules.) Suitable tasks include the following: • a traffic-light system with green, red and amber lights flashing on and off in the correct sequence; • three lamps that light up in rotation; • a 'divider' that takes a square-wave input and gives a square-wave output with half the original frequency.	 	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Draw a circuit diagram for a device that switches a heater on when the temperature falls below freezing.*		
	Write a few sentences describing how a transistor can be used as a switch in a circuit containing a potential divider.		
	A student builds a timing circuit in which a 500 μF capacitor discharges through a 2.2 kΩ resistor and she finds that the time delay is about 1 second. Explain what will happen to the time delay if she uses: a. *a 1000 μF capacitor and a 2.2 kΩ resistor;* b. *a 500 μF capacitor and a 1 kΩ resistor.*		
	An exclusive OR (XOR) gate gives a high output when either of the two inputs, but not both, are high. a. *Draw a truth table for an XOR gate.* b. *Design and make an XOR gate using a combination of AND, OR and NOT gates.*		
	Use an astable and a bistable circuit to make a 'divider' that takes a square-wave input and gives a square-wave output with half the original frequency.	Provide appropriate apparatus.	

GRADE 11A: Physics 6

Electromagnetic induction

UNIT 11AP.6
10 hours

About this unit

This unit is the sixth of seven units on physics for Grade 11 advanced.

The unit is designed to guide your planning and teaching of physics lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For consolidation activities, look at the scheme of work for Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already be able to describe a magnetic field as an example of a field of force, know that it can be represented by means of field lines, and know the pattern of magnetic flux due to a coil and a solenoid. They should be able to define potential difference and the volt, solve problems using the relationships $P = VI$ and $P = I^2R$. They should know that the magnetic field around a current-carrying conductor can interact with a magnetic field generating a force.

Expectations

By the end of the unit, students know that the relative motion of a conductor in a magnetic field induces an e.m.f. in the conductor and know the factors that influence the magnitude and direction of the e.m.f. They describe the commercial production of AC, perform calculations related to its parameters, and know why and how transformers are used in its distribution.

Students who progress further understand concepts of magnetic flux and flux linkage and use Faraday's and Lenz's laws, can describe how eddy currents form and know some of their applications. They use the concepts of root mean square current and voltage, and solve numerical problems involving the period, frequency and peak value of alternating current.

Resources

The main resources needed for this unit are:

- sensitive galvanometer(s) (analogue instruments, ideally with centre zero)
- pendulums made from solid and perforated aluminium sheets (Waltenhofen's pendulums)
- copper and plastic tubes (e.g. as used in plumbing), each with diameter about 2 cm and length about 1.5 m
- aluminium discs, with and without perforations, mounted on a central axis
- bicycle dynamo
- kit for making a simple DC motor
- double beam cathode ray oscilloscope (CRO)
- demountable transformer
- labels from electrical equipment mentioning rms values
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *electromotive force*, *electromagnetic induction*, *induced e.m.f.*, *galvanometer*, *magnetic flux*, *magnetic flux linkage*
- *Faraday's law*, *Lenz's law*, *eddy current*
- *alternating current (AC)*, *root mean square*, *period*, *frequency and peak value (of AC)*
- *transformer*, *primary voltage*, *secondary voltage*, *turns ratio*

Standards for the unit

Unit 11AP.6

10 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS	
4 hours **Electromagnetic induction** **3 hours** **Electricity generation** **3 hours** **Electricity in use**	10A.31.4	Distinguish between electromotive force and potential difference ...	11A.31.1	Describe the production of an induced e.m.f. by the relative motion between a conductor and a magnetic field and know the factors that influence the magnitude of the e.m.f.		
	10A.30.5	Describe a magnetic field as an example of a field of force and know that it can be represented by means of field lines.	11A.31.2	Understand the concepts of magnetic flux and flux linkage and use Faraday's and Lenz's laws to solve numerical problems related to electromagnetic induction.		
	10A.30.7	Know the pattern of magnetic flux due to a single current-carrying wire, a coil and a solenoid ...	11A.31.3	Describe how eddy currents form and know some of the applications of eddy currents, such as zone refining of semiconductors.		
			11A.31.4	Know that alternating current is induced in a coil rotating in a uniform magnetic field and explain the operation of a simple AC generator.		
			11A.31.5	Describe the commercial production of alternating current using a gas turbine as the primary source of kinetic energy.	11A.32.8	Understand that … nuclear fission can be used ... as a source of energy …
	10A.28.3	Know and use the terms ... *amplitude, phase difference, period, frequency* ...	11A.31.6	Describe and use the concepts of *root mean square current* and *voltage*, *period*, *frequency* and *peak value* applied to alternating current; solve numerical problems related to them.		
	10A.31.2	Define potential difference and the volt. Solve problems using the relationships $V = W/Q$, $P = VI$, $P = I^2R$.	11A.31.7	Describe the action of a transformer and explain its importance in the long-distance transmission of electricity; solve problems related to power transmission.		

Objectives	Possible teaching activities	Notes	School resources
4 hours **Electromagnetic induction** Describe the production of an induced e.m.f. by the relative motion between a conductor and a magnetic field and know the factors that influence the magnitude of the e.m.f. Understand the concepts of magnetic flux and flux linkage and use Faraday's and Lenz's laws to solve numerical problems related to electromagnetic induction. Describe how eddy currents form and know some of the applications of eddy currents, such as zone refining of semiconductors.	**Producing an e.m.f.** Set up a circus of activities and exhibits involving the induction of an e.m.f. Each should be accompanied by brief instructions. You might need to introduce and explain the term *galvanometer*. Ask students to work in pairs to visit each in turn and make notes of their observations and results. Discuss students' observations with the whole class and establish the following points. 1 Each example involves changing the magnetic field around a conductor either by relative motion or by changing the current giving rise to a magnetic field. 2 Changing the magnetic field around a conductor can give rise to a deflection on a galvanometer or CRO, indicating that there is a voltage. 3 The size of the voltage depends on the speed of motion, the direction of motion and the magnetic field strength. 4 The commercial generation of electricity involves coils being made to rotate in magnetic fields. Introduce and explain the term *electromagnetic induction*. Remind students of the term *electromotive force* (*e.m.f.*), its SI units, and the relationship between e.m.f., charge and energy. Refer to the activities outlined in the Notes column on the right and ask students to sketch the magnetic field lines of a bar magnet and a horseshoe magnet. Discuss the ways in which a coil and a single loop of wire can be moved within these fields in order to induce an e.m.f. and establish that an e.m.f. is induced only if a conductor cuts across magnetic field lines. Also establish that, in the case of a closed coil or loop, this involves a change in the number of field lines threading through, or 'linking', the coil. Point out that, if the magnetic field is that of an electromagnet being switched on or off, the lines can be pictured as coming together as the field grows stronger or moving apart as the field becomes weaker and falls to zero, and a nearby coil 'cuts' the lines as they move. Encourage students to use Java applets illustrating how the relative motion of a conductor and magnetic field lines gives rise to an induced e.m.f. By suitable questioning, establish that point 3 above is equivalent to stating that the size of an induced e.m.f. depends on the rate at which field lines are cut or (equivalently) on the rate of change of the number of lines linking a coil. Ask students each to produce a written qualitative explanation of one or more of the practical activities outlined in the Notes column on the right.	Activities should include the following. In each, tell students to investigate changing the speed and direction of movement. Where possible, use coils with various numbers of turns. • Connect a flexible lead to a sensitive galvanometer. Move the lead between the poles of a horseshoe magnet. • Connect a coil to a sensitive galvanometer. Move a bar magnet in and out of the coil. • Connect a coil to a CRO. Suspend a bar magnet from a spring so that it can oscillate in and out of the coil with a period of about 1 s. • Connect a coil to a battery. Connect a second coil to a sensitive galvanometer. Move one coil. Switch the current on and off. • Connect a bicycle dynamo to a lamp and/or a CRO. Turn the handle. Suitable exhibits include pictures, video clips and information leaflets about electricity generation in power stations. Enquiry skill 11A.4.2 **ICT opportunity:** Use of Java applets.	Use this column to note your own school's resources, e.g. textbooks, worksheets.

