Science units
Grade 11 foundation

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Science scheme of work: Grade 11 foundation units

180 hours

1st semester
101 teaching hours

Biology: 31 hours

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

Unit 11FB.1: Linking cell structures to function
Mitochondria, ATP and biochemistry of aerobic respiration. Cell membrane structure and transport.
9 hours

Unit11FB.2: Human transport system
Human blood system, heart structure and function. Blood vessels and red blood cells.
10 hours

Unit 11FB.3: 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: 30 hours

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

Unit 11FC.1: Obtaining chemicals revisited
Haber process, nitric acid and fertilisers. Sulfur and the contact process. Limestone and cement.
10 hours

Unit 11FC.2: Metals
Reactivity series of metals. Alloys. Oxidation and reduction.
7 hours

Unit 11FC.3: Electrochemical cells
Cell potentials and electrochemical cells. Environmental issues and rechargeable cells.
10 hours

Physics: 40 hours

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

Unit 11FP.1: Movement and forces
Newton's laws of motion. Mass and weight. Force, mass and acceleration. Inertial and gravitational mass. Momentum conservation.
15 hours

Unit 11FP2: Temperature and heat
Thermal energy transfer and equilibrium. Conduction, convection and radiation. Convection currents and weather. Specific heat capacity and latent heat.
11 hours

Unit 11FP.3: Optics and light
Reflection and refraction. Image formation. Long and short sight. Total internal reflection. Dispersion.
11 hours

Science scheme of work: Grade 11 foundation units

180 hours

2nd semester
79 teaching hours

Biology: 29 hours

Unit 11FB.4: Biological basis of Inheritance
Homologous chromosomes. Mitosis and meiosis. DNA, genes and variation. Mutations.
9 hours

Unit 11FB.5: Diversity of life
Classification of organisms. Micro-organisms. Cell culture.
10 hours

Unit 11FB.6: Ecological relationships and populations
Interactions between organisms. Population dynamics. Human impact on the environment.
10 hours

Chemistry: 30 hours

Unit 11FC.4: Reaction rates revisited
Exothermic and endothermic reactions. Activation energy and energy profiles. Catalyst and activation energies. Bond breaking and making.
10 hours

Unit 11FC.5: An introduction to organic chemistry
Nomenclature, structure, bonding and shape. Alkanes and alkenes. Aliphatic electrophilic and nucleophilic addition and substitution reactions.
10 hours

Unit 11FC.6: Some functional groups
Alcohols, halogen compounds, aldehydes and ketones, carboxylic acids and their derivatives.
10 hours

Physics: 20 hours

Unit 11FP.4: Current electricity
Current and charge. Conductors, semiconductors and insulators. Voltage and resistance. Electrical power. Internal resistance.
10 hours

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

GRADE 11F: Biology 1

Linking cell structures to function

UNIT 11FB.1
9 hours

About this unit

This unit is the first of six units on biology for Grade 11 foundation.

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 Grades 11A and 12A, and Grade 10F.

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, most students describe the structural features of mitochondria and how these relate to the chemical processes of respiration. 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. They outline the reaction steps in the glycolysis, the Krebs cycle and oxidative phosphorylation stages of respiration.

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.

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
- 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*

Standards for the unit

Unit 11FB.1

9 hours		**SUPPORTING STANDARDS**		**CORE STANDARDS** **Grade 11 standards**		**EXTENSION STANDARDS**
2 hours **Mitochondria and respiration** **1 hour** **The role of ATP** **2 hours** **The stages of aerobic respiration** **4 hours** **The structure and function of the cell membrane**	10F.7.2	Recognise and know the function of a nucleus, mitochondria, chloroplasts, endoplasmic reticulum and ribosomes.	11F.5.1	Describe the structure of mitochondria and relate this to the biochemical reactions of respiration.	11A.5.1	Describe the structure of mitochondria and chloroplasts and link their structures to the biochemical and photochemical reactions of respiration and photosynthesis.
	10F.5.1	Describe the composition and molecular structure of glucose, amino acids, glycerol, fatty acids, triglycerides, phospholipids, chlorophyll and haemoglobin.	11F.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.				
			11F.6.1	Describe the role of ATP as the universal energy currency in all living organisms and relate this to respiration.	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.	11F.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.53	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.

9 hours	SUPPORTING STANDARDS	CORE STANDARDS Grade 11 standards	EXTENSION STANDARDS
			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). 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.

Activities

Objectives	Possible teaching activities	Notes	School resources
2 hours **Mitochondria and respiration** Describe the structure of mitochondria and relate this to the biochemical reactions of respiration.	Start by asking students to recall earlier work from Unit 10FB.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.	**Mathematics:** Mathematical skills are needed to determine sizes from scales or magnifications.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	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 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 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.	
1 hour **The role of ATP** Describe the role of ATP as the universal energy currency in all living organisms and relate this to respiration.	Introduce this component by linking the mitochondria to energy; ask students to recall earlier work from Grade 9 to see what they understand by the term *respiration* and then ask where the main location for respiration is in the cell.	Recall Standard 9.8.1 on aerobic respiration.	
	Link the production of ATP to the other organic molecules, such as carbohydrates, lipids and proteins discussed in Unit 10FB.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 10F.5.1.	
	Ask students to recall the word and formula equations for aerobic respiration. Then link to Unit 10F.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.	Recall Standard 9.8.1. 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).	
2 hours **The stages of aerobic respiration** Describe the reaction steps in the three stages of aerobic respiration (glycolysis, Krebs cycle and oxidative phosphorylation), including the roles of oxygen and ATP	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. 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 OHTs with the events of the three stages on separate overlays so the stages can be shown in sequence. Prepare sets of cards in which each card shows a different respiration event.	

Objectives	Possible teaching activities	Notes	School resources
	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 11F.2.3	
4 hours **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.		

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.	*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.		
	Draw graphs from given data on the uptake of substances in different conditions and then explain the differences between them.	Present students with tables of data displaying the uptake of substances in different conditions (e.g. different sugars taken up from the intestines with and without a metabolic poison such as cyanide).	
	Examine drawings or micrographs of cells in different strengths of sugar solutions and explain what has happened to the cells.	Present students with drawings or micrographs of cells in different strengths of sugar solution.	

GRADE 11F: Biology 2

Human transport system

UNIT 11FB.2
10 hours

About this unit

This unit is the second of six units on biology for Grade 11 foundation.

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 12F and Grade 10F.

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 difference between red and white blood cells. They should know the basic structure and function of the human heart and the names and locations of the major blood vessels. They should be able to relate the structure of arteries, veins and capillaries to their functions.

Expectations

By the end of the unit, students explain why multicellular animals need a transport system for respiratory gases, water, food and waste, and describe the structure and function of the human circulatory system.

Students who progress further know the structure and functions of red and white blood cells and the role of blood, fluid tissue and lymph in transport. They understand the roles of the constituents of blood in the transport of oxygen and carbon dioxide. They know the human blood groups and their significance.

Resources

The main resources needed for this unit are:

- large number of 1 cm^3 cubes
- animal hearts or model heart
- microscopes
- video camera and monitor
- video clips of the heart and circulatory system in action
- electronic equipment for measuring pulse and blood pressure (optional)
- sample ECG trace
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *surface area to volume ratios*
- *cardiac cycle*
- *double circulation*, *single circulation*

Standards for the unit

Unit 11FB.2

10 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
1 hour **Why a transport system is needed** **3 hours** **Heart structure and function** **2 hours** **Heartbeat and cardiac cycle** **1 hour** **Double circulation and the major blood vessels** **2 hours** **Structure and function of arteries, veins and capillaries** **1 hour** **Red blood cells and oxygen**			11F.7.1	Explain why large animals need transport systems for respiratory gases, water, food and waste in terms of their surface to volume ratio.		
	8.8.1	Know the basic structure of the heart and relate this to its function.	11F.7.2	Describe the external and internal structure of the heart. Relate features to functions in pumping blood round the body and maintaining separation of oxygenated and deoxygenated blood.		
	8.8.2	Know the different valves of the heart and how they function.				
			11F.7.3	Know how the heartbeat is initiated and maintained, and describe the cardiac cycle.		
	8.8.3	Know the positions, functions and names of the major blood vessels.	11F.7.4	Know that the human blood system is a double closed system and know the names, locations and roles of the major blood vessels.		
	8.8.4	Recognise the differences between arteries, veins and capillaries, and relate their structure to their function.	11F.7.5	Differentiate between arteries, veins and capillaries in terms of wall thickness and valves, and relate their structure to their function.		
	8.7.5	Compare and contrast the similarities and differences between red and white blood cells and their functions.	11F.7.6	Know that red blood cells carry oxygen.	12A.7.1	Explain the structure and function of human red blood cells, phagocytes and lymphocytes and the differences between the functions of blood, fluid tissue and lymph in the transportation of substances to and from cells.
					12A.7.2	Know the composition of the blood and explain the roles of red cells, plasma, haemoglobin and carbonic anhydrase in the transportation of oxygen and carbon dioxide.

Objectives	Possible teaching activities	Notes	School resources
1 hour **Why a transport system is needed** Explain why large animals need transport systems for respiratory gases, water, food and waste in terms of their surface to volume ratio.	A stimulating starting point for discussion is to ask students why there are no large single-celled organisms in everyday life (e.g. *amoeba* as big as the classroom). Ask students to suggest why the body needs a transport system and collate their answers on the board or OHP. Discuss the answers and raise comparisons with other animals, especially smaller ones.		Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Ask students to work in pairs to investigate how the relationship of surface area to volume alters as an animal becomes larger. Distribute sufficient numbers of cubes to allow students to construct three cubes of increasing dimensions as a simulation exercise. Discuss the relationships	Give each pair about 40 identical $1\,\text{cm}^3$ cubes; this will enable them to construct and compare cubes of $1\,\text{mm}^3$, $(2\,\text{mm})^3$ and $(3\,\text{mm})^3$. **Mathematics:** Students who are more advanced in mathematics could also work out the comparable relationships for spheres.	
	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.	Ensure water is absolutely still before adding dye.	
3 hours **Heart structure and function** Describe the external and internal structure of the heart. Relate features to functions in pumping blood round the body and maintaining separation of oxygenated and deoxygenated blood.	Issue students with a copy of a heart diagram with numbered labels and see if they can recall any of the details (from Grade 8). Ask them to write their answers on another piece of paper or in pencil on the diagram so they can be corrected if necessary.	This activity also relates to Standards 8.8.1 and 8.8.2.	
	Use an OHT template diagram and ask each student in turn to label one of the heart features.	Prepare a suitable OHT template.	
	Show students a model of the heart so they can appreciate the relative size and appearance of the main parts. Allow pairs of students to examine it in turn and describe its observable features.		
	A real heart from a suitable animal provides students with a rare opportunity to appreciate the nature of the heart's structures. Carefully dissect a heart as a demonstration or allow students to do their own dissection, either singly or in pairs.		
	Watch and discuss a video on the heart's action. Ask students to make notes from the video and pause the video at appropriate intervals to reinforce or clarify students' understanding of important points.		
	Show students information about the heart from the Internet using the interactive whiteboard, or ask them to research the details themselves using the Internet. Direct them to selected sites as necessary.	**ICT opportunity**: Use of the Internet.	
	Provide students with a partly completed account of the flow of blood through the heart and ask them to fill in the gaps, using their own research or information from their textbook.	Prepare appropriate worksheets for students to complete.	

Objectives	Possible teaching activities	Notes	School resources
2 hours **Heartbeat and cardiac cycle** Know how the heartbeat is initiated and maintained, and describe the cardiac cycle.	As an introduction to this topic, ask students to work in pairs and measure pulse rates at rest. Discuss and compare variations between rates as a class with published rates.	Pulse rates can easily be taken manually although electronic pulse and blood pressure equipment is widely available	
	Provide students with a heart diagram showing just the positions of the control features (e.g. the pacemaker/sinoatrial node (SAN) position) and ask them to label these features. Use a prepared OHT or ask students to look in their textbooks to complete the diagram. Show students a video of how the heartbeat is initiated and propagated. Explain the process of conduction of the heartbeat and the cardiac cycle and show students an example of an ECG trace. Ask students to explain the different phases of the ECG trace in relation to their diagram.	Prepare worksheets for students.	
	Ask students to use the library or the Internet to investigate how the artificial pacemaker works.	**ICT opportunity:** Use of the Internet.	
	Ask students to carry out an investigation into how heart rate varies with exercise and explain the moderation of the heartbeat by nerve action.	Enquiry skills 11F.1.3, 11F.3.2	
1 hour **Double circulation and the major blood vessels** Know that the human blood system is a double closed system and know the names, locations and roles of the major blood vessels.	Provide students with a simplified outline diagram of the human circulatory system and tell them to label the blood vessels and colour them appropriately to distinguish oxygenated and deoxygenated blood. An interesting exercise is to ask students to pretend that they are a red blood cell going around the circulation system and to describe their journey and their relationship to the degree of blood oxygenation along the route. Get one student to relate his or her journey to the class and make them pause at suitable points so that you can ask another student to discuss the changes occurring (e.g. in the lung capillary bed) or to name the next blood vessel. Watch and discuss a video of the human circulatory system. Ask students to write down the advantages of a double circulation over a single circulation (as found in fish). Discuss the answers together.	Prepare copies of worksheets for students. This activity also relates to Standards 8.8.3 and 8.8.4.	
	Encourage students to use the library and the Internet to investigate the changing picture of the human circulatory system through historical claims and challenges.	**ICT opportunity:** Use of the Internet.	