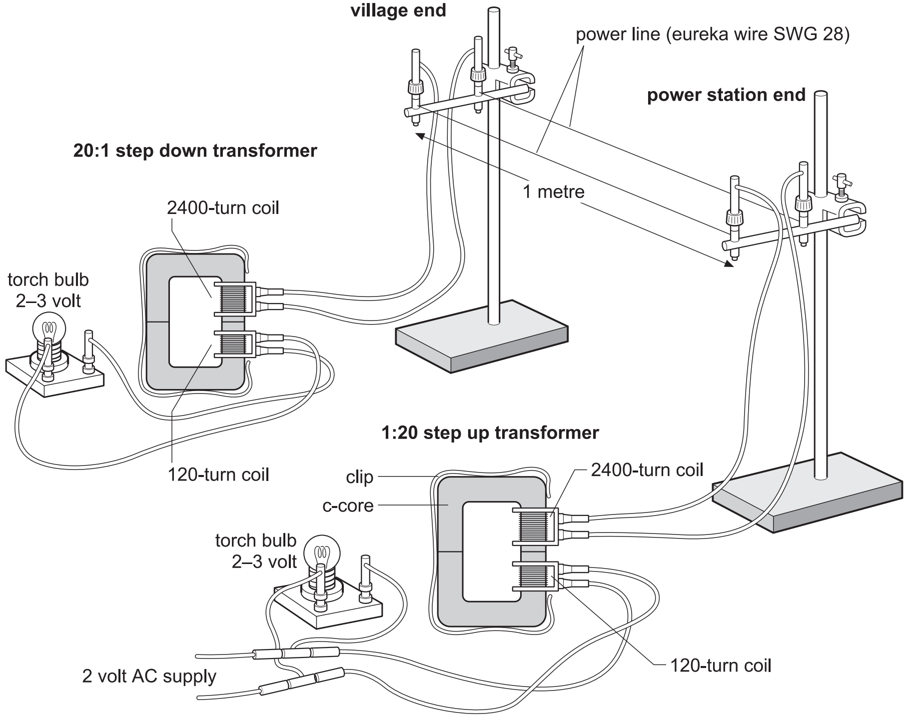
Objectives	Possible teaching activities	Notes	School resources
	Faraday's law Continue the previous discussion to provide a more quantitative treatment of electromagnetic induction. Introduce *Faraday's law* of electromagnetic induction in words (i.e. the induced e.m.f. is directly proportional to the rate of change of *flux linkage*). Then talk through the following steps to explain what is meant by magnetic flux linkage and how it can be quantified. Illustrate each step with clear diagrams on the board or OHP. 1 Loosely, magnetic flux means magnetic field lines, and magnetic flux density is the number of field lines passing through unit area at right angles to the field direction. 2 The quantity B, which was introduced in an earlier unit as magnetic field strength, is more properly known as *magnetic flux density*. Remind students of the SI unit of magnetic flux density (i.e. the tesla, T). 3 The total magnetic flux passing perpendicularly through a coil with area A is $\Phi = BA$. Tell students that the SI unit of magnetic flux, Φ, is the weber, Wb ($1\,\text{Wb} = 1\,\text{T}\,\text{m}^{-2}$ and $1\,\text{T} = 1\,\text{Wb}\,\text{m}^{-2}$) and that magnetic flux density is sometimes expressed in $\text{Wb}\,\text{m}^{-2}$ rather than T. 4 The *flux linkage* through a coil with N turns is equal to $N\Phi$. Each turn of the coil contributes to any induced e.m.f. Flux linkage is sometimes given the SI unit weber-turns; although the number of turns is dimensionless so does not need a unit, this form of the unit serves as a reminder of the distinction between flux and flux linkage. 5 Faraday's law gives the size of the induced e.m.f. In SI units, the proportionality constant is dimensionless and equal to 1, so using calculus notation the law can be written $\mathcal{E} = \text{d}(N\Phi)/\text{d}t$. Provide plenty of numerical and algebraic examples that allow students to practise using Faraday's law. If students are mathematically fluent, some of these should include the use of differential calculus.	**Mathematics:** Differential calculus notation is used.	
	Lenz's law Tell the class that you are going to describe how to make a machine from which energy can be extracted without limit (i.e. a 'perpetual motion' machine). Tell them that they simply need to arrange for a coil to rotate in a magnetic field in such a way as to induce an e.m.f. in the coil, and to connect the coil into a circuit so that a current can circulate within it. Remind them that in an earlier grade they saw that a current-carrying coil within a magnetic field experiences electromagnetic forces that make the coil rotate. So the current driven by the induced e.m.f. will lead to an acceleration of the coil's rotation. As the coil rotates more rapidly, the e.m.f. and current increase, thus increasing the forces on the coil and accelerating its rotation still further. The rotating coil can be connected so that energy is transferred to external devices, but the electromagnetic forces due to the induced current will maintain the rotation (i.e. the coil and magnet form a perpetual motion machine). Summarise the steps that you have just described on the board or OHP. Probably, by now, students will be protesting that the machine you are describing is impossible. Even if they have not made such comments, admit that you have been leading them astray. Establish by questioning and prompting that the machine would violate the conservation of energy. Ask students to identify the deliberate error in the steps you have outlined (it is the statement that the electromagnetic forces will act to accelerate the coil's rotation). Point out that, since energy is conserved and the machine is impossible, the forces must act to *retard* the coil's rotation.		