Objectives	Possible teaching activities	Notes	School resources
2 hours **Structure and function of arteries, veins and capillaries** Differentiate between arteries, veins and capillaries in terms of wall thickness and valves, and relate their structure to their function.	Demonstrate the structure of cross-sections of arteries, veins and capillaries on a monitor using a video camera attached to a microscope. Ask students to use a microscope to observe, draw and label cross-sections of arteries, veins and capillaries.	Set up a demonstration with a microscope and video camera and display a suitable slide on the monitor.	
	Ask students to use a microscope to observe and measure the thickness of arteries, veins and capillaries. If no micrometer is available, then photomicrographs with scale bars could serve the same purpose.	Microscopes with eyepiece graticules, ideally calibrated using stage micrometers, are the minimum requirement for this exercise.	
	Provide students with a diagram of all the blood vessels connected in the correct sequence (artery, arterioles, capillaries, venules, veins) and ask them to find out and explain what changes take place in blood pressure, speed of blood flow, cross-sectional surface area and blood composition as blood flows through each structure in turn. Show students graphs displaying variations in blood pressure, velocity and cross-sectional surface area and ask them to explain the variations and patterns displayed. Ask students to explain charts displaying and comparing the amounts of elastic tissue, smooth muscle and connective tissue in the blood vessels. Provide students with a partly completed account of the structure and function of blood vessels and ask them to fill in the gaps, using their own research or information from their textbook.	Prepare OHTs and copies of worksheets for students.	
	Ask students to find out why veins have valves and what muscle pumps are.		
	Demonstrate valves in the veins of the forearm by briefly applying a tourniquet and showing, like William Harvey, the position of valves.	**Safety:** Only do this as a demonstration; apply the tourniquet for a brief time (e.g. 1 minute).	
1 hour **Red blood cells and oxygen** Know that red blood cells carry oxygen.	Ask students to use a microscope to observe, draw and label blood cells.	This activity also relates to Standard 8.7.5.	
	Ask students to investigate the structure of the red blood cell and relate this to its function to answer questions about its size, the biconcave shape, the lack of a nucleus and the presence of haemoglobin. Discuss the significance of the loose attachment of oxygen to haemoglobin when carried in the blood. Compare this with the attachment of carbon monoxide and its poisoning effect. Show students a video clip (perhaps downloaded from the Internet) of the changes in the colour of oxygenated and deoxygenated blood. Ask students who enjoy large numbers to calculate how many oxygen molecules are carried by a fully saturated red blood cell.	**Safety:** Using fresh human blood samples is no longer an option because of health risks such as HIV, hepatitis and CJD.	

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 why most cells are less than 1 mm^3 by reference to three cubes of dimensions 1 mm^3, (2 mm)^3 and (3 mm)^3.*	Supply students with a sheet showing three enlarged cubes of labelled dimensions (1 mm)^3, (2 mm)^3 and (3 mm)^3.	
	Examine the accompanying ECG and explain how the trace relates to the events occurring in the heart. Explain how the heartbeat originates and its pathway through the heart.	Supply students with an ECG trace.	
	Explain how blood flows through the heart in one complete circulation of the body.		
	*What do you understand by the term **double circulation** and what are its advantages over a single circulation, as seen in a fish?*		
	Imagine you are a red blood cell. Explain the changes that happen to you as you travel around the circulatory system of the body.		
	Draw a table to compare and contrast the properties of arteries and veins.		
	Explain how a red blood cell is ideally suited to its function.		

GRADE 11F: Biology 3

Human gas exchange system and health

UNIT 11FB.3
9 hours

About this unit

This unit is the third of six units on biology for Grade 11 foundation.

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:

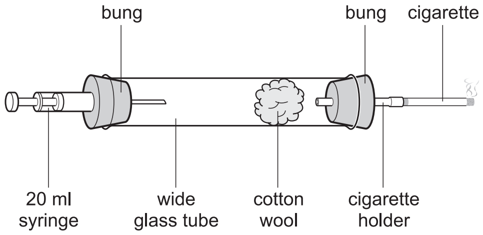
- gas exchange structures: *trachea*, *bronchus*, *bronchioles*, *alveoli*, *respiratory membrane*, *diaphragm*, *pleural membranes*, *thoracic cavity*, *external intercostals*, *internal intercostals*
- lung volumes: *tidal volume*, *expiratory reserve volume*, *inspiratory reserve volume*, *vital capacity*
- *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 11FB.3

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).	11F.8.1	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.			
1 hour **The effects of smoking**			11F.8.2	Differentiate between tidal volume and vital capacity of the lungs.	
	8.7.4	Know that smoking damages the lungs and reduces the efficiency of gas exchange.	11F.8.3	Describe the effects of tar and carcinogens in tobacco smoke on the gaseous exchange system and the cardiovascular system.	
2 hours **Lung diseases**			11F.8.4	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**			11F.9.1	Explain blood pressure and factors that affect it.	
			11F9.2	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 11F.1.2, 11F.3.1, 11F.4.1 **Safety**: Tubing mouthparts must be sterile for each student. Water may be spilt on the laboratory floor – make sure no one slips.	

Objectives	Possible teaching activities	Notes	School resources
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.	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.	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 11F.1.6, 11F.2.2, 11F.3.4	
2 hours **Lung diseases** Describe the symptoms of chronic bronchitis, emphysema, asthma and lung cancer and their effects on the gaseous exchange system.	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.	**ICT opportunity:** Use of the Internet.	

Objectives	Possible teaching activities	Notes	School resources
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.	Ask students to recall earlier work in Unit 11FB.2, 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).	This relates to Standards 11F.7.2–11F.7.6.	
	Ask students to recall earlier work from Unit 11FB.2 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 11F.7.3.	
	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 11F.1.3, 11F.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 11F: Biology 4

Biological basis of inheritance

UNIT 11FB.4
9 hours

About this unit

This unit is the fourth of six units on biology for Grade 11 foundation.

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 12F and Grade 10F.

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 know the difference between genes and alleles and that they are sections of DNA. They understand that changes in DNA bases cause variation. They know 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.

Students who progress further 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.

Resources

The main resources needed for this unit are:

- microscopes, slides of mitosis and meiosis
- 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
- 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*

Objectives for the unit

Unit 11FB.4

9 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
3 hours **Understanding cell division by mitosis**	10F.11.1	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.	11F.10.1	Explain the significance of organisms having a set of homologous chromosomes.	12F.11.1	Explain the terms *gene*, *allele*, *phenotype*, *genotype*, *dominant*, *recessive* and *co-dominant*.
3 hours **Understanding meiosis**			11F.10.2	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.		
3 hours **Understanding genetic inheritance**	10F.11.2	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.	11F.10.3	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.	12F.11.3	Explain how variation occurs through segregation of alleles during gamete formation and through the crossing over of chromosome segments during meiosis.
					12F.11.2	Use genetic diagrams to solve genetic problems involving monohybrid crosses.
					12F.11.4	Know how X and Y chromosomes determine sex in humans and the inheritance pattern of sex-linked characteristics.
	10F.12.1	Identify environmental and genetic causes of variation and distinguish between continuous and discontinuous variation within a population.	11F.11.1	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.		
			11F.11.2	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.		

Objectives	Possible teaching activities	Notes	School resources
3 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 10FB.5. 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 11.3. 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 11.3. 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 10F.11.1).		
	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 11.3.4	
3 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.	You could also refer to chiasmata here, although this is not fully covered until Unit 12FB.5 (Standard 12F.11.3).	
	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.	Printed photographs and OHT slides of the stages of meiosis are required.	
	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.	Enquiry skill 11.3.4	
	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').	Prepare suitable sets of cards on meiosis. Enquiry skill 11.3. 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 11.3. 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 11.3. 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.	You could also refer to chiasmata here, although this is not fully covered until Unit12FB.5 (Standard 12F.11.3).	

Objectives	Possible teaching activities	Notes	School resources
3 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 10FB.1 on protein synthesis. Give examples of gene mutations involving a single base difference (e.g. sickle cell gene).	Review Unit 10FB.4 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 11.3.4	
	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 10FB.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 11.1.8	
	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 11.3.4	
	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.	

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.		

GRADE 11F: Biology 5

Diversity of life

UNIT 11FB.5
10 hours

About this unit

This unit is the fifth of six units on biology for Grade 11 foundation.

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 12F and Grade 10F.

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 identify causes of variation within populations and distinguish between continuous and discontinuous variation.

Expectations

By the end of the unit, students know that species are clustered into groups. They know about the hierarchy of classification and the key features of the kingdoms and main phyla of animals and plants. They recognise the main features of viruses, bacteria and fungi. They know how micro-organisms and cells can be cultured.

Students who progress further 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. They know how micro-organisms are used in the food industry and in the treatment of wastewater.

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, monitor
- sterile swabs, inoculating loops, immersion oil
- autoclave, strong disinfectant
- nails, screws, nuts, bolts, pins, clips, staples
- sets of cards on classification
- computer, datalogger, sensors (light, oxygen, pH and temperature)
- fermenter, magnetic stirrer, air pump
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *Prokaryotae*, *Protoctista*, *Fungi*, *Animalia*, *Plantae*
- *kingdom*, *phylum*, *class*, *order*, *family*, *genus*, *species*
- *binomial system, dichotomous key*
- *taxonomic hierarchy*
- *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*

Objectives for the unit

10 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
2 hours **Classifying organisms**	10F.12.1	Identify environmental and genetic causes of variation and distinguish between continuous and discontinuous variation within a population.	11F.12.1	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.	12F.12.2	Know that natural selection and breeding isolation can lead to speciation.
2 hours **The five kingdoms**			11F.12.2	Know the distinguishing features of the five kingdoms: Prokaryotae, Fungi, Protoctista, Plantae and Animalia.	12F.12.3	Explain how natural selection and evolution over a long period of time have resulted in a great diversity of forms among living organisms.
2 hours **The major phyla of animals and plants**			11F.12.3	Use knowledge of the key features of the major phyla of animals and plants to recognise a typical member.		
4 hours **Micro-organisms: form and culture**			11F.14.1	Know the basic distinguishing features of viruses and types of bacteria and microbial fungi.		
			11F.14.2	Know methods for the laboratory and bulk culture of micro-organisms and cell lines.	12F.13.3	Explain some uses of micro-organisms in food production.
					12F.13.4	Explain how micro-organisms are used in the treatment of wastewater.

Activities

Objectives	Possible teaching activities	Notes	School resources
2 hours **Classifying organisms** 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.	Discuss with students why it is necessary to classify organisms. They may have carried out an ecological investigation and be able to recall the need to identify organisms for scientific recording. Additionally, the need to label organisms unambiguously becomes more obvious when the international study of organisms is considered. Discuss why Latin names are used. Give examples of the binomial system, such as: man, *Homo sapiens;* the domestic cat, *Felis silvestris*; the meadow buttercup, *Ranunculus acris.* Encourage students to discover the work of the Swedish naturalist Carl Linnaeus by searching the Internet. Invite individual students to define the term *species* from their own knowledge. Clarify the concept of *species* by posing a biological riddle: 'Which animal, if it died out today, could be born again tomorrow?' The answer is a hybrid animal, such as the mule (the offspring of a donkey and a horse). Discuss other hybrid animals, such as the tigon (the offspring of a tiger and a lion) in this context. Now ask 'Is the mule a species?' Students should realise that it is not and that the condition 'the ability to produce fertile offspring' is central to the definition of a species.	**ICT opportunity:** Use of the Internet. Enquiry skill 11F.2.1	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Explain to students 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. Encourage students to make up a mnemonic to help them memorise the hierarchy of classification (e.g. 'King Philip Counts Our Family Gold and Silver' – kingdom, phylum, class, order, family, genus and species). Ask students to complete a table to show the scientific names in the taxonomic hierarchy for a few common organisms. Suggest a selection of common animals and plants; include a few examples of closely related organisms and others with less similarity. Discuss the results as a class.	Prepare a table of classification for students to complete. Prepare other taxonomic examples on an OHT to show students.	
	Provide pairs of students with specimens, photographs, silhouettes or drawings of a range of animals (e.g. five insects), each with an identifying letter: A, B, C, D and E. Now ask students to create a dichotomous classification key and use it to identify the five insects. If they need help to start off, suggest a first question that divides the insect group into two. For example: 1 'Has antennae longer than10 mm' go to 2 'Has antennae equal to or less than 10 mm' go to 3 Discuss the results with pairs and the class.		
	Let students carry out a simulation exercise by classifying some common inanimate objects. This will help them understand the principles of keys and classification. For example, provide students with a collection of a variety of fixings and fasteners and ask them to make a key to identify each item. The first question might be: 1 'Has a screw thread' go to 2 'No screw thread' go to 3 Discuss the results with individuals and the class.	Provide a collection of a variety of fixings and fasteners (e.g. nails, screws, nuts and bolts, pins, clips, staples) for this classification exercise.	