Objectives	Possible teaching activities	Notes	School resources
	Tell students that the example discussed above illustrates *Lenz's law* of electromagnetic induction: the direction of an induced e.m.f. or current is such that any resulting electromagnetic forces act so as to oppose the change causing it. In symbols, the law is represented by a negative sign in the expression $\mathcal{E} = -d(N\Phi)/dt$. Ask students to write an account of Lenz's law, perhaps based on the example discussed above, explaining that it is essentially a statement of energy conservation applied to electromagnetic induction.		
	Eddy currents Divide the class into small groups and give each a briefing sheet and apparatus for a demonstration involving eddy currents. Each group should rehearse their demonstration in the style of a magic conjuring trick then perform it to the rest of the class. After students have performed the demonstrations, discuss them with the whole class. Explain how a changing magnetic field can induce a current that circulates within the body of a conductor (i.e. an *eddy current*). Using suitable questioning, establish that there will be electromagnetic forces due to the interactions between eddy currents and the magnetic fields producing them, and that these forces will act as described by Lenz's law (i.e. they will act to oppose the changes causing them). Establish that slits or perforations within a conductor will inhibit the circulation of eddy currents and hence the electromagnetic forces will be reduced or eliminated. For one or more of the demonstrations, ask students to sketch a series of diagrams showing the directions of the magnetic field, the eddy currents and the resulting electromagnetic forces. Tell them to explain how these account for the observed results. Ask students to use the Internet and library resources to research one application of eddy currents. They should produce an illustrated written report of their findings and include a bibliography listing their sources. Suitable examples of applications of eddy currents include: • eddy current braking; • zone refining of semiconductors; • induction motors.	Suitable examples include the following. • Pendulums made from a solid and a perforated sheet of aluminium. Show that the perforated sheet will oscillate within a magnetic field but the solid one will not. • Jumping rings. Mount a coil (e.g. 100 turns) so that a metal rod (e.g. a retort stand) passes vertically along its axis. Place an aluminium ring on the rod above the coil. Connect the coil to an AC supply (the ring jumps upwards). Repeat with a split ring (which does not jump). • Drop a strong 'button magnet' first through a long plastic tube (it falls freely) then through a metal tube of similar length (it falls very slowly). • Mount an aluminium disc so that it can rotate freely. When it is rotating, bring a magnet close to the disc (it rapidly comes to a halt). Repeat with a perforated disc (it continues rotating). **ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.6, 11A.1.8, 11A.2.5, 11A.3.4	

Objectives	Possible teaching activities	Notes	School resources
3 hours **Electricity generation** Know that alternating current is induced in a coil rotating in a uniform magnetic field and explain the operation of a simple AC generator. Describe the commercial production of alternating current using a gas turbine as the primary source of kinetic energy.	**Generating AC** Using suitable models, diagrams and Java applets, explain the operation of a simple AC generator. Pay particular attention to the directions of the induced e.m.f. and current. Introduce the terms *alternating voltage* and *alternating current*, and establish that the abbreviation AC can be applied to either. Ask students, in pairs, to make a simple AC generator using the same apparatus as used in an earlier grade to make a simple electric motor. Instead of connecting the coil to a DC input, they should test the generators by connecting the coil to a CRO, and observe what happens when the coil is set in motion by flicking it with a finger. Tell them to produce a brief written report of their work. Establish that, in principle, any electric motor can be used in reverse as a generator and discuss with students how a simple AC generator can be adapted to produce a rectified output (i.e. a varying DC output). You might need to point out that the term DC refers to direction only, and that it is possible to have a varying DC voltage or current. With more advanced students, introduce and use mathematical expressions for the generation of a sinusoidal e.m.f. and current. Consider a flat coil rotating in a uniform magnetic field, about an axis at right-angles to the field direction. Guide students through the derivation of an expression relating the amplitude of the e.m.f. $\mathcal{E}$ to the flux density B, area of coil A, number of turns N and angular frequency ω. Show that if the coil is square-on to the field when $t = 0$, then the flux passing through the coil is $\Phi = BA \sin \omega t$, hence $\mathcal{E} - d(N\Phi)dt = -BAN\,\omega \cos \omega t$. Provide examples that allow students to practise using mathematical relationships involving the generation of an e.m.f. and current.	Enquiry skills 11A.4.1, 11A.4.2 **Mathematics:** Use of differential calculus. Only students taking the advanced course are explicitly required to understand and use angular frequency, which they will meet in Unit 12AP.1. With some students, you might wish to omit this mathematical treatment of induced e.m.f.	
	Power station If possible, arrange a visit to Doha power station. Tell students beforehand that their task will be to collect information in preparation for producing a poster or a PowerPoint presentation, which should include information about environmental issues and how they are addressed. If a visit is impossible to arrange, ask students to collect information about Doha and other power stations using the Internet and other resources. Divide the class into groups and ask each group to focus on one or two of the following points: • the system for using gas turbines to drive generators; • the source of the gas, and how it reaches the power station; • any waste products from the gas combustion, and how they are dealt with; • the need to cool the machinery and how this is achieved; • the siting of transmission cables and transformers close to the power station. After they have collected their information, ask students to work in pairs or small groups to produce their posters or PowerPoint presentations. Ideally, these should be presented to an audience of students studying other subjects.	**Visit opportunity:** Visit Doha power station. **ICT opportunity:** use of the Internet; use of PowerPoint. Enquiry skills 11A.1.6, 11A.1.8, 11A.2.2, 11A.2.3, 11A.2.5, 11A.3.4	

Objectives	Possible teaching activities	Notes	School resources
3 hours **Electricity in use** Describe and use the concepts of *root mean square current* and *voltage*, *period*, *frequency* and *peak value* applied to alternating current; solve numerical problems related to them. Describe the action of a transformer and explain its importance in the long-distance transmission of electricity; solve problems related to power transmission.	**Describing AC** Use a CRO to display a voltage trace from a low-voltage AC power supply derived from the mains. Establish that the trace is a sinusoidal waveform. Ask suitable questions to remind students of terms such as *frequency*, *amplitude* and *period* and their SI units. Use the CRO to determine the period and frequency of the AC mains. Ask students what it might mean to specify a value for an AC voltage or current. Establish that one useful parameter is the *peak voltage* or *peak current* (i.e. the amplitude of a sinusoidal waveform). Display labels from several items of electrical equipment that specify *root mean square* (*rms*) values of current and/or voltage. Use the following steps to explain what is meant by rms and why it is useful to specify root mean square values of varying voltage or current. 1 Display a graph showing a sinusoidal voltage on the board or OHP. Establish that its mean value is zero so this is not a useful parameter. 2 Draw on work from earlier grades to establish that power $P = VI = I^2R = V^2/R$. 3 Ask students to sketch graphs showing how the current and power vary with time when a sinusoidal voltage is applied to a resistor. Establish that, while the current and voltage take both positive and negative values, the power is always positive (i.e. there is always a net transfer of energy from the circuit). 4 Ask students to use their sketch graphs to deduce (by inspection) the relationship between peak and mean power (the mean is half the peak). 5 Explain how rms voltage and current are related to the peak and average powers, and establish that the rms values are useful parameters as they are related directly to the average power. 6 Establish that, if an AC supply is to be replaced by a DC supply that produces the same power in a given circuit, the DC voltage must be equal to the rms voltage of the AC supply. Explain that, unless otherwise specified, AC voltages and currents specified on items of electrical equipment are rms values. 7 Show that, for a sinusoidal voltage, $V_{rms} = V_{peak}/\sqrt{2}$ and $I_{rms} = I_{peak}/\sqrt{2}$. Provide students with some numerical and algebraic examples that allow them to practise using peak and rms voltages and currents and the relationships between them.		
	Transformers Ask students to work in pairs to explore how changes in one circuit can induce an e.m.f. in another. Provide the necessary apparatus and a briefing sheet that guides them though the following steps. Remind them of the activity that introduced this unit. 1 Use insulated wire and wind two coils (each of about 20 turns) on two iron C-cores. 2 Connect one coil to a sensitive galvanometer and the other to a battery. 3 Observe the galvanometer reading as the cores are moved together and apart. 4 Clip the cores together to form a closed loop. Observe the galvanometer reading as the battery is connected and disconnected. 5 Replace the battery with a low-voltage AC power supply. Replace the galvanometer with (in turn) an AC voltmeter, a small torch bulb and a CRO.	Prepare a suitable student briefing sheet. Enquiry skills 11A.4.1, 11A.4.2	

Objectives	Possible teaching activities	Notes	School resources
	Discuss students' results with the whole class and by suitable questioning establish that a changing current in one circuit can induce an e.m.f., and hence a current, in another to which it is magnetically linked.		
	Introduce the term *transformer* and use a demountable transformer to demonstrate the relationship between the *primary voltage* $V_{p.}$, *secondary voltage* (induced secondary e.m.f.) V_s, and the *turns ratio* N_p/N_s. Introduce the terms *step-up transformer* ($V_s > V_p$) and *step-down transformer* ($V_s < V_p$). Use a double-beam CRO to show the relative phases of the primary and secondary voltages. Ask students to sketch diagrams showing the traces and make sure they are able to explain that the peak induced e.m.f. occurs when the rate of change of primary voltage is greatest, whereas when the primary voltage passes through a peak the secondary e.m.f. is zero.		
	Discuss with students the relationship between the primary and secondary currents. Talk through the following steps: 1 The primary voltage and the turns ratio determine the secondary voltage. 2 The secondary voltage and the resistance of the secondary circuit (coil plus any load) determine the secondary current ($I_s = V_s/R$). 3 The power output to the secondary circuit is $P_s = V_sI_s$. 4 The input power must be at least as great as the output power (otherwise energy would not be conserved). If the transformer is one hundred per cent efficient, the input and output powers are equal. 5 If $P_s = P_p$ then $V_sI_s = V_pI_p$, $I_s/I_p = V_p/V_s = N_p/N_s$. Thus, in a transformer that steps up the voltage, the primary current is greater than the secondary current, and, if the voltage is stepped down, the primary current is less than the secondary current. 6 The primary current is determined by the resistance of the secondary circuit as well as by the primary voltage and the turns ratio. Point out that the relationships established above apply both to ratios of rms voltages and currents and to ratios of peak voltages and currents. Use the demountable transformer to show the principle of an induction furnace and induction welding. Discuss with students the likely sources of inefficiency in a transformer. Draw attention to the use of laminated cores. Students should be able to draw on earlier work to explain how eddy currents would circulate in a solid core, leading to dissipation of energy through heating. Provide plenty of numerical and algebraic examples that allow students to practise using relationships involving the turn ratio of a transformer.		

Objectives	Possible teaching activities	Notes	School resources
	Electricity transmission Set up a model power transmission system as shown below. First demonstrate the system *without* either of the transformers and show that, if electricity is transmitted at low voltage, there is a significant drop in output voltage at the end of long transmission lines: the lamp at the 'village end' glows only faintly, and voltmeters connected across each lamp show that the output voltage is much less than the input. Show that inserting a step-up transformer near the 'power station' and a step-down transformer at the 'village end' of the transmission lines restores the output voltage to a value close to the input.  Let students spend a few minutes brainstorming in pairs or small groups to suggest an explanation for what they have observed. To guide their discussions, display a large clear diagram on the board or OHP showing a load connected in series with two other resistors (i.e. the transmission lines). Use algebraic and numerical examples to explain how increasing the input voltage reduces the current and hence also reduces the power dissipation in the transmission lines, ensuring that the output voltage is not much less than the input. By suitable questioning and discussion, establish that a DC supply system would be inefficient to operate, as the voltage could not be stepped up or down by transformers. Provide algebraic and numerical examples that allow students to practise solving problems related to power transmission.	Source: Adapted from T. Duncan (1978) *Exploring Physics*, Book 5, John Murray. © Tom Duncan 1970.	

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*A student connects a coil to a CRO. Using the terms* ***magnetic flux linkage*** *and* ***induced e.m.f.*** *in your answer, describe and explain the deflection on the CRO screen that you would expect to see:* a. *as a bar magnet is moved into the coil;* b. *when the coil is moved with a bar magnet at rest inside it.*		
	A magnetic flux of 8.0 Wb passes through a coil of 40 turns. The flux is steadily reduced to zero over a time interval of 1.5 s. What is the size of the e.m.f. induced in the coil?		
	Using diagrams to show the directions of magnetic field lines, eddy currents and electromagnetic forces, explain why a pendulum made from a perforated sheet of aluminium will swing freely between the poles of a strong magnet but one made from a solid sheet will not.		
	Find out the frequency of the AC mains electricity supply in Qatar and calculate its period.		
	A flat circular coil with 60 turns, diameter 5 cm, is suspended in a uniform magnetic field of flux density 4.5 mT. The coil rotates with a frequency 2.0 Hz about an axis at right-angles to the field and is connected into a circuit that has a total resistance of 35 Ω. a. *Derive an expression for the induced e.m.f. in the coil as a function of time.* b. *Calculate the peak value of the induced e.m.f.* c. *Calculate the peak current in the circuit.*		
	If the voltage of the electrical mains is stated to be 110 V rms, and assumed to be sinusoidal, what is the peak mains voltage?		
	a. *A 120 V generator is connected to transmission lines with total resistance 2 Ω and a load with resistance 10 Ω. Calculate:* i. *the current in the circuit;* ii. *the power loss in the transmission lines;* iii. *the pd across the load.* b. *Transformers with turns ratios 1:20 and 20:1 are inserted at the ends of the transmission lines. Calculate:* i. *the input voltage to the circuit;* ii. *the current;* iii. *the power loss in the transmission lines;* iv. *the pd across the load.*		

GRADE 11A: Physics 7

Atomic and nuclear physics

UNIT 11AP.7
10 hours

About this unit

This unit is the seventh of seven units on physics for Grade 11 advanced.

The unit is designed to guide your planning and teaching of physics lessons. It provides a link between the standards for science and your lesson plans.

The teaching and learning activities should help you to plan the content and pace of lessons. Adapt the ideas to meet your students' needs. For extension or consolidation activities, look at the scheme of work for Grade 12A and Grade 10A.

You can also supplement the activities with appropriate tasks and exercises from your school's textbooks and other resources.

Introduce the unit to students by summarising what they will learn and how this builds on earlier work. Review the unit at the end, drawing out the main learning points, links to other work and real world applications.