Objectives	Possible teaching activities	Notes	School resources
	Consider demonstrating different ways of representing the taxonomic hierarchy.		
	One scheme uses a *box-in-box* approach. The outermost box represents the kingdom; inside this are several separate boxes representing phyla; inside each phylum box are several boxes representing classes; and so on. The final boxes are the individual species.	Produce 'box in box' scheme on OHT.	
	Another scheme uses a *family tree* approach. Start with the kingdom alone at the top; then place several phyla in a horizontal line below, each connected to the kingdom above with a rule; repeat this process for classes emanating from each phylum; continue down the 'tree' through layers of families, genera and eventually species.	Produce 'family tree' scheme on OHT.	
2 hours **The five kingdoms** Know the distinguishing features of the five kingdoms: Prokaryotae, Fungi, Protoctista, Plantae and Animalia. Use knowledge of the key features of the major phyla of animals and plants to recognise a typical member.	Provide a list of about 20 different organisms, including representatives of all five kingdoms, and ask students to classify the organisms into logical categories. Discuss the results. This exercise will show you how much students already know about classification in terms of the five kingdoms.	Prepare a list of suitable organisms from all five kingdoms.	
	Confirm the identity of the five kingdoms: Prokaryotae, Protoctista, Fungi, Plantae and Animalia.		
	Tell students to use their textbooks, the library or the Internet to find out the main distinguishing features of members of the five kingdoms. Discuss students' findings as a class and make sure that everyone has complete and accurate information.	**ICT opportunity:** Use of the Internet.	
	Consolidate students' understanding of the five kingdom system. Arrange a selection of examples of organisms from all of the five kingdoms around the room. Try to find a large number, at least 30, to make the exercise more interesting, challenging and varied. Tell students to identify and write down the kingdom for each specimen and also give one or more reasons to justify their selection. Start individual students at different positions in the room at different specimens to avoid any queuing. Also, get students to draw up a blank table before the start. You could even introduce a time limit of, say, one minute for each specimen. This enables you to regulate the time for this activity and maintain a smoother flow of students around the room.	These examples can take a variety of forms: live specimens, preserved specimens, specimens viewed under the microscope, models, photographs or diagrams.	
	Provide students individually with a set of cards containing the names of the five kingdoms separately mixed up with other cards containing the main distinguishing features of the kingdoms. Then ask them to arrange the cards in their correct matched categories. This activity could also be run as a competition to see which student completes the exercise correctly in the shortest time. The winner will not necessarily be the first student to finish.	Prepare sets of cards containing the names of the five kingdoms separately mixed up with other cards containing the main distinguishing features of the kingdoms.	
	Alternatively, have your own set of 'kingdom cards', mixed face down. Give each student a 'distinguishing feature' card face down. Turn the kingdom card over and call out the kingdom shown. Tell students to turn their cards over and raise their hand if they think they have a distinguishing feature of this kingdom. Confirm correct answers and record a mark for each correct student. Then repeat the process by turning over another kingdom card.		
	Get students to make a wall display to illustrate the different kingdoms, either individually, in pairs or in groups. If carried out in pairs or groups, make each member responsible for one kingdom.		

Objectives	Possible teaching activities	Notes	School resources
2 hours **The major phyla of animals and plants** Use knowledge of the key features of the major phyla of animals and plants to recognise a typical member.	Provide a list of about 20 different animals, including representatives of the major phyla of animals, and ask students to classify the animals into logical categories. Discuss the results. This exercise will show you how much students already know about classification in terms of the main categories (phyla) of animals. Repeat the above exercise with a list of about 20 plants to see how much students already know about the classification of plants. Ask students to use their textbooks, the library or the Internet to find out the main distinguishing features of members of the major phyla of animal and plant kingdoms. Discuss and confirm agreement and accuracy with students as a class activity. Consolidate students' understanding of the major phyla of animals and plants. Arrange a selection of examples of organisms from all of the major phyla of animals and plants around the room. Try to find a large number, at least 30, to make the exercise more interesting, challenging and varied. Tell students, working singly or in pairs, to identify and write down the phylum for each specimen and also give one or more reasons to justify their selection. Use the same techniques as suggested in the activity on kingdoms to make the activity run smoothly.	Prepare lists of suitable animals and plants. **ICT opportunity:** Use of the Internet. These examples can take a variety of forms: live specimens, preserved specimens, specimens viewed under the microscope, models, photographs or diagrams.	
	Provide students individually with a set of cards containing the names of the major phyla separately mixed up with other cards containing the main distinguishing features of these phyla. Then ask them to arrange the cards in their correct matched categories. This activity could also be run as a competition to see which student completes the exercise correctly in the shortest time. The winner will not necessarily be the first student to finish. Alternatively, have your own set of 'major phyla' cards, mixed face down. Give each student a 'distinguishing feature' card face down. Turn the major phyla card over and call out the category shown. Tell students to turn their cards over and raise their hand if they think they have a distinguishing feature of this category. Confirm correct answers and record a mark for each correct student. Then repeat the process by turning over another phylum card.	Prepare sets of cards containing the names of the major phyla separately mixed up with other cards containing the main distinguishing features of the phyla.	
	Get students to make a wall display to illustrate the different major phyla in the animal and plant kingdoms; this can be done individually, in pairs or in groups. If carried out in pairs or groups, make each member responsible for one kingdom or for one phylum if larger groups are involved. Students could make a photographic display to illustrate the different major phyla in the animal and plant kingdoms using the local environment as the source of subjects for study		

Objectives	Possible teaching activities	Notes	School resources
4 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.	
	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 life cycle.	**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 10FB.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.	
	Method of respiration Ask students to research the library or 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.	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.	
	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.	Enquiry skill 11F.4.1	
	Liquid cultures of micro-organisms can be grown in nutrient broth in an assortment of sterile plugged glassware or plastic containers.		
	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 11F.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.	**ICT opportunity:** Use of a computer/datalogger to measure growth of micro-organisms and sensors for light, pH, oxygen, and temperature. Enquiry skills 11F.3.2, 11F.3.3	
	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.		
	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.	**ICT opportunity:** Use of the Internet.	
	Encourage them to produce a flow chart to display the stages in the process of industrial fermentation.		

Assessment

<table>
<tr><th></th><th>Examples of assessment tasks and questions</th><th>Notes</th><th>School resources</th></tr>
<tr><td rowspan="6">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.</td><td>Identify the main distinguishing features of the five kingdoms by drawing up a table with two columns and completing as follows:
<table>
<tr><th>Kingdom</th><th>Distinguishing features</th></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table></td><td>Alternatively, students could be given a prepared table showing the five kingdoms written in and asked to complete the ‘distinguishing features’ column.</td><td></td></tr>
<tr><td>Explain why the horse and the donkey are recognised as species while the mule is not a species.</td><td></td><td></td></tr>
<tr><td>a. Place the following in the correct taxonomic hierarchical order, starting from the largest category:
family order class kingdom species genus
b. In classification, why is a binomial system used together with Latin names?</td><td></td><td></td></tr>
<tr><td>Describe how bacteria are classified according to features such as:
a. shape;
b. nutritional requirements;
c. respiratory demands.</td><td></td><td></td></tr>
<tr><td>a. Draw a diagram of a virus and label it.
b. What are the distinguishing features of viruses?</td><td></td><td></td></tr>
<tr><td>Write a brief account of how micro-organisms are grown in bulk.</td><td></td><td></td></tr>
</table>

GRADE 11F: Biology 6

Ecological relationships and populations

UNIT 11FB.6
10 hours

About this unit

This unit is the sixth of six units on biology for Grade 11 foundation.

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 10F.

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 interactions between organisms can cause changes in the size of populations. 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

10 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS	
4 hours **Interactions between organisms**			11F.13.1	Explain examples of a predator–prey relationship and the possible effects on the population size of both the predator and the prey.		
			11F.13.2	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.		
			11F.13.3	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.
3 hours **Ecosystems are dynamic**	10F.13.1	Describe how the organisms in a pyramid of numbers relate to their biomass and to energy flow through food chains and food webs.	11F.13.4	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.
3 hours **Impact of human activities**	10F.13.2	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.
			11F.13.5	Explain examples of short- and long-term human impact on a variety of environments.		

Activities

Objectives	Possible teaching activities	Notes	School resources
4 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.	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.)	Prepare a suitable graph and OHT.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	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.	**ICT opportunity:** Use of a computer simulation to investigate a dynamic relationship.	
	• 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.	**ICT opportunity:** Use of a spreadsheet to enter data from an investigation.	

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 11F.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.	**ICT opportunity:** Use of the Internet.	
	Get students to produce a flow chart of the events in the fluctuations of lemming populations.		
	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 11F.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
3 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.		
3 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.	A suitable graph can be found in M. Roberts, M. Reiss and G. Monger (1993), *Biology Principles and Processes*, Nelson.	
	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).	**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.	**Field work opportunity:** Sample a river community with appropriate equipment, including nets. Enquiry skill 11F.1.7	
	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.	Enquiry skill 11F.1.8	
	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.		
	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.	Enquiry skill 11F.1.3	
	Encourage students to produce a poster displaying the impact of humans on the environment.	Enquiry skill 11F.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 11F: Chemistry 1

Obtaining chemicals revisited

UNIT 11FC.1
10 hours

About this unit

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

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 activities, look at the scheme of work for Grade 12A.

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 atoms combine in different ways. They should appreciate that these rearrangements can be used to make useful materials.

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.

Students who progress further will know in detail the processes for manufacturing ammonia, nitric acid and sulfuric acid, and the chemistry behind the limestone industry.

Resources

The main resources needed for this unit are:

- video clips of the Haber and contact processess
- demonstration equipment for the synthesis of sulfur trioxide
- fume cupboard
- tin lids, Bunsen burners, limestone or solid calcium carbonate, universal indicator solution
- cement, gravel, sand, small moulds (e.g. yoghurt pots)
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *oxidation*
- *Haber process*, *contact process*
- *lime*, *quicklime*, *slaked lime*

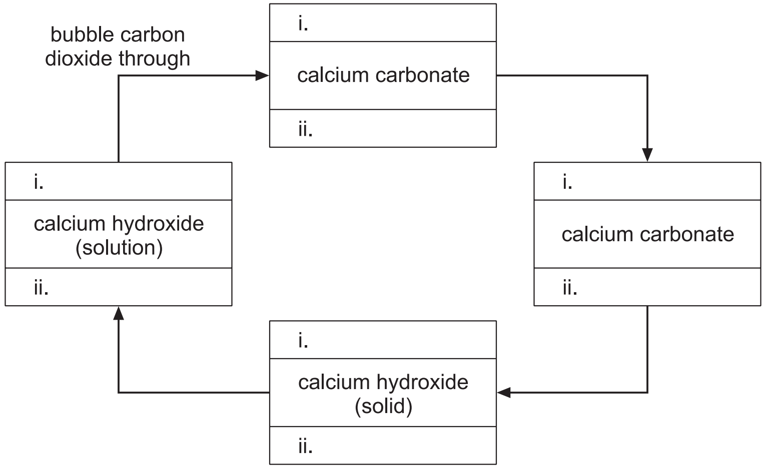
Standards for the unit

10 hours	SUPPORTING STANDARDS	CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS	
4 hours **Haber process and ammonia**		11F.15.1	Know the essential details of the Haber process for making ammonia from nitrogen.		
		11F.15.2	Know the essential details of the commercial oxidation of ammonia to nitric acid and of the main commercial uses of nitric acid.	12F.16.12	Know the main properties and uses of nitrates and understand their environmental impact.
3 hours **Contact process and sulfur**		11F.15.3	Understand the industrial importance of ammonia and nitrogen compounds derived from ammonia and nitric acid.	12F.16.11	Know the test for ammonia, the main properties and uses of its compounds and their reaction with warm alkali.
3 hours **Limestone and cement**		11F.15.4	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.	12F.16.7	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.
		11F.15.5	Know the essential details of the contact process for manufacturing sulfuric acid and understand the industrial importance of sulfuric acid.	12F.16.8	Know the importance of sulfur dioxide in the preparation of sulfuric acid and in food preservation.
		11F.15.6	Know that limestone is a source of many important agricultural and industrial chemicals and describe the conversion of limestone into quicklime and slaked lime.		
		11F.15.7	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.		

Activities

Objectives	Possible teaching activities	Notes	School resources
4 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 Haber process for the manufacture of ammonia from nitrogen. Ask them each 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 11F.1.8, 11F.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 11F.1.8, 11F.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 11F.2.1, 11F.3.4	
3 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 the video 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. Enquiry skills 11F.4.1, 11F.4.2	

Objectives	Possible teaching activities	Notes	School resources
3 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.	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 placed in water. Enquiry skills 11F.4.1, 11F.4.2	
	Ask students individually to research the production of cement and produce an annotated flow chart for the processes involved.	**ICT opportunity:** Use of the Internet.	
	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: cement, gravel, sand, small moulds to set the concrete (e.g. yoghurt pots). Enquiry skills 11F.1.1–11F.1.5, 11F.1.8, 11F.3.1–3.4	

	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 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.*  		

GRADE 11F: Chemistry 2

Metals

UNIT 11FC.2

7 hours

About this unit

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

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 12F and Grades 8 and 10F.

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 wbuilds 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 arrange metals in order of reactivity based on their reactions with air, oxygen, water and dilute acids, and know the products of these reactions. Students should recognise periodicity in the properties of elements and their compounds, with particular reference to 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 know the origins of metallic properties and that metals vary in reactivity in a manner linked to their position in the periodic table. They know how useful properties of metals can be designed into alloys.

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. They understand and explain why alloys are often more rigid and stronger than pure metals.