Previous learning

To meet the expectations of this unit, students should already be able to describe the kinetic particle model, and be able to describe the distribution of charge and mass within an atom. They should know that metals contain electrons that are free to move, and that a flow of charged particles constitutes an electric current. They should be able to describe the commercial generation of electricity in terms of using an energy source to drive turbines.

Expectations

By the end of the unit, students describe a simple model for the nuclear atom and the evidence for it, and recognise that some nuclides are unstable and decompose to simpler ones, emitting three forms of radiation in the process. They characterise the three radiation forms and know some of their uses. They distinguish between nuclear fission and fusion and understand the dangers associated with them. They have an understanding of the properties of the electron and some of its main uses.

Students who progress further show an understanding of the spontaneous random nature of radioactive decay, and understand and can use the concept of half-life. They describe how elements are produced within stars, and know how such processes sustain a star's energy output.

Resources

The main resources needed for this unit are:

- old TV set or cathode-ray oscilloscope (CRO) that can be dismantled
- examples of radioactive materials (e.g. coffee beans, Brazil nuts, house dust that has been collected in a vacuum cleaner)
- boxes (e.g. shoeboxes) with a large hole cut in opposite sides and covered with a curtain made from strips of opaque flimsy material
- sand, large foam chips, small container (e.g. 35 mm film canister) filled with lead shot
- approximately 100 coins and/or dice and/or drawing pins
- videos highlighting the positive and negative aspects of nuclear power

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *cathode ray*, *cathode*, *anode*, *thermionic emission*, *electron gun*
- *radioactive*, *alpha radiation*, *beta radiation*, *gamma radiation*, *ionising radiation*, *background radiation*
- *nucleus*, *nucleon*, *proton number*, *nucleon number*, *isotope*, *radioisotope*, *nuclide*
- *decay*, *activity*, *half-life*
- *nuclear fission*, *nuclear fusion*, *chain reaction*

Standards for the unit

Unit 11AP.7

10 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
5 hours **The nuclear atom** **3 hours** **Radioactive decay** **2 hours** **Nuclear fission and fusion**	10A.27.1	Describe the kinetic particle model ...	11A.32.1	Interpret the results of Rutherford's scattering experiment and describe how it led to modern models of the structure of the atom.		
	10A.17.1	Describe the distribution of mass and charge within an atom and deduce the numbers of protons, neutrons and electrons present in both atoms and ions given proton and nucleon numbers.	11A.32.2	Describe a simple model for the nuclear atom in terms of protons, neutrons and electrons, use the common notation for representing nuclides and write equations representing nuclear transformations.	12A.30.3	Explain atomic spectra and permitted electron orbitals in terms of the quantisation of angular momentum
	10A.30.1	Distinguish between conductors, semiconductors and insulators with reference to moving electrons or ions ...				
			11A.32.3	Understand the spontaneous and random nature of nuclear decay, interpret decay data in terms of half-life and explain the source of the background radiation.		
			11A.32.4	Know the properties of α-, β- and γ-radiations, including the dangers to life and health.		
			11A.32.5	Know some common uses of radioisotopes.		
			11A.32.6	Know the source of energy in stars, including the Sun.	12A.31.5	Explain the process of element formation in stars and know how this leads to the generation of energy.
			11A.32.7	Distinguish between nuclear fission and nuclear fusion, and know how heavier elements are formed in older stars by nuclear fusion.	12A.30.6	Show an understanding of the interconversion of matter and energy and use the equation $E = mc^2$ and recognise that this explains the phenomenon of nuclear energy.
	11A.31.5	Describe the commercial production of alternating current using a gas turbine ...	11A.32.8	Understand that while nuclear fission can be used peacefully as a source of energy, there are significant social, political and environmental dimensions to its use.		
	10A.31.1	Know that electric current is the rate of flow of charged particles ...	11A.32.9	Show an understanding of the properties of the electron and the operation of the cathode-ray tube and the television tube.	12A.30.5	Show an understanding of wave–particle duality in the properties of the electron.
	10A.30.3	Describe an electric field as an example of a field of force ...				

Objectives	Possible teaching activities	Notes	School resources
7 hours **The nuclear atom** Show an understanding of the properties of the electron and the operation of the cathode-ray tube and the television tube. Interpret the results of Rutherford's scattering experiment and describe how it led to modern models of the structure of the atom. Know the properties of α-, β- and γ-radiations ... Describe a simple model for the nuclear atom in terms of protons, neutrons and electrons, …	**Atomic models** At the start of this section, give students a research task: ask them to use library and Internet resources to explore the historical development of ideas about the small-scale structure of matter. Suitable topics include the following. • Democritus and ancient Greek ideas about atoms. • Mediaeval theories about 'elements' (fire, earth, air and water). • Dalton and the beginnings of modern atomic theory. • Islamic scientists' theories about the nature of matter. • Mendeleev and the chemical elements. • J. J. Thompson's measurements of *e*/*m* for cathode rays. • Crookes, Hertz, G. P. Thompson and the nature of the electron. • Chadwick and the discovery of the neutron. • Dirac, Anderson and antimatter. • Gell-Mann and the quark model. • The modern standard model of particle physics (quarks and leptons). Give each pair or individual a different topic to research, and tell them to prepare a maximum of ten PowerPoint slides for presentation to the rest of the class. They should include an acknowledgment of their sources. Allocate at least one session near the end of this section for students to give their presentations and discuss them with the whole class.	Enquiry skills 11A.1.6, 11A.1.8, 11A.2.1, 11A.3.4 **ICT opportunity:** Use of the Internet; use of PowerPoint.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	The nature of cathode rays Perform a sequence of demonstrations using a variety of cathode-ray tubes. Initially, do not tell students that these involve streams of electrons; rather, ask students what they can deduce from observing the demonstrations. Suitable examples include the following. • *Maltese cross*. Establish that something must be emerging from the negative (cathode) end of the tube, which causes the phosphorescent screen at the far end to glow. Establish that it must be travelling in straight lines (it casts a sharp shadow). Use a bar magnet to show magnetic deflection of the shadow (and, by implication, the beam). • *Deflection tube*. Establish that a narrow beam must be emerging from a horizontal slit and impinging on the phosphorescent screen mounted within the tube. Show how the beam can be deflected vertically by applying a pd to create an electric field between the horizontal plates. • *Fine beam tube*. Establish that there is a narrow beam that causes the gas within the tube to glow. Use Helmholtz coils to deflect the beam magnetically. Tell students that *cathode rays* were first observed in the nineteenth century (when it became technologically possible to make evacuated glass tubes and to produce a steady high voltage). They were named because they emerged from the *cathode* (negative electrode), and were a subject of great curiosity and experimentation. Students might be able to suggest that the rays have a negative charge. Show how a Perrin tube and gold-leaf electroscope can be used to establish that this is indeed the case.	For maximum impact, perform the demonstrations in a partially darkened room.	

Objectives	Possible teaching activities	Notes	School resources
	Point out that establishing the nature of the cathode rays was a major challenge to nineteenth-century scientists. Explain that it took a series of very careful experimental measurements by J. J. Thompson to establish that the rays were a stream of negatively charged particles (as opposed to a wave within the low-pressure gas in the tube). Students should be able to appreciate that the force on a charged particle within an electric (or magnetic) field depends on its charge, while the resulting acceleration and deflection depend also on its mass. Measurements of the motion of cathode rays thus enabled J. J. Thompson to deduce a value of charge/mass for cathode rays. Explain that Thompson's results were remarkable not only in establishing the particulate nature of cathode rays, but also in obtaining the *same* value of charge/mass irrespective of the metal used for the cathode. Point out that the result was remarkable because, at the time, it was thought that each element was composed of its own unique and indivisible atoms: extracting identical particles from different metals did not fit this picture. Tell students that the cathode-ray particles soon acquired the name *electron* by which they are still known.		
	Using cathode rays Return to the cathode-ray tube demonstrations used earlier and explain to students, with the aid of a suitable diagram, how the electron beams are produced in an *electron gun*. Point out the heated metal cathode where electrons are released by *thermionic emission*, and the *electrodes* used to accelerate and direct the beam. Point out that cathode-ray tubes are widely used in visual displays. Show students the inside of a TV set and/or a cathode-ray oscilloscope. Students should be able to identify the electron gun and the coils or plates used for deflection. Explain how a coloured display is achieved using three different phosphors that glow red, greed or blue when excited by a high-speed electron. In a brief brainstorming session, get students to suggest situations where cathode-ray tubes are used. Examples might include medical applications (e.g. heart monitors) and radar screens. Ask students to write a description of the operation and use of one example of a cathode-ray tube, either historical or modern.		
	Radioactivity Set up a circus of activities illustrating aspects of radioactivity. Provide a worksheet so that students can work in pairs or individually to visit each station in turn and record their observations. The worksheet, and the initial briefing you give to students, should emphasise safety procedures. Suitable examples include the following. • Use a Geiger counter to detect *background radiation* and the radiation from naturally occurring sources such as coffee beans, Brazil nuts and house dust (collected in a vacuum cleaner). • Compare *alpha, beta* and *gamma* sources by exploring the range of radiation in air. • Compare alpha, beta and gamma sources by exploring the absorption of radiation by various materials. • Show the effect of a magnetic field on beta radiation. • Observe alpha and beta radiation in a diffusion cloud chamber. • Display a photographic film that has been affected by *ionising radiation*. • Use a spark counter to show the presence of ionising radiation.	Prepare a suitable student worksheet. **Safety:** Radioactivity experiments must only be directed by teachers who have had appropriate training. Alternatively, do these activities as demonstrations to the whole class. Enquiry skills 11A.4.1, 11A.4.2	

Objectives	Possible teaching activities	Notes	School resources
	Discuss students' observations with the whole class and, by suitable questioning, establish the following points. • Radioactivity is a natural phenomenon, and background radiation is all around us. Rocks, soil, air and water all contain radioactive materials that contribute to the background radiation. • Radioactivity involves the emission of something that can be detected by the *ionisation* it produces. Human senses alone cannot detect it but it can be detected by various instruments. • The *ionising radiation* can be classified into three types: *alpha*, *beta* and *gamma*, which can distinguished by their penetrating power. • Beta radiation can be deflected by an electromagnetic force. The direction of deflection shows that it carries a negative charge. Tell students how radioactivity was first discovered in the nineteenth century by Henri Becquerel, who noticed its effect on a photographic film stored next to a mineral containing uranium compounds. Explain that experiments similar to the ones they have done led scientists to conclude that beta radiation consists of high-energy electrons, alpha radiation is high-energy He^{2+} ions, and gamma is electromagnetic radiation. Ask students to suggest how the discovery of radioactivity might have affected people's ideas about the nature of matter: at the time, atoms of each element were thought to be unique, indivisible and unchanging, and the emission of similar radiation from many different substances undermined this picture.		
	Scattering experiments Set up a circus of activities in which each station consists of an upturned box (e.g. a shoebox) concealing an obstacle. Cut a large hole (about 10 cm wide) in opposite sides of each box and cover the holes with a curtain made from strips of opaque flimsy material (e.g. black polythene). Tell students to visit each station in turn, roll a large marble or ball-bearing through the box and try to deduce its contents. Encourage them to try rolling the marble or ball-bearing at different speeds. Do not allow them to look inside the boxes! Suitable obstacles include: a layer of sand; some large foam chips, a small container (e.g. a 35 mm film canister) full of lead shot, a ball-bearing or marble similar to those supplied for rolling, or nothing. Discuss students' observations and deductions. Then explain that they have been modelling an important technique for studying the structure of matter (i.e. fire high-energy particles at a sample of matter and observe their scattering).	Enquiry skills 11A.1.1, 11A.1.3, 11A.2.1, 11A.3.3, 11A.4.1	
	Rutherford's experiments Use a PowerPoint presentation to tell students about an early example of a scattering technique: Rutherford's design of experiments, carried out by Geiger and Marsden, in which alpha particles were fired at thin metal foil. Show pictures and diagrams of the apparatus and explain how the experimenters counted individual scintillations that revealed the impact of an alpha particle on a screen.	Enquiry skills 11A.1.1–11A.1.3, 11A.2.1, 11A.3.3, 11A.4.1	

Objectives	Possible teaching activities	Notes	School resources
	Tell students that, at the time (early twentieth century) scientists believed that atoms consisted of a large cloud of positively charged matter in which electrons were embedded. Ask them to predict how alpha particles would be scattered by a sheet of such atoms packed close together (they would undergo multiple small deflections and emerge in a direction close to their original path). Tell students that Geiger and Marsden found that most particles were completely undeviated, but a *very* small fraction were reflected back through large angles – and that Rutherford was very surprised by this result. Ask students to suggest how the results might be interpreted and, by suitable questioning, guide them to Rutherford's explanation (i.e. that most of each atom is empty space, but there is a small dense concentration of mass – the *nucleus*). Explain that Rutherford also suggested that the nucleus carried a positive charge, and this enabled him to use his knowledge of electrostatic forces to predict what fraction of alpha particles of a given energy would be scattered through a given angle by a nucleus of a given charge and size. Geiger and Marsden carried out a series of experiments using Rutherford's predictions and were able to deduce the charge and size of several metal nuclei. Get students to use a gravitational analogue of Rutherford's experiment: rolling marbles towards a hill, shaped so that the change in gravitational potential energy mimics the change in electrostatic potential energy close to a point charge. Tell them to explore the relationship between initial kinetic energy, direction of approach and scattering angle. They should also explore the same relationship using Java applets. The exploration of scattering should be empirical at this stage. Establish that Rutherford's experiment overturned people's ideas about atoms and led to the model that is still accepted today: a small dense nucleus that carries a positive charge and nearly all the mass of the atom, surrounded by electrons that have negative charge and a much smaller mass than the nucleus. Point out that initially the nucleus was thought to contain protons and electrons, with further electrons in orbit around it such that the total numbers of protons and electrons were equal, but with the discovery of the neutron (in another scattering experiment) the model was revised, and we now believe that the nucleus contains protons and neutrons but no electrons.	Inverse-square laws of gravitation and electrostatics do not feature until Units 12AP.1 and 12AP.5. **ICT opportunity:** Use of Java applets.	
	Discussion of atomic models Ask students to deliver the PowerPoint presentations they prepared during their work in this section. Organise the presentations so that the ideas are presented in chronological order. Point out the historical place of the two examples studied in detail in this section: the nature of cathode rays and the development of the nuclear model. In discussion, ask students to consider factors influencing the development of scientific ideas, and how ideas about the structure of matter have been affected by economic, social, cultural and other contexts. Students should appreciate the importance of technological developments leading to experiments and observations that have radically affected people's ideas about matter.	**ICT opportunity:** Use of PowerPoint. Enquiry skills 11A.2.1, 11A.2.2, 11A.2.4, 11A.3.4	