Resources

The main resources needed for this unit are:

- magnesium ribbon, cobalt glass, Bunsen burners
- samples of transition metal compounds
- class sets of the periodic table
- ball-bearings of two different sizes and colours (approximately 100 × 1.5 cm diameter and 10 × 2 cm diameter)
-

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *oxidation*, *reduction*, *redox*, *electron transfer*, *oxidation number*
- *alloy*

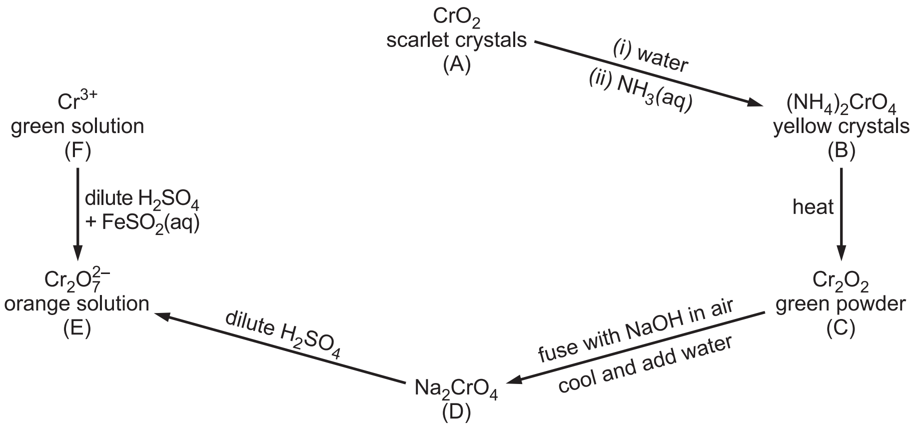
Standards for the unit

Unit 11FC.2

7 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS	
4 hours **Redox**			11F.18.1	Explain oxidation and reduction in terms of gain or loss of oxygen and in terms of electron transfer.		
			11F.18.2	Explain redox reactions in terms of change in oxidation number.		
1 hour **Reactivity and the periodic table**	10F.17.7	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.	11F.18.3	Know that variable oxidation number is an important feature of transition metal chemistry and explain it in terms of the elements' electronic structures.	12F.17.4	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.
2 hours **Alloys**	8.13.1	Deduce a reactivity series for common metals based on their reactions with air, oxygen, water and dilute acids.	11F.16.1	Know that metals can be arranged in order of reactivity according to their reaction with agents such as air, water and acids, and that this order is related to their position in the periodic table.		
			11F.16.2	List a number of alloys, including the common forms of steel, and their uses, and compare their properties with those of the metals from which they are made.		
	8.13.13	Explain the physical properties of metals by the particle theory.	11F.16.3	Explain, in terms of particle theory, why alloys are often much harder and more rigid than the pure metal from which they are predominantly made.		

<table>
<tr><th>Objectives</th><th>Possible teaching activities</th><th>Notes</th><th>School resources</th></tr>
<tr><td rowspan="2">**4 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>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><td></td></tr>
<tr><td>**1 hour**
Reactivity and the periodic table
Know that metals can be arranged in order of reactivity according to their reactions with agents such as air, water and acids, and that this order is related to their position in the periodic table.</td><td>Review the reactivity series of metals with the class. Ask students to colour-code the periodic table, using different colours for different reactivity patterns (e.g. does not react with air).</td><td></td><td></td></tr>
</table>

Objectives	Possible teaching activities	Notes	School resources
2 hours **Alloys** List a number of alloys, including the common forms of steel, and their uses, and compare their properties with those of the metals from which they are made. Explain, in terms of particle theory, why alloys are often much harder and more rigid than the pure metal from which they are predominantly made.	Provide students with a list of uses for different steels and an information sheet on how different elements in steel affect the properties of the steel. Ask students to go through the uses of steel and to decide what the desired properties are for each one. They should then write next to the use which elements need to be present in that steel to enable it to perform. At this stage present students with the specifications for a number of different steels. Then they can match each steel to a composition. This task may be carried out individually or in small discussion groups		
	Do the following demonstration to show why alloys are usually more rigid and harder than the principal metal from which they are made. Place some ball bearings (all the same size) in a clear box. Show how the balls flow easily over each other. Add a few larger ball bearings (painted a different colour) to the box and demonstrate how this interrupts the flow of the ball-bearings. Ask students to relate this to what happens in metals and alloys		

	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**		
	Explain, using diagrams, why the addition of manganese to a steel causes the steel to become harder.		

GRADE 11F: Chemistry 3

Electrochemical cells

UNIT 11FC.3
10 hours

About this unit

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

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. There are no relevant extension or consolidation activities in other grades.

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 have an appreciation of the concept of the mole.

Expectations

By the end of the unit, students understand and use the concepts of redox potential and half-cell potential.

Students who progress further know, understand and use the concepts of redox potential and half-cell potential in a wide range of examples.

Resources

The main resources needed for this unit are:

- 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:

- *cell potential*, *half-cell*
- *standard electrode potential*, *standard cell potential*
- *dry cell*, *accumulator*
- *faraday*

Standards for the unit

Unit 11FC.3

10 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards	EXTENSION STANDARDS
5 hours **Electrochemistry** **3 hours** **Applications of electrochemistry** **2 hour** **Calculations in electrochemistry**		11F.18.4	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.	
		11F.18.5	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.	
		11F.18.6	Know the half-cell reactions of everyday cells, such as the dry cell and the accumulator.	
		11F.18.7	Describe the function of a fuel cell with particular reference to the hydrogen–oxygen cell.	
		11F.18.8	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).	
		11F.18.9	Know and use the concept of the faraday (96 500 coulombs) as a mole of electrons.	

Activities

Objectives	Possible teaching activities	Notes	School resources
5 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.	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.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
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.	Demonstrate how to set up an electrochemical cell using two metal ion/metal half-cells. Explain how to 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 11F.1.1–11F.1.4, 11F.3.1, 11F.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 11F.1.4–11F.1.6, 11F.1.8, 11F.3.1, 11F.3.3	

Objectives	Possible teaching activities	Notes	School resources
	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.	
3 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 11F.2.2, 11F.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	
2 hours **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 11F.3.1–11F.3.3, 11F.4.1, 11F.4.2	

<table>
<tr><th></th><th>Examples of assessment tasks and questions</th><th>Notes</th><th>School resources</th></tr>
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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

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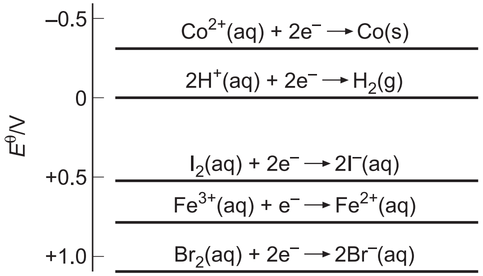

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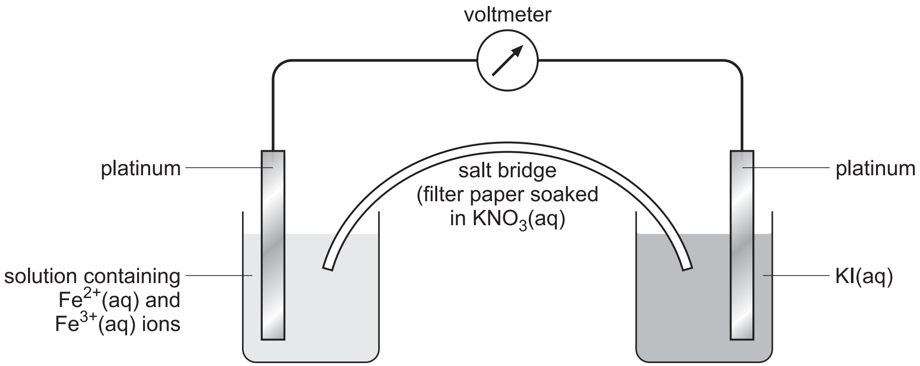
Look at the apparatus in the diagram. When the circuit is complete, a brown colour appears around the platinum in the right-hand beaker.

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.

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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.

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GRADE 11F: Chemistry 4

Reaction rates revisited

UNIT 11FC.4

10 hours

About this unit

This unit is the fourth of six units on chemistry for Grade 10 foundation.

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 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 the difference between endothermic and exothermic reactions and be familiar with the energy profile of a reaction.

Expectations

By the end of the unit, students know that reactions are accompanied by energy changes and that endothermic changes are associated with bond breaking and exothermic ones with bond making. They know and use the concepts of enthalpy of reaction and activation energy.

Students who progress further explain and use the concept of standard enthalpy change (ΔH), with particular reference to combustion, formation, solution and neutralisation, and calculate enthalpy changes from experimental results

Resources

The main resources needed for this unit are:

- anhydrous copper sulfate, anhydrous cobalt chloride
- polystyrene cups, thermometers, anhydrous copper sulfate, citric acid, baking soda (sodium hydrogencarbonate), vinegar, iron filings, barium hydroxide octahydrate, dry ammonium chloride, anhydrous calcium chloride
- 'ball and stick' model kits
- assortment of liquid fuels (e.g. methanol, ethanol, propan-2-ol, butan-1-ol), spirit burners, copper calorimeters, balances, thermometers
- small whiteboards (class set)
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly*:*

- *exothermic*, *endothermic*
- *standard enthalpy change* (ΔH)
- *bond breaking*, *bond formation*

Standards for the unit

10 hours	SUPPORTING STANDARDS	CORE STANDARDS Grade 11 standards	EXTENSION STANDARDS
3 hours **Exothermic and endothermic reactions** **1 hour** **Energy profiles** **3 hours** **Enthalpy changes** **3 hours** **Bond breaking and making**	9.16.1 Know that in some reactions energy is given out and in others it is taken in. 9.16.2 Construct and interpret an energy profile of a reaction.	11F.17.1 Know that chemical reactions are accompanied by energy changes, usually in the form of heat energy, and that the energy changes can be exothermic or endothermic. 11F.17.2 Construct reaction energy profiles showing enthalpy changes in the reaction and activation energy. 11F.17.3 Know that a catalyst can provide an alternative energy profile with a lower activation energy. 11F.17.4 Explain and use the concept of standard enthalpy change (ΔH), with particular reference to combustion, formation, solution and neutralisation, and calculate enthalpy changes from experimental results. 11F.17.5 Recognise that bond breaking is associated with endothermic changes and bond formation is associated with exothermic changes.	

Objectives	Possible teaching activities	Notes	School resources
3 hours **Exothermic and endothermic reactions** Know that chemical reactions are accompanied by energy changes, usually in the form of heat energy, and that the energy changes can be exothermic or endothermic.	Provide each student with a thermometer and prepare a circus of reactions that can take place in insulated vessels (e.g. polystyrene cups). Ask students to carry out the reactions individually and to record any temperature changes that occur as the reactions proceed. Suitable reactions include: • adding water to anhydrous copper sulfate; • mixing citric acid solution with baking soda (sodium hydrogencarbonate); • adding vinegar to iron filings; • mixing barium hydroxide octahydrate crystals with dry ammonium chloride; • adding water to calcium chloride. Ask students to classify their reactions. Discuss with the class the classifications used and focus on classifications to do with changes in temperature. Define *exothermic* and *endothermic* changes. Discuss the idea of *system* and *surroundings*. Ask students, individually, to classify each of the reactions above as endothermic or exothermic		Use this column to note your own school's resources, e.g. textbooks, worksheets.
1 hour **Energy profiles** Construct reaction energy profiles showing enthalpy changes in the reaction and activation energy. Know that a catalyst can provide an alternative energy profile with a lower activation energy.	Introduce the class to energy profile diagrams and, through question and answer, draw a general energy profile diagram for both an exothermic and an endothermic reaction. Introduce the concepts of *activation energy* and *enthalpy change* of reaction (including the sign convention) and label these on the diagrams. Tell students to copy down these profiles and add detail for one of the examples they have carried out in the lab. Use whole class questioning to revise the work done on catalysts in Grade 10. Draw a second energy profile diagram for an exothermic reaction. Tell students to copy this into their books and add a second line to represent the energy profile for the same reaction catalysed.		

Objectives	Possible teaching activities	Notes	School resources
3 hours **Bond breaking and making** Recognise that bond breaking is associated with endothermic changes and bond formation is associated with exothermic changes.	Ask students to discuss in pairs where they think the energy comes from in exothermic reactions and where it goes to in endothermic reactions. Brainstorm ideas as a whole class. Provide students with balanced equations for the complete combustion of methane and methanol, together with ΔH values for both reactions, and ask them to draw energy profile diagrams for each reaction. Ask them to think about why the two reactions have different ΔH values. Draw up the structures of all the reactants and products on the board or OHP. Taking the reactions in turn, ask students, in pairs, to make models of each reactant using 'ball and stick' model kits. Ask students then to convert the reactants into products and note down the number and type of bonds broken and made in each reaction and tabulate their results. Define *bond enthalpy*. Then give students the bond enthalpy values for all the bonds involved and ask them to calculate the ΔH values of the two reactions. Now ask them all to write a short paragraph explaining why the magnitude and sign of ΔH are different in different chemical reactions. Consolidate students' understanding by writing a series of equations for a number of simple reactions on the board or OHP. Provide bond enthalpy diagrams and ask students to list the reactions in order of increasing numerical values of ΔH. Ask them to explain their answers to a fellow student and then check their answers against the correct answers.	Enquiry skill 11F.2.3	
3 hours **Enthalpy changes** Explain and use the concept of standard enthalpy change (ΔH), with particular reference to combustion, formation, solution and neutralisation, and calculate enthalpy changes from experimental results.	Ask students to work in groups of four, using books, the library or the Internet, to research the definitions of ΔH^{θ}_{c}, ΔH^{θ}_{f}, ΔH^{θ}_{soln}, $\Delta H^{\theta}_{neutralisation}$. Then get them to work as a group to produce an effective way of remembering these definitions (e.g. they might produce a play, a game or a song). These can be presented to the whole class. Write a series of reactions on the board or OHP and, as you finish writing each one, ask students to use mini-whiteboards to write which ΔH this equation represents and to hold their answers up for you to see. Ask students to work in pairs to determine the enthalpy of combustion for a number of different alcohols (e.g. methanol, ethanol, propan-2-ol, butan-1-ol) using spirit burners to heat water in a copper calorimeter. Depending on the ability of the students you may wish to carry this out as a practical with instructions or as an investigation. You will need to guide them in the calculations. (e.g. do a worked example for the whole class, which they then use as a model to calculate results using their own data). Encourage students to evaluate the procedure and results in order to make recommendations for improvements.	**ICT opportunity:** Use of the Internet. **Safety:** All the alcohols are highly flammable. Keep lids on the spirit burners when not in use. Methanol is toxic, butan-1-ol is harmful. Enquiry skills 11F.1.1–11F.1.5, 11F.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.	*Draw an energy-level diagram for petrol burning in air. Use this to explain why petrol does not undergo combustion spontaneously at room temperature.*		
	a. *3.57 g of propan-1-ol was burned in a spirit burner and used to heat 200 g of water in a copper calorimeter. The water rose from 23 °C to 45 °C. Calculate the enthalpy change for the combustion of propan-1-ol using this information. (Assume the specific heat capacity for water to be 4.2 J K^{-1} g^{-1})* b. *The standard enthalpy change for the combustion of propan-1-ol is –2021 kJ mol^{-1}.* *How does this compare with the value you calculated in part a? Try to account for any differences in the two values.*		

GRADE 11F: Chemistry 5

An introduction to organic chemistry

UNIT 11FC.5
10 hours

About this unit

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

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 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 and alkenes. 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 will be able to name more complex aryl compounds

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
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *alkanes*, *alkenes*,
- *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*

Standards for the unit

10 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
2 hours **Naming alkanes**			11F.19.1	Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: • alkanes and alkenes; …	
4 hours **Chemistry of alkanes and alkenes**			11F.19.2	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.	11F.19.3	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.	
			11F.19.4	Describe the chemistry of alkenes as the chemistry of the double bond, exemplified by addition and polymerisation.	
2 hours **Isomerism in alkanes and alkenes**			11F.19.5	Illustrate structural and geometric isomerism in alkanes and alkenes.	
			11F.19.6	Describe the stereochemistry of alkanes and alkenes and related molecules.	
			11F.19.7	Know that petroleum and natural gas are sources of organic compounds and describe the processes of catalytic cracking and gas-to-liquid refining.	
2 hours **The origin of organic compounds**	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.	11F.19.8	Know that many organic compounds are made from plant and animal material.	

Objectives	Possible teaching activities	Notes	School resources
2 hours **Naming alkanes** Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: • alkanes …	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.
4 hours **Chemistry of alkanes and alkenes** Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: • … 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.	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 11F.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. 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).	**Safety:** Students must not handle bromine. Use appropriate safety precautions (gloves, goggles, fume cupboard). **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
	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.		
2 hours **Isomerism in alkanes and alkenes** Illustrate structural and geometric isomerism in alkanes and alkenes Describe the stereochemistry of alkanes and alkenes and related molecules	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		
2 hours **The origin of organic compounds** 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.	Ask students to use 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 11F.1.6, 11F.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 11F.1.6, 11F.1.8, 11F.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.	*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**		
	Draw the structural formulae for the following compounds: a. *bicyclobutane;* b. *decane;* c. *methylpropane;* d. *butylcyclopentane.*		
	Write balanced equations for the complete and incomplete combustion of octane.		
	When an alkane is cracked, each molecule forms at least two new molecules. a. *What reaction conditions are needed to cause cracking reactions in alkanes?* b. *Which of the following rules are correct in writing an equation for cracking* i. *There are more total molecules on the reactant side* ii. *There are more total molecules on the product side.* iii. *All the molecules are unsaturated after cracking.* iv. *Some of the molecules are unsaturated after cracking.* v. *Molecules are always smaller after cracking.* c. *Write three different equations for the cracking of heptane.* **From G. Burton, 2000, Salters Advanced Chemistry, *Chemical Ideas*, 2nd edn, Heinemann**		

GRADE 11F: Chemistry 6

Some functional groups

UNIT 11FC.6
10 hours

About this unit

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

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 activities, look at the scheme of work for Grade 12F.

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 halogenoalkanes, alcohols, alcohols, aldhehydes, ketones, carboxylic acids, esters, acyl chlorides, amines and nitriles.

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
- 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
- Internet access

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *halogenoalkanes*, *alcohols*, *aldhehydes*, *ketones*, *carboxylic acids*, *esters*, *acyl chlorides*
- *nucleophiles*, *substitution*, *elimination*, *hydrolysis, dehydration, esterification, condensation*, *oxidation*

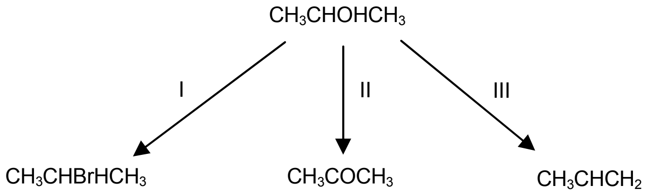
Standards for the unit

10 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
2 hours **Halogenoalkanes** **4 hours** **Alcohol and carbonyl chemistry** **4 hours** **Carboxylic acid and ester chemistry**		11F.19.1	Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: • halogenoalkanes; • alcohols; • aldhehydes and ketones; • carboxylic acids, esters and acyl chlorides; • amines, nitriles, amides and amino acids	12F.18.1	Interpret and use the nomenclature and structural formulae of the following classes of compound: • arenes; • halogenoarenes; • phenols;
		11F.19.9	Describe the chemistry of halogenoalkanes as exemplified by substitution reactions and the elimination of hydrogen halide to form an alkene.		
		11FC19.10	Know some of the important applications of halogenoalkanes.		
		11F.19.11	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.		
		11F.19.12	Classify alcohols as primary, secondary and tertiary, and describe the formation of aldehydes and ketones by oxidation of the corresponding alcohol by acidified dichromate.		
		11F.19.13	Describe the chemistry of the carbonyl group as exemplified by aldehydes and ketones.		
		11F.19.14	Describe the formation of carboxylic acids and their reactions to form esters and salts.		
		11F.19.15	Describe the characteristic structure of esters and know that they can be hydrolysed to the alcohol and acid.		
		11F.19.16	Know the main commercial uses of esters in perfumes and flavourings.		

Objectives	Possible teaching activities	Notes	School resources
2 hours **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 11F.1.6, 11F.1.8	Use this column to note your own school's resources, e.g. textbooks, worksheets
	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.	
4hours **Alcohol and carbonyl 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 • amides and amino acids **[continued]**	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.	**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 11F.4.1	

Objectives	Possible teaching activities	Notes	School resources
[continued] 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.	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.	**ICT opportunity:** Use of the Internet. Enquiry skills 11F.1.6, 11F.1.8, 11F.2.4, 11F.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).	
	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.		

Objectives	Possible teaching activities	Notes	School resources
4 hours **Carboxylic acid and ester chemistry** Know, interpret and use the nomenclature and molecular and structural formulae of the following classes of compound: … • carboxylic acids, esters and acyl chlorides; • … nitriles … 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.	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.	Enquiry skill 11F.4.1	
	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.	**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 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.	Prepare suitable sets of cards.	
	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.	**Safety:** Pentanol is flammable. Glacial ethanoic acid is corrosive.	
	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.	Enquiry skills 11F.3.1–11F.3.3	
	Ask students to use their textbook, the library or the Internet to research the main uses for esters and produce visual representations of usage.	**ICT opportunity:** Use of the Internet. Enquiry skills 11F.1.8, 11F.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.	*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. *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**		
	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**		
	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 11F: Physics 1

Movement and forces

UNIT 11FP.1
15 hours

About this unit

This unit is the first of five units on physics for Grade 11 foundation.

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 12F and Grade 10F.

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, 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

15 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
4 hours **Newton's first and second laws of motion**	10F.22.2	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.	11F.20.1	State Newton's laws of motion and apply them to real situations.	12F.20.1	Define work and apply the concept of work as the product of a force and displacement in the direction of the force.
2 hours **Newton's third law of motion**	10F.22.3	Know that a force acting on an object can cause deformation or velocity change.	11F.20.2	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 $F = ma$.		
3 hours **Momentum**			11F.20.3	Distinguish between inertial and gravitational mass.		
			11F.20.4	Distinguish between mass and weight.		
3 hours **Mass, weight and gravity**			11F.20.5	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.	11F.20.6	Know that the weight of a body may be taken as acting at a single point known as its centre of gravity.		
3 hours **The principle of moments**	10F.22.4	Identify forces acting on a body, determine resultants, resolve forces into components and use the vector triangle to represent forces in equilibrium.	11F.20.7	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.	11F.20.8	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
4 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. 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 11F.1.1, 11F.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 $1\,\text{N} = 1\,\text{kg}\,\text{m}\,\text{s}^{-2}$. 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 10F.21.1.	
2 hours **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!	
3 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.	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 11F.1.1, 11F.1.2 This activity also relates to Standards 10F.21.1 and 10F.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. 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
3 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 and to prepare to present their best idea to the rest of the class. They should use items available in the laboratory to test and demonstrate 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 11F.1.4, 11F.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.		
3 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 11F.1.1–11F.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 11F: Physics 2

Temperature and heat

UNIT 11FP.2
11 hours

About this unit

This unit is the second of five units on physics for Grade 11 foundation.

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 12F and Grade 10F.

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

11 hours	SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS	
2 hours **Temperature**	8.17.1	Know that temperature is a measure of how hot something is and the common unit of temperature is the degree Celsius.	11F.21.1	Define temperature and explain how a temperature scale is constructed. Know how different types of thermometer work and list their advantages and disadvantages.		
5 hours **Heat transfer**			11F.21.2	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.		
4 hours **Heating and cooling**	8.17.3	Know that heat is transferred by conduction, convection and radiation and cite everyday examples of each.	11F.21.3	Know that heat is transferred by conduction, convection and radiation; explain conduction and convection in terms of particle movement.		
	10F.23.1	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.	11F.21.4	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.	11F.21.5	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.	11F.21.6	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.	12F.20.4	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.
	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.				
			11F.21.7	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 11F.4.1, 11F.4.2	

Objectives	Possible teaching activities	Notes	School resources
5 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.	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 11F.1.4, 11F.4.1, 11F.4.2	
	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.	As far as resources and safety permit, allow students a free choice of apparatus and approach. Enquiry skills 11F.1.1–11F.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 11F.1.1, 11F.4.1. 11F.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 11F.1.6, 11F.1.8, 11F.2.2, 11F.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 11F.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 $\mathrm{J\,kg^{-1}\,°C^{-1}}$. Provide plenty of algebraic and numerical examples of calculations involving specific heat capacity.	This also relates to Standard 10F.21.1.	
	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 10F.21.2, 10F.21.3. Enquiry skills 11F.1.1, 11F.1.3, 11F.1.5, 11F.4.1, 11F.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 10F.21.1. **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 10F.21.2, 10F.21.3. Enquiry skills 11F.1.1, 11F.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 $c = 232\ \text{J kg}^{-1}\ {}^\circ\text{C}^{-1}$ *and water has* $c = 4.2 \times 10^3\ \text{J kg}^{-1}\ {}^\circ\text{C}^{-1}$*. By making suitable assumptions, calculate the resulting temperature of the tea.*		
	An electric heater supplies energy at a rate of $2000\ \text{J s}^{-1}$*. 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* $c = 4.2 \times 10^3\ \text{J kg}^{-1}\ {}^\circ\text{C}^{-1}$ *and specific latent heat of vaporisation* $l = 2.3 \times 10^6\ \text{J kg}^{-1}$*.)*		

GRADE 11F: Physics 3

Optics and light

UNIT 11FP.3
11 hours

About this unit

This unit is the third of five units on physics for Grade 11 foundation.

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 8 and Grade 12.

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 light travels in straight lines and be able to draw and interpret diagrams showing reflection, refraction and dispersion of light. They should be able to describe how light is reflected at a surface and understand the difference between reflection by rough and smooth surfaces, know the characteristics of an image formed in a plane mirror, and describe everyday applications of reflection. They should be able to describe how light is refracted at a plane surface and describe everyday applications of refraction, and demonstrate how white light can be split into coloured light by refraction and explain examples of dispersion in everyday life.

Expectations

By the end of the unit, most students know that light travels in straight lines and how it is reflected and refracted; they are aware of some of the applications of these properties. They understand dispersion and recognise some of its natural consequences, and know how the eye receives and focuses light.

Students who progress further know how curved mirrors form an image. They understand refraction in terms of a change in the velocity of light and can explain total internal reflection. They understand the concept of focal length, can show how images are formed by converging and diverging lenses and know how long and short sight can be corrected.