Objectives	Possible teaching activities	Notes	School resources
4 hours **Radioactive decay** ... use the common notation for representing nuclides and write equations representing nuclear transformations. Understand the spontaneous and random nature of nuclear decay, interpret decay data in terms of half-life and explain the source of the background radiation. Know the properties of α-, β- and γ-radiations, including the dangers to life and health. Know some common uses of radioisotopes.	**Using radioactivity** If possible, arrange a class visit to a hospital to see how radioactive materials are used in imaging, diagnosis and treatment. During the visit, draw attention to safety information and procedures as well as to the benefits of using radioactivity. If a visit cannot be arranged, set up a display of posters, leaflets and other information around the lab showing medical uses of radioactivity. Give students time to study the display. Discuss the visit or display and focus on each of the following aspects in turn. • *Terminology*. Define the terms *nucleon*, *proton number* (atomic number), *nucleon number* (mass number), *isotope, radioisotope* and *nuclide*. Remind, or tell, students of the conventional notation used to represent nuclides. Provide several examples that allow students to practise using these terms and notation. • *Safety*. Establish that radiation can damage or destroy living tissue. This can be useful (e.g. in treatment of tumours) but can also be hazardous if healthy tissue is affected. • *Properties of radiation*. Ask students to suggest why particular isotopes are chosen for medical use. They should be able to appreciate the relevance of the absorption experiments they carried out earlier (e.g. gamma emitters are used where highly penetrating radiation is needed for imaging).	**Visit opportunity:** Visit a local hospital. Enquiry skills 11A.2.3, 11A.2.5	
	Set students a challenge: give them a limited time (e.g. 24 hours) in which to use the Internet and library resources to list as many uses of radioactivity as they can find. For each, they should note the type of radiation used and, if possible, the isotope used as its source. Examples might be drawn from industry, research and the home. Display students' lists in the lab (and maybe offer small prize for the longest and most detailed or diverse list).	**ICT opportunity:** Use of the Internet. Enquiry skills 11A.1.8, 11A.2.5, 11A.3.4	
	Radioactive transformations With the aid of suitable diagrams and equations displayed on the board or OHP, along with any available models or Java applets, explain to the class the nuclear transformations that occur when an unstable nucleus emits alpha, beta or gamma radiation. Show how the electron (beta particle) is represented using conventional nuclear symbols and emphasise that the total proton number (charge) and nucleon number are both separately conserved in any reaction. Explain that beta decay involves a neutron transforming into a proton, with the emission of an electron. Organise a game in which each student is given a card with symbols showing either the starting point or the products of a radioactive transformation. Designate three areas of the lab as alpha, beta and gamma. Students should first find their partners (i.e. the student holding the other part of their transformation) and then decide which group they should join. Students within each group should then look at one another's cards and decide whether any pairs are in the incorrect group. Give students plenty of examples that allow them to practise writing and interpreting equations involving radioactive transformation.		

Objectives	Possible teaching activities	Notes	School resources
	Decay and half-life Refer to the previous activity and establish that a pure sample of a radioactive isotope will change its composition over time (i.e. the original nuclide will *decay*). Explain how the amount of the original isotope present can be related to its *activity* (i.e. the number of decays per second): the greater the number of unstable nuclei present, the greater the number of emissions. Demonstrate and explain how to monitor the activity of a short-lived isotope. Show how the background count must first be determined. Then obtain measurements of the count-rate at regular intervals, subtract the background count and plot a graph of count-rate against time to produce a decay curve. If apparatus and local safety requirements permit, let students work in pairs to obtain their own decay curves for the decay of protactinium or another short-lived isotope. Tell them to use a datalogger and PC to collect and display the measurements, and to discuss how to select the appropriate sampling rate. Discuss the decay curves and establish that the time for the activity (and hence the number of unstable nuclei) to halve from any initial value is independent of the value chosen (i.e. there is a constant *half-life*). Tell students to use their own graphs to determine a value for the half-life of the isotope studied. Encourage them to comment on the precision and accuracy of their results and to suggest ways in which these might be improved. Refer to earlier work in which students studied some uses of radioactivity. Ask students to suggest whether an isotope with a long or a short half-life would be desirable in each case. For example, in medical use a short half-life is desirable for isotopes injected into patients (there is a high activity for only a short time), whereas a long half-life would lead to the patient being exposed to radiation for a long period. On the other hand, isotopes used in industrial monitoring devices should have long half-lives so that their activity remains almost constant while the device is in use. If students have not already identified archaeological dating as a use for radioactivity, draw their attention to it now and explain how it can be used to estimate the ages of once-living materials that exchanged carbon with the atmosphere until their death. Give students plenty of examples that allow them to practise using the concept of half-life.	**Safety:** Radioactivity experiments must only be directed by teachers who have had appropriate training. **ICT opportunity:** Use of a datalogger. This activity also relates to Standard 10A.25.2. Enquiry skills 11A.1.1, 11A.1.3, 11A.1.5, 11A.3.1–11A.3.3, 11A.4.1, 11A.4.2	
	Modelling decay and half-life Divide the class into pairs or small groups and allocate each a different model illustrating the random nature of radioactive decay. Provide a briefing sheet for each activity which guides students to record data and plot a decay curve. In each of the following, students should repeatedly drop a large number of the objects, remove according to instructions, and plot a graph of the number remaining after each drop. • Drawing pins. Remove all those that lie on their backs. • Coins. Remove all those that land 'heads'. • Dice. Remove all those that show 6. • Dice. Remove all those that show either 1 or 2.	Prepare suitable briefing sheets.	