Resources

The main resources needed for this unit are:

- a variety of curved reflectors
- ray boxes
- a variety of converging and diverging lenses, both spherical and cylindrical
- model eye made from large round flask and converging lenses with three different focal lengths
- large model or poster showing the structure of the eye
- camera and other optical instruments that can be dismantled

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *normal (ray)*, *angle of incidence*, *angle of reflection*, *image*, *convex*, *concave*, *converge*, *diverge*, *tangent*, *focus*
- *refraction*, *refractive index*, *angle of refraction*, *critical angle*, *total internal reflection*, *dispersion*
- *lens*, *converging lens*, *diverging lens*, *inverted*, *diminished*, *magnified*, *real image*, *virtual image*, *focal length*
- for more advanced students: *principal axis*, *principal focus*, *linear magnification*

Standards for the unit

Unit 11FP.3

11 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
2 hours **Reflection**	8.18.1	Know that light travels in straight lines ...	11F.22.1	Know that light travels in straight lines and can be reflected by plane surfaces, and explain how images are formed in plane mirrors. Explain common applications of this phenomenon.	12F.21.1	Know what happens to waves when they are reflected and refracted; explain diffraction, superposition and constructive and destructive interference in terms of wave motion.
5 hours **Refraction and dispersion**			11F.22.2	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.	12F.21.2	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.
4 hours **Lenses and the eye**	8.18.3	Represent a ray of light by a line in diagrams showing reflection, refraction and dispersion of light.	11F.22.3	Show how images are formed by converging and diverging lenses and understand the concept of focal length. Explain common applications of these phenomena.		
	8.18.4	Describe how light is reflected at a surface and understand the difference between reflection by rough and smooth surfaces. Know the characteristics of an image formed in a plane mirror. Describe everyday applications of reflection.	11F.22.4	Know and explain some common uses of curved mirrors.		
	8.18.5	Describe how light is refracted at a plane surface and describe everyday applications of refraction.	11F.22.5	Explain total internal reflection and its application in fibre optics.		
	8.18.6	Demonstrate how white light can be split into coloured light by refraction and explain examples of dispersion in everyday life (e.g. oil on water, rainbows).	11F.22.6	Show and explain the dispersion of light.		
			11F.22.7	Explain, in terms of refraction and dispersion, natural phenomena such as rainbows, mirages, the colour of the sky, the colour of sunsets and the difference between real and apparent depth of water.		
			11F.22.8	Know how the eye receives and focuses light and how short and long sight can be corrected.		

Objectives	Possible teaching activities	Notes	School resources
2 hours **Reflection** Know that light travels in straight lines and can be reflected by plane surfaces, and explain how images are formed in plane mirrors. Explain common applications of this phenomenon. Know and explain some common uses of curved mirrors.	**Plane mirrors** In order to review their knowledge and understanding from earlier grades, ask students to work in small groups to plan and present some demonstrations that show some uses of plane mirrors and explain how a plane mirror forms an image. To help students with this activity, introduce (or remind students of) the terms *incident ray*, *reflected ray* and *normal*. Ensure that students know how the angles of incidence and reflection are defined and that they are equal. If possible, arrange for students to present their demonstrations to a younger class (e.g. Grade 8); if this is not possible, then they should present to their own class. As a follow-up, discuss with the whole class the nature of the image formed by a plane mirror. Introduce and explain the term *virtual image*. Show how rays reflected from a plane mirror can be extrapolated in order to deduce the position and size of the image. Allow students to practise drawing, labelling and using ray diagrams for plane mirrors.	Suitable examples for image formation include: • use a ray box to show the paths of incident and reflected rays; • locate the image (e.g. place a small mirror upright on the bench, fix an upright pencil a few centimetres in front of the mirror, then place a second upright pencil behind the mirror and adjust its position so that it appears to coincide with the image of the first pencil); • draw ray diagrams showing the formation of an image. Uses might include: hair-dressing; periscope; kaleidoscope; dentists' mirrors; interior decoration.	Use this column to note your own school's resources, e.g. textbooks, worksheets.
	Curved mirrors Set up a display/circus showing some uses of curved mirrors for reflecting light and other radiation. Include pictures as well as actual mirrors. Include some examples of both convex and concave reflectors. In the latter category include some that converge a parallel beam to a focus (e.g. satellite aerial), and others that produce a parallel beam from a small source (e.g. headlamp reflector). Tell students to visit each exhibit in turn in pairs. Where possible, they should experiment with the relative positions of the reflector and source and explore the effect this has on the reflected radiation and on any image produced. If a visible image is produced, students should note whether it is inverted, and whether it is bigger or smaller than the original object. Then ask students to work in pairs using ray boxes to explore reflection at curved surfaces. Ask them to draw ray diagrams to record their observations. Include both circular and parabolic reflectors. To help students describe their results, introduce the terms *convex*, *concave*, *converge* and *diverge*. Show more advanced students how a curved reflector forms an image. With the aid of a large diagram on the board or OHP, show students how to draw a tangent to a curved surface and then treat the tangent as a plane mirror to deduce the direction of a reflected ray. Introduce the term *focus* for a concave parabolic reflector and establish that an incoming parallel beam converges at the focus, and a point source at the focus gives rise to a parallel beam. Introduce and explain the term *real image* and establish that such an image can be produced by a concave reflector. Show how ray diagrams can be used to deduce the position, size and nature of real and virtual images formed by convex and concave reflectors. Ask students to draw several examples of ray diagrams showing reflection at curved surfaces.	Suitable examples include: • car headlamp plus reflector; • car wing mirror; • shaving/make-up mirror; • satellite TV aerial; • radio telescope; • solar furnace; • reflecting optical telescope. Enquiry skills 11F.4.1, 11F.4.2	

Objectives	Possible teaching activities	Notes	School resources
5 hours **Refraction and dispersion** 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. Explain total internal reflection and its application in fibre optics. Show and explain the dispersion of light. Explain, in terms of refraction and dispersion, natural phenomena such as rainbows, mirages, the colour of the sky, the colour of sunsets and the difference between real and apparent depth of water.	**Refraction** Remind students of their work on refraction in earlier grades by using a ray box to demonstrate the refraction of a light ray by a glass block. Introduce and define the term *angle of refraction.* With the aid of large clear diagrams on the board or OHP, explain refraction as a consequence of a change in the speed of light. Define *refractive index* in terms of a ratio of speeds. Relate the change of speed to the angles of incidence and refraction and hence explain the geometry of refraction and introduce Snell's law. Ask students to work in pairs to determine refractive index using a glass block and a ray box. Tell them to draw ray diagrams to record their measurements. Set students a challenge: working in small groups, they should devise a method to determine the refractive index of water. Discuss their suggestions and ensure that any safety hazards (such as water coming into direct contact with electrical equipment) are avoided. Then give students access to suitable apparatus to carry out their proposed measurements. Provide plenty of examples that allow students to practise drawing labelled ray diagrams showing refraction, and examples of calculations using refractive index.	**Mathematics:** A knowledge of the trigonometry of right-angled triangles is required. In order to help explain refractive index and the geometry of refraction in terms of a change in speed, it might be useful to bring forward some work from Grade 12. See Unit 12FP.2. **Safety:** Avoid direct contact between water and electrical equipment unless suitably insulated. Enquiry skills 11F.1.1, 11F.1.3, 11F.1.5, 11F.3.1, 11F.3.2, 11F.4.1, 11F.4.2	
	Total internal reflection Give each pair of students a semi-circular glass block and a ray box. Demonstrate how to direct a single ray through the curved surface towards the centre of curvature so that the angles of incidence and refraction at the straight surface are both 0° and the ray emerges with no change of direction. Then ask students to use their own apparatus to explore what happens as the block is gradually rotated about the centre of curvature. Tell them to draw ray diagrams to record their observations. Discuss students' observations with the whole class and establish that: • regardless of the angles, some light is always internally reflected at the straight surface; • when the angle of incidence at the straight surface exceeds a certain critical value, no light emerges and there is total internal reflection; • the angles of incidence and reflection at the straight surface are always equal (i.e. the surface acts as a plane mirror). Ask more advanced students to suggest how critical angle is related to refractive index, then use diagrams on the board or OHP to explain the relationship.	Enquiry skill 11F.4.2	
	Either set up a circus of activities involving total internal reflection and arrange for pairs of students to visit each in turn, or perform a series of demonstrations to the whole class. Suitable examples include the following. • Arrange a line of rectangular glass blocks end to end so that a single ray from a ray box undergoes several total internal reflections before emerging. • Attach a rubber tube to a tap. Hold a torch so that its beam shines along the stream of water emerging from the tube. Move the tube so that the stream of water curves and observe that the light beam follows the curve. • Display a decorative fibre-optic lamp. • Use a piece of fibre-optic cable to direct the beam from a torch.		

Objectives	Possible teaching activities	Notes	School resources
	• Set up a transparent-sided tank containing water to which a few drops of milk have been added. Shine a laser beam through the end of the tank so that it is totally internally reflected at the water–air interface. (The slightly cloudy water enables the beam to be seen.)	**Safety:** When using a laser, ensure that it cannot shine into anyone's eyes.	
	Encourage students to use the Internet and library resources to research uses of fibre optics in telecommunications, medicine and engineering. Ask each pair of students to produce a colourful and informative poster for display in the classroom. They should include references to the sources they consulted.	**ICT opportunity:** Use of the Internet. Enquiry skills 11F.1.6, 11F.1.8	
	Prisms		
	In a darkened room, demonstrate light passing through a glass prism to form a spectrum projected onto a screen. Review students' work from earlier grades by suitable questioning, and hence establish that white light is composed of many colours. Introduce the term *dispersion*.	Shine a beam of light from a slide projector through a narrow slit. Adjust the orientation of the prism so as to achieve maximum dispersion.	
	Ask students, in pairs, to use ray boxes to trace the path of a single ray through a prism and observe dispersion. Encourage them to experiment with the prism in various orientations, some of which will produce total internal reflection. Then they should aim to make the ray pass through *without* being totally internally reflected. Tell them to draw ray diagrams to record their observations and to note the relative amounts of refraction experienced by red and blue light. Discuss students' observations with the whole class. By suitable questioning, establish that blue light undergoes a greater speed change on refraction than red light, and hence a greater change of direction.	Enquiry skill 11F.4.2	
	Demonstrate a water prism made from a mirror immersed at an angle in a bowl of water. Use light from the Sun and adjust the position of the mirror so that the spectrum is projected onto a screen or wall. Ask students, in pairs or small groups, to set up the same demonstration themselves. As a challenge, ask them to draw a ray diagram for the demonstration. Then discuss their suggestions with the whole class before showing on the board or OHP how it can be drawn. Provide students with several examples that allow them to practise drawing ray diagrams showing refraction and dispersion.	**Safety:** Ensure that students do not look at the Sun nor at its reflection in a mirror. For maximum dispersion, the beam of light within the water should meet the mirror at an angle of incidence close to 0°. Enquiry skills 11F.4.1, 11F.4.2	
	Refraction and dispersion		
	Divide the class into small groups and give each a briefing sheet describing one example of refraction and/or dispersion. Suitable examples include: • the 'appearing coin' trick; • the 'bending' of a stick in water; • the difference between real and apparent depth; • formation of a mirage; • the colour of the sky and sunsets; • formation of a rainbow. Ask each group to prepare a demonstration, which they should then perform and explain to the rest of the class. Allow access to suitable apparatus and encourage students to use PowerPoint, OHP slides and posters as visual aids.	Prepare student briefing sheets in advance. Some examples are more straightforward than others; match the tasks to students' abilities. The mechanism underlying the dispersion that causes the sky to appear blue and the setting Sun to appear red is *not* refraction. It is the 'Rayleigh scattering' of light by small dust particles and water droplets in the atmosphere: blue light is scattered more than red. Though not a requirement, it might be helpful to discuss this. **ICT opportunity:** Use of PowerPoint. Enquiry skills 11F.1.4, 11F.3.4	

Objectives	Possible teaching activities	Notes	School resources
4 hours **Lenses and the eye** Show how images are formed by converging and diverging lenses and understand the concept of focal length. Explain common applications of these phenomena. Know how the eye receives and focuses light and how short and long sight can be corrected.	**Lenses and images** Provide students with a variety of (spherical) converging and diverging lenses. Tell them to take each lens in turn and observe the effects of looking through the lens at nearby and distant objects, with the lens held close to the eye and at arm's length. Tell them to explore what happens if light from a widow shines through the lens onto a sheet of white paper. Ask them to make brief notes to record their observations, using appropriate terms such as *real image*, *virtual image*, *inverted*, *upright*, *magnified* and *diminished*. Check that students are using these terms correctly and that they know how to use a converging lens to project a real image of a distant object onto a screen. Then ask students, in pairs, to use ray boxes to explore the passage of light through a variety of (cylindrical) converging and diverging lenses. Tell them to draw ray diagrams to record their observations. Discuss students' observations with the whole class. By means of suitable questioning and with the aid of diagrams on the board or OHP, draw out the connections between the three parts of this activity. Establish that a real image is produced when rays from a (point) source meet and therefore a diverging lens cannot on its own produce a real image. Discuss the formation of a virtual image and establish that a diverging lens on its own produces such an image, as does a converging lens when it is close to an object.	Enquiry skills 11F.4.1, 11F.4.2	
	Focal length Introduce the term *focal length* and explain, with the aid of a large diagram on the board or OHP, how it is defined for both a converging and a diverging lens. Establish, by means of a diagram and suitable questioning, that when light from a very distant object enters a lens, rays from a single point on the object are approximately parallel. Hence establish that when a lens forms an image of a distant object, the lens–image distance is close to focal length. Ask students to work in pairs using ray boxes to produce parallel sets of rays and hence determine the focal length of some converging and diverging cylindrical lenses. They should also determine the focal length of a spherical converging lens by forming a real image of a distant object. Students should note, qualitatively, the relationship between the focal length and the curvature of a lens: a highly curved lens has a short focal length.	Enquiry skills 11F.4.1, 11F.4.2 Though not a requirement, it is helpful to introduce the concept of the 'power' of a lens and establish that a low-power lens has a long focal length and vice versa.	
	Objects and images Let students download and use Java applets that illustrate how the location, nature and size of an image depends on the position of the object and on the focal length of a lens. Tell them to change one variable at a time and to make brief notes to record their findings (e.g. 'as a converging lens is brought closer to a distant object, the image moves away from the lens and becomes ...'). Use large clear diagrams on the board or OHP to show more advanced students how to construct an accurate ray diagram to determine the location, nature and size of an image formed by a lens. Introduce and define the terms *principal axis*, *principal focus* and *linear magnification*. Show that the linear magnification is equal to the ratio of image distance to object distance. Provide more advanced students with several examples that allow them to practise drawing and interpreting ray diagrams involving single lenses.	**ICT opportunity:** Use of the Internet and Java applets. Enquiry skill 11F.1.3	

Objectives	Possible teaching activities	Notes	School resources
	The eye		
	With the aid of an anatomical model or large diagram showing the structure of the eye, explain to students the function of the various parts and how the eye forms an image. Give students a handout containing an unlabelled diagram of the eye and ask them to add labels and notes.	Prepare student handouts in advance.	
	Encourage students to use the Internet to research some historical theories of vision. Give each pair or small group the name of one person whose thinking and/or experimentation contributed to our understanding of vision (e.g. Euclid, Galen, A-Kindi, Al-Hazen, Kepler, Bacon). Ask each pair or group to produce a single sheet of paper in the form of a CV for their subject (i.e. it should state the person's name, their dates of birth and death, where they lived and worked, and a brief summary of their work). Photocopy these and distribute them to the rest of the class.	**ICT opportunity:** Use of the Internet. Enquiry skills 11F.1.8, 11F.2.1, 11F.2.3, 11F.3.4	
	Refer to the models and diagrams used earlier and explain how the eye lens can be adjusted to vary its curvature and hence its focal length. By means of suitable questioning, establish that the closer the object, the stronger the lens (i.e. the shorter the focal length) required to produce a clear image on the retina.		
	Define *near point* and *far point*. Then ask students to determine the approximate positions of their own individual near and far points. If students wear spectacles or contact lenses, they could compare their measurements made with and without these aids.		
	Use a model eye made from a large round flask to demonstrate and explain *long sight* and *short sight* and how they can be corrected using spectacle lenses. Ask students to draw labelled ray diagrams to show how long and short sight arise and how the conditions can be corrected using spectacle lenses.	The flask should contain coloured water in order to show the path of a light beam passing through it. Attach three converging lenses, of different power, to the side of the flask. One lens should be chosen so that it brings a parallel beam of light to a focus on the far side of the flask ('normal vision'). One of the other lenses should have a shorter focal length ('short sight'), and the other a longer focal length ('long sight').	
	Optical instruments		
	Set up a circus of optical instruments. If possible, some of these should be dismantled so that their optical systems are visible while others should be intact and useable. Ask students to explore each in turn and make brief notes on their operation and construction. Encourage more advanced students to draw ray diagrams for the instruments. More advanced students should discuss chromatic aberration and its correction. Shine a broad beam of light (e.g. from a slide projector) onto a screen through a large highly curved converging lens to show students the effect. By suitable questioning, establish that, as when passing through a prism, different colours of light passing through the lens are refracted by different amounts and hence experience dispersion. Students might be able to suggest one way that chromatic aberration can be reduced: mask the edges of the lens so that only the central part is used – light passing through this part undergoes less deviation and hence less dispersion than light passing close to the edges. Discuss the advantages and disadvantages of this approach: it is simple but reduces the brightness of the image. Explain the principle of achromatic compound lenses and point out examples of instruments, such as binoculars, where they are commonly used.	Suitable instruments include: • simple camera; • SLR camera; • binoculars; • microscope.	

Objectives	Possible teaching activities	Notes	School resources
	Prepare and distribute a briefing sheet that explains how to make an optical system for an astronomical telescope and guides students through the following steps:	Prepare student briefing sheet in advance.	
	• Use a weak (long-focal-length) converging lens to make a real image of a distant object.		
	• Project the image onto a translucent screen.	For the translucent screen, use tracing paper.	
	• Place a strong converging lens to give a magnified view of the image.	Enquiry skills 11F.4.1, 11F.4.2	
	• Remove the translucent screen.		
	Ask students to work in pairs to assemble the system as described.		
	Ask more advanced students to devise and carry out a measurement of the linear magnification of their telescope and to draw a ray diagram showing the formation of the intermediate and final images.	Enquiry skill 11F.1.1	

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.	*Write a short magazine article on* ***curved mirrors****. Use diagrams to explain how curved mirrors reflect light, and include at least two different examples of curved mirrors in use.*		
	Draw a clear labelled diagram to show the path of a light ray through a rectangular glass block. Label the angles of incidence and refraction at each surface.		
	Write brief definitions of the terms ***refraction*** *and* ***dispersion*** *suitable for a scientific dictionary. Illustrate your definitions with a clear labelled diagram showing how a prism disperses white light.*		
	Explain what is meant by a ***real image****. Use a converging lens to produce a real image and hence estimate the focal length of the lens.*	Provide a spherical converging lens, a means of measuring distance and a screen (or sheet of white paper).	
	An object 2 cm high is placed on the principal axis of a converging lens of focal length 20 cm. The distance between object and lens is 30 cm. By drawing an accurate ray diagram, find the linear magnification of the image and its distance from the lens. State whether the image is upright or inverted, and whether it is real or virtual.		
	Make a leaflet explaining how long and short sight are caused and how they can be corrected. The leaflet should include diagrams. It should be suitable for people visiting an optician, and should be made from a single sheet of A4 paper.		

GRADE 11F: Physics 4

Current electricity

UNIT 11FP.4
10 hours

About this unit

This unit is the fourth of five units on physics for Grade 11 foundation.

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 © Education Institute 2005. For consolidation and extension activities, look at the scheme of work for Grade 10F and Grade 12F.

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 the concept of electrical potential difference between two points on a circuit and know how it is measured. They should know that electrical components have resistance, which is measured in ohms, and that the resistance of a wire depends on its diameter, length and the material from which it is made

Expectations

By the end of the unit, students know that an electric current is a stream of charged particles and solve problems related to current and potential difference.

Students who progress further understand and use the concept of resistivity. They distinguish between electromotive force and potential difference and understand the concept of internal resistance.

Resources

The main resources needed for this unit are:

- ping-pong ball coated with conductive paint
- EHT supply
- pair of metal plates (e.g. 20 cm × 20 cm)
- electrical appliances labelled with their power ratings
- leaflets giving information about power ratings of electrical appliances
- bill(s) from electricity company showing energy usage in kW h and the cost per unit
- conductive putty

Key vocabulary and technical terms

Students should understand, use and spell correctly:

- *electric current*, *charge*, *ammeter*, *coulomb*
- *potential difference*, *volt*, *voltmeter*
- *power*, *watt*
- *resistance*, *ohm*, *ohmic*, *non-ohmic*, *series*, *parallel*, *resistivity*
- *electromotive force* (*e.m.f.*), *terminal potential difference*, *internal resistance*, *short circuit*, *open circuit*

Standards for the unit

10 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards		EXTENSION STANDARDS
4 hours **Electric current and potential difference**	10F.25.1	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.	11F.23.1	Know that electric current is the rate of flow of charged particles, define charge and the coulomb, and solve problems using the relationship $Q = It$.		
4 hours **Resistance**	9.21.1	Understand the concept of electrical potential difference between two points on a circuit and know that it is measured in volts using a voltmeter.	11F.23.2	Define potential difference and the volt. Solve problems using the relationships $V = W/Q$, $P = VI$, $P = I^2R$.	12F.20.5	Define power as the rate of doing work or converting energy and solve problems using $P = W/t$.
2 hours **Power supplies**					12F.22.7	Describe the action of a transformer and explain its importance in the long-distance transmission of electricity ...
	9.21.5	Know that electrical components have resistance that impedes the flow of electricity through them and that this is measured in ohms.	11F.23.3	Define resistance and solve problems using the relationships $V = IR$ and $R = \rho l/A$ for multiple resistances connected in series and in parallel.	11F.24.2	Explain the variation in resistance shown by devices such as the potentiometer ... 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.				
	9.21.3	Recognise that the potential difference across a component is a measure of the energy carried by the current and transferred by the component ...	11F.23.4	Distinguish between electromotive force and potential difference and understand the concept of internal cell resistance.	12F.22.1	Describe the production of an induced e.m.f. ...

Objectives	Possible teaching activities	Notes	School resources
4 hours **Electric current and potential difference** Know that electric current is the rate of flow of charged particles, define charge and the coulomb, and solve problems using the relationship $Q = It$. Define potential difference and the volt. Solve problems using the relationships $V = W/Q$, $P = VI$	**Current and charge** Set up a circus of demonstrations showing the movement of *charge*. Tell students, in pairs, to visit each demonstration in turn and answer the following questions: • How is the motion of charge detected? • How is the charge made to move? • What are the moving charged particles? Also tell them to record any ammeter readings. Discuss students' observations with the whole class and, by suitable questioning, establish the following points. • Movement of charge can sometimes be seen (e.g. movement of coloured ions; sparks) and/or heard (e.g. the 'crack' accompanying a spark), or deduced by some other effect (e.g. the deposit of copper on a cathode; the glow on a phosphorescent screen). • Charge is made to move by forces of electrostatic attraction and repulsion. Point out that a DC power supply has a positive and a negative terminal. You might also want to point out that a power supply imparts energy to mobile charges. • Continuous flow of charge (e.g. in the shuttling ball demonstration) constitutes an electric current, which can be detected with an ammeter. • Current can involve a flow of positive and/or negative charge (e.g. ions, electrons). Tell or remind students that in metals the mobile charges are electrons (which have negative charge). Also establish that the direction of current is conventionally defined to be that in which *positive* charge would flow, regardless of the signs of any actual moving charges. Establish, by suitable discussion, that *electric current* can be measured as the rate of flow of charge past a point. Introduce, or remind students of, the SI unit of charge, the *coulomb* (C), and the relationship $I = Q/t$, which relates current I to the charge Q flowing past a given point in a time interval t. Remind students of the SI unit of current, the ampere (A). Provide plenty of algebraic and numerical examples that allow students to practise using the relationship between charge, current and time. Include references to the ammeter readings that students have recorded in the circus of demonstrations.	Suitable demonstrations include: • shuttling ping-pong ball (connect a sensitive galvanometer in series) (see Unit 10FP.5 for notes); • conduction by coloured ions (see Unit 10FP.5 for notes); • piezo-electric gas lighter; • Van de Graaff generator producing sparks; • electrolysis of copper sulfate solution (connect an ammeter in series); • rub a polythene rod with a dry cloth and use the rod to attract small pieces of paper; • Maltese cross tube. **Safety:** When using an EHT supply, ensure that the safety resistor is included in the circuit and that nobody comes into electrical contact with the terminals.	Use this column to note your own school's resources, e.g. textbooks, worksheets.

Objectives	Possible teaching activities	Notes	School resources
	Current in circuits Prepare a handout containing diagrams of several simple circuits accompanied by questions asking students to predict and explain what will happen when each circuit is assembled. When students have worked individually or in pairs to answer the questions, demonstrate the circuits to the whole class. (It is unlikely that all students will have predicted all outcomes correctly.) Establish first that current is the same all around a series circuit and that currents combine algebraically at branching points. Emphasise that this conservation of current reflects the conservation of charge at all points in a circuit. Discuss with students any models or analogies that they might have used in earlier grades to aid their understanding of electric circuits. Such models generally fall into two categories. • *Carrier model*. For example, trucks or runners (charge) circulate round a road or track (circuit) collecting objects (energy) from a source (power supply) for delivery to a destination (lamps or other devices). • *Driver model*. For example, a cyclist or a pump (power supply) moves a chain or pumps water (current) around a closed loop (circuit) doing work on a bicycle wheel or turbine (lamps or other devices), hence energy is transferred. Ask students to say how well, or badly, such models help to explain and predict what happens first in a simple circuit with one bulb connected to a power supply, then in the slightly more complex circuits described on the right. Bring out the point that a carrier model works well for modelling the conservation of current, but a driver model is much more satisfactory for modelling the transfer of energy in a circuit. A picture based on a driver model accounts for the 'instant' transfer of energy between power supply and load, and raises no awkward questions about how each carrier 'knows' how much energy to deposit at each point on its journey around the circuit.	Suitable circuits include the following. • Two identical lamps in series with a power supply. (Which is brighter? Why?) • A series circuit containing identical lamps and two or more ammeters. (Predict the relative readings of the ammeters.) • Two identical lamps in parallel with a power supply. (Which is brighter? Why? What happens if one lamp is disconnected?) • Two identical lamps in parallel with a power supply. One ammeter in each branch of the circuit and one in the unbranched section. (Predict the relative readings of the ammeters. Predict what will happen if one branch of the circuit is broken.) When demonstrating the circuits, ensure that the lamps really are identical, and that their resistance is much greater than the internal resistance of the power supply. Use ammeters with very low resistance and try to ensure that all meters are identically calibrated. Enquiry skill 11F.1.2	
	Potential difference and energy Continue the discussion from the previous activity, focusing attention on the transfer of energy in a circuit. By suitable questioning, establish how much students recall and understand about *potential difference* from their work in earlier grades. Remind, or tell, students that potential difference (pd) between two points in a circuit is the energy transferred by each coulomb moving between those points, i.e. $V = W/Q$, where V is the potential difference and W the total energy transferred between those two points. Discuss the SI unit of pd (the volt, V) and establish that $1\ \text{V} = 1\ \text{J C}^{-1}$. If students have not had much experience using voltmeters, demonstrate how such a meter should be connected in parallel with the rest of the circuit. Then get students to work in pairs to set up some simple electric circuits and use voltmeters to measure the pd across the various devices. Include the circuits described in the previous activity. Discuss students' results and establish that the sum of pds across all the devices is equal to the terminal pd of the power supply, and that the pds across two of more parallel branches are always the same regardless of the devices connected. Explain that these observations reflect the conservation of energy: around any loop of a circuit, the energy transferred from the power supply to devices in the circuit is equal to the energy transferred from the devices to the surroundings.	This activity also relates to Standard 10F.21.1.	