Objectives	Possible teaching activities	Notes	School resources
	Display and discuss the decay curves. Establish that, in each case, the plotted points lie close to a smooth curve with a constant half-life (i.e. a curve that closely resembles a radioactive decay curve). By suitable discussion and questioning, establish the following points. • In all the examples the decay is random: it is impossible to predict which individual object will decay at any one time. • Although the individual decay is random, there is a well-defined decay probability, so it is possible to predict the fraction of the objects decaying. • This spontaneous random behaviour is a good model for radioactive decay. It is impossible to predict which nucleus will decay, but the fraction decaying in a given time, and hence the half-life, can be determined accurately. Students should also use computer models to simulate the random nature of radioactive decay.	**ICT opportunity:** Use of computer models.	
4 hours **Nuclear fission and fusion** Know the source of energy in stars, including the Sun. Distinguish between nuclear fission and nuclear fusion, and know how heavier elements are formed in older stars by nuclear fusion. Understand that while nuclear fission can be used peacefully as a source of energy, there are significant social, political and environmental dimensions to its use.	**Nuclear fission** Using suitable visual aids and nuclear equations, explain to students the principles underlying power generation using nuclear fission. Establish the following points. • Electricity can be produced using steam-driven turbines that drive generators. A variety of energy sources can be used to power the turbines. • Some massive nuclei can decay by splitting (*fission*) in which the products have greater kinetic energy (i.e. are hotter) than the original nuclei. • Fission can be induced artificially in some nuclei (e.g. uranium-235) by neutron absorption. • Uncontrolled fission can lead to a runaway *chain reaction* and explosion. This is exploited in nuclear weapons. • Fission can be controlled by the use of control rods to absorb excess neutrons, leading to a steady reaction and the emission of heat. This is exploited in nuclear power stations. Ask students to draw flow charts showing the processes involved in generating electricity from fissile materials. Show students one example of a video or other material highlighting the positive aspects of nuclear power (e.g. from a nuclear power company) and one focusing on negative aspects (e.g. produced by an environmental pressure group). Point out that producers of such materials often act from a position of self-interest, so when using the information it is important to be aware of possible bias. Set the task of preparing to debate whether or not a nuclear power station should be built near their home town. Tell students to look for evidence to support the case for nuclear power, and for evidence making a case against it. Ask two students to introduce the case for, and two to introduce the case against nuclear power. Then ask other students in turn to add to, or dispute, the evidence presented. During the debate, encourage students to consider both sides and to form their own opinions. Hold a vote at the end.	Enquiry skills 11A.1.6, 11A.1.8, 11A.2.3, 11A.3.4 Students will meet the relationship $E = mc^2$ in Unit 12AP.6	

Objectives	Possible teaching activities	Notes	School resources
	Nuclear fusion on earth Explain to students that the *fusion* (joining) of light nuclei can also lead to an increase in the particles' kinetic energy and so could, in principle, be used as a power source for electricity generation. Point out that the process gives rise to fewer waste-disposal problems than nuclear fission, and that water could be a plentiful cheap source of light nuclei (i.e. hydrogen). Ask students to suggest reasons why nuclear fusion power is not yet a commercially viable option, despite several decades of research and development. By suitable questioning and prompting, establish that fusion requires two positively charged particles to join, and this is made difficult by electrostatic repulsion. Establish that the reacting particles need to approach one another at high speed so as to come close enough to react before the repulsion reverses their motion. Students should appreciate that high speeds imply high temperature. They should also appreciate that, in order to increase the likelihood of a collision between nuclei, the material undergoing fusion should have high density. Tell students that, in order to promote fusion in prototype reactors, temperatures of the order 10^8 K are required. Ask students what problems might arise when dealing with such high-temperature material (it tends to vaporise any other material with which it comes into contact, including the walls of any container). If time permits, let students search the Internet for examples of nuclear fusion experiments on Earth, including 'cold fusion'. Point out that the results of some experiments are open to question, and that the reports of cold fusion have been widely (though not completely) discredited. Give students some examples that allow them to practise using nuclear symbols and equations to show fission and fusion reactions.	**ICT opportunity:** Use of the Internet.	
	Nuclear fusion in the stars Refer to the previous discussion and explain to students that, while the high temperatures and densities required for nuclear fusion are hard to achieve on Earth, they are found within the cores of stars, including the Sun. Tell students that, until nuclear fusion was discovered early in the twentieth century, the energy source of the Sun was a great puzzle: no conventional source (such as burning oil or coal) could sustain the Sun's power output for more than a few thousand years, which conflicted with other evidence about the age of the Earth. However, models of the Sun's output involving nuclear fusion of hydrogen can account for the observed power output and supposed age of the Sun. The energy released by fusion reactions in the Sun's core (centre) heats the overlying material so that it radiates electromagnetic radiation that we receive on Earth as heat and light.		

Objectives	Possible teaching activities	Notes	School resources
	Ask students to work in pairs to research information about nuclear fusion reactions in stars. Guide students by suggesting they look for answers to the following questions. • Which elements were present in the very early Universe? • Which reactions are involved in the processes known as the pp and CNO cycles that create helium from hydrogen? • What are the typical temperatures and densities in the core of a Sun-like star, and in the core of a star with ten times the mass of the Sun? • After the production of helium, what are the reactions that produce carbon and heavier elements? • Why can large, hot stars produce heavy elements in their cores, whereas Sun-like stars cannot? • What happens when a very hot, massive, short-lived star can undergo no further fusion? How are heavy elements recycled into later generations of stars and planets? Tell students to display their findings by making a colourful poster. Display the posters around the lab.	Enquiry skills 11A.1.6, 11A.1.8, 11A.3.4 Heavy elements are produce in the cores of very hot, massive, short-lived stars, which exhaust their nuclear fusion and come to a catastrophic end while still young. Only low-mass, cool, stars survive long enough to become 'old', but their core temperatures never become high enough to initiate fusion of heavy elements.	

Assessment

	Examples of assessment tasks and questions	Notes	School resources
Assessment Set up activities that allow students to demonstrate what they have learned in this unit. The activities can be provided informally or formally during and at the end of the unit, or for homework. They can be selected from the teaching activities or can be new experiences. Choose tasks and questions from the examples to incorporate in the activities.	*Write a short article for an encyclopaedia explaining how a cathode-ray tube can be used in a TV. Illustrate your article with diagrams and include the following terms:* ***electron gun****,* ***thermionic emission****,* ***charge****,* ***electric field****,* ***electrode****.*		
	Carry out an experiment to determine the range of alpha radiation in air, and use your results to explain how an alpha source can be used in a simple smoke detector.	Provide suitable apparatus and ensure that safety procedures are followed.	
	When Rutherford saw the result of Geiger and Marsden's experiments, he said it was as if a cannon-ball had bounced back from a sheet of tissue paper. Explain why Rutherford was so astonished by the result and describe the theory he developed to explain it.		
	A radioactive isotope of carbon has 6 protons and nucleon number 14. a. *Write an equation using conventional symbols showing what happens when this nuclide undergoes beta decay.* b. *This isotope has a half-life of 5600 years. If a sample initially contained 1 mg of the isotope, how much would remain after 11 200 years?*		
	Repeatedly drop a large number of dice and on each occasion remove all those that show an even number. Explain how this process is similar to radioactive decay.		
	Write a paragraph to explain why nuclear fusion is difficult to achieve on Earth but occurs readily in the cores of the Sun and other stars.		