Objectives	Possible teaching activities	Notes	School resources
	Power, current and potential difference Set up a display of electrical appliances labelled with their power ratings and leaflets giving information about power ratings of electrical appliances. Tell students to visit each exhibit in turn and note any information about current, voltage and power, and the units used. Show on the board or OHP how the relationships $Q = It$ and $V = W/Q$ can be combined to eliminate Q, hence $P = VI$, where P is the *power* (i.e. the rate of energy transfer). Discuss the SI unit of power and show that $1\,\text{W} = 1\,\text{J}\,\text{s}^{-1}$. Point out that some appliances are labelled with power ratings in equivalent units, such as kV A.		
	Hand out copies of an electricity bill and point out that the 'unit' used for charging is the kW h. Explain that the unit measures power × time, so it is a unit of energy. Ask students to calculate the number of joules transferred by a 1 kW appliance operating continuously for 1 hour.		
	Ask students, working in pairs or small groups, to measure the electrical power input to one or more devices. Ideally, they should use a joulemeter for one measurement and a combination of voltmeter and ammeter for another.	Enquiry skill 11F.4.1	
	Provide plenty of algebraic and numerical examples that allow students to practise using the relationships between charge, energy, current, potential difference, power and time. Some examples should use data relating to the exhibition of appliances.		
4 hours **Resistance** Define resistance and solve problems using the relationships $V = IR$ and $R = \rho l / A$ for multiple resistances connected in series and in parallel. Solve problems using the relationship... $P = I^2R$.	**Current, potential difference and resistance** By means of some quick-fire questions, remind students of their work on resistance from earlier grades. Establish the following points: • Electrical components have resistance that impedes the flow of current through them. Students might consider how resistance is modelled in a 'driver' model of a circuit as outlined above. • Resistance R is defined as $R = V/I$. Emphasise that this relationship is *not* 'Ohm's law'. • The SI unit of resistance is the ohm (Ω), and $1\,\Omega = 1\,\text{V}\,\text{A}^{-1}$.	Include a resistor made from an alloy such as constantan, whose resistivity does not change with temperature. Suitable non-ohmic conductors include a thermistor and a filament lamp. **Mathematics:** Plotting and interpreting straight-line graphs.	
	Ask students, in pairs, to investigate the relationship between current and pd for a variety of ohmic and non-ohmic conductors. Tell them to plot graphs of pd against current and to carry out two calculations of the resistance of each conductor: one at high current and one at low current.	Enquiry skills 11F.1.1, 11F.1.3, 11F.4.1, 11F.4.2	
	Discuss students' results with the whole class. Point out that the resistance of so-called *ohmic* conductors remains constant over a wide range of currents and voltages (i.e. current is directly proportional to pd as described by Ohm's law): their graphs of current against pd are always straight lines through the origin. *Non-ohmic* conductors do not obey Ohm's law: their resistance varies with voltage and their graphs of current against pd are curved lines.	This discussion also relates to Standard 10F.21.3.	
	Revisit the previous discussion of electrical power and ask students to derive expressions for electrical power, P, in terms of I and R, and in terms of V and R.		
	Provide plenty of numerical and algebraic examples that allow students to practise using relationships between current, pd, resistance and power. Point out that, while in practice many conductors are non-ohmic, it is usual to assume ohmic behaviour when solving theoretical circuit problems.		

Objectives	Possible teaching activities	Notes	School resources
	Resistors Divide the class into pairs and give each pair a light-sensitive or temperature-sensitive resistor. Tell students their task is to investigate, as quantitatively as possible, how the resistance depends on light or temperature. Encourage them to use their ingenuity in devising ways to vary and monitor light intensity or temperature. They should have access to suitable apparatus on request (e.g. power supplies, meters, lamps, thermometers). Ideally, use several different types of resistor so that there is little duplication among the class. Ask each pair to prepare an OHP transparency summarising their method and results so that these can be presented to the rest of the class, photocopied and distributed.	Enquiry skills 11F.1.1, 11F.1.3, 11F.1.4, 11F.3.1, 11F.3.2, 11F.3.4, 11F.4.1	
	Combining resistors Show the class a selection of commercially available resistors and/or pages from a catalogue issued by an electronics supply company. Point out that resistors are mass produced with only a limited number of different values. Explain that although these might not always be the most appropriate for use in particular applications, other values can be produced by combining two or more resistors in various ways. On the board or OHP, show students how resistors can be combined in *series*. Referring to previous activities and discussions, talk through the following steps: 1 The current is the same in all resistors. 2 The pd across the combination is the sum of the pds across the individual resistors. 3 The combination of resistors can be replaced by a single resistor $R = R_1 + R_2 + ...$ without changing either the current or the pd. Similarly, show how resistors can be combined in *parallel*: 1 The pd across each resistor is the same. 2 The current entering and leaving the combination is the sum of currents in the individual resistors. 3 Replacing the combination with a single resistor such that $1/R = 1/R_1 + 1/R_2 + ...$ does not alter the current or pd. Work through some numerical examples on the board or OHP. Emphasise that, when resistors are combined in parallel, the net resistance is always less than that of any of the individual resistors.	**Mathematics:** Use of reciprocals.	
	Ask students, in pairs or individually, to use a circuit simulation software package to measure the resistances of various series and parallel combinations of resistors. In each case, they should verify that the results are in accordance with their calculations. Provide several numerical and algebraic examples to give students practice calculating combinations of resistors. Include some that involve both series and parallel combinations within the same circuit.	**ICT opportunity:** Use of circuit simulation software.	

Objectives	Possible teaching activities	Notes	School resources
	Resistivity Divide the class into pairs or small groups and provide them with samples of conducting putty, batteries, meters and connectors. Explain that their task is to review work on resistance from earlier grades, and to prepare a simple demonstration to show how the resistance of a conductor depends on its length and cross-sectional area. Tell them to write an instruction sheet for their demonstrations, explaining clearly what measurements to make and how to present them in order to show the relevant information. The instructions should be written for use by a Grade 9 student. If possible, the sheets should then be passed on to Grade 9 classes for use in their lessons. Introduce the concept of *resistivity* ρ as the constant of proportionality in the relationship between resistance, length and cross-sectional area. Ask students to use the relationship $R = \rho l / A$ to deduce the SI units of resistivity. Remind students of Grade 10 work when they considered conductivity, and tell them that conductivity $\sigma = 1/\rho$.	This activity also relates to Standard 10F.21.1. Enquiry skills 11F.1.3, 11F.3.4, 11F.4.1, 11F.4.2	
	Ask students to work in pairs to determine the resistivity of the conductive putty used earlier and of a metal. Give them access to, and if necessary training in the use of, appropriate measuring instruments (e.g. a micrometer) and ask them to consider the precision and accuracy of their measurements and their final result. Tell them to produce a brief written report describing their method, stating their results and suggesting how precision and accuracy might be improved. Provide plenty of algebraic and numerical examples that allow students to practise using the relationship between resistance, length, area and resistivity.	This activity also relates to Standard 10F.21.2. Enquiry skills 11F.1.1, 11F.1.3, 11F.1.5, 11F.3.1–11F.3.3, 11F.4.1, 11F.4.2	
2 hours **Power supplies** Distinguish between electromotive force and potential difference and understand the concept of internal cell resistance.	**Internal resistance** Perform the following demonstrations to illustrate the effects of internal resistance. • Use an EHT supply with an internal safety resistor. Set the supply to a few kilovolts. Ask students to predict what will happen if a milliammeter is connected between the terminals (they will almost certainly predict a huge current that will burn out the meter). Demonstrate what really happens: there is a current of just a few milliamps. • Connect a voltmeter to the terminals of a dry cell. Ask students to predict what will happen to the voltmeter reading if a torch bulb is connected, then show what happens (the meter reading falls). Then connect an identical bulb in parallel: the bulbs glow less brightly and the meter reading falls further. Using clear diagrams on the board or OHP, explain that any real power supply has some *internal resistance* and show how this can account for the observations. Introduce the terms *terminal potential difference* and *electromotive force* (*e.m.f.*) and explain that both are ‘voltages’ (i.e. a measure of energy transferred to, or by, charge). Show the derivations of relationships between current I, terminal pd V, e.m.f. $\mathcal{E}$, internal resistance r and external resistance R (e.g. $\mathcal{E} = I(R + r) = V + Ir$).	This activity also relates to Standard 10F.21.3.	

Objectives	Possible teaching activities	Notes	School resources
	Introduce the terms *open circuit* and *short circuit*. Show by algebraic and numerical examples that on open circuit the terminal pd is equal to the e.m.f., and a short circuit produces a current $I = \mathcal{E}/r$. Discuss some real-life examples, in addition to those demonstrated earlier, where internal resistance has a noticeable effect (e.g. the dimming of car headlamps when the starter motor is used: connecting a low resistance to the car battery causes a drop in the terminal pd). Emphasise that the simple picture discussed earlier in this unit (where adding components in parallel with a power supply does not affect the terminal pd) is not incorrect, but does assume an ‘ideal’ power supply (i.e. one with no internal resistance). In practice, a power supply connected to a resistance much greater than its internal resistance behaves like an ideal supply, and in theoretical circuit problems there is often an implicit assumption that any internal resistance can be ignored. Ask students to work in pairs to determine the internal resistance and e.m.f. of a power supply (e.g. a dry cell). They should connect various external resistances and measure the current and the terminal pd. Tell them to decide, giving reasons, how best to process and display their results: you might need to point out to them the advantages of plotting a graph (e.g. a plot of V against I is a straight line of gradient $-r$ and y-intercept E). Provide students with plenty of algebraic and numerical examples involving internal resistance, e.m.f. and terminal pd.	**Mathematics:** Plotting and interpreting straight-line graphs. Enquiry skills 11F.1.1–11F.1.4, 11F.4.1, 11F.4.2	
	Maximum power Encourage advanced students to explore how the internal and external resistance affect the power transferred by a power supply to a circuit (i.e. power transfer is maximum when $R = r$). This can be approached in various ways, depending on time available and students’ mathematical abilities. • Use a spreadsheet to calculate the power output (VI) to various loads connected to a supply of given e.m.f. and internal resistance. • As above, but perform calculations with a range of values using a calculator. • A semi-quantitative argument: on open circuit, V is large but I is zero, so output power is zero; on short circuit, I is large but V is very small, so power is small; the maximum power must be achieved somewhere between these two extremes. • Use differential calculus to deduce the value of R for which VI is maximum.	**Mathematics:** Use of differential calculus **ICT opportunity:** Use of a spreadsheet.	

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.	*In the electrolysis of copper sulfate solution, two electrons must reach the cathode for every atom of copper that is deposited. If the current is 1.5 mA, how many copper atoms will be deposited in 5 minutes? (Electron charge* $e = 1.60 \times 10^{-19}$ *C.)*		
	A microwave oven has a power of 800 W and takes 10 minutes to cook a meal. A conventional electric oven draws a current of 5 A when connected to a 110 volt supply and takes 40 minutes to cook the same meal. Which oven is cheaper to operate?		
	a. *Use the expressions* $V = IR$ *and* $P = VI$ *to derive an expression for P in terms of V and R.* b. *An air-conditioner is designed to have a power of 250 W when run from a 110 V supply. What is its resistance?*		
	A student has three 10-ohm resistors. How many different resistances can be produced by combining some or all of them? Draw diagrams to show the different combinations and in each case calculate the overall resistance.		
	A certain steel wire has resistivity $1.5 \times 10^{-8}\ \Omega$*m and diameter 1.0 mm. What length of wire is needed to make a resistance of* $2.0\ \Omega$*?*		
	Explain why car headlamps dim when the starter motor is used.		

GRADE 11F: Physics 5

Electronic control circuits

UNIT 11FP.5
10 hours

About this unit

This unit is the fifth of five units on physics for Grade 11 foundation.

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 10F.

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

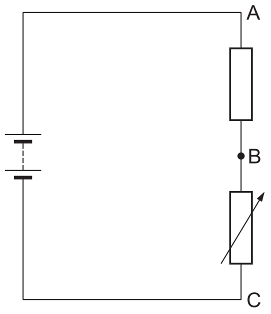
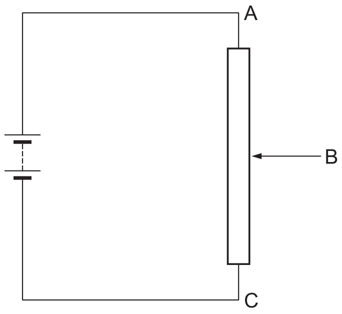
Key vocabulary and technical terms

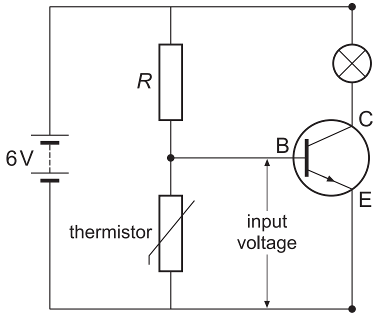
Students should understand, use and spell correctly:

- *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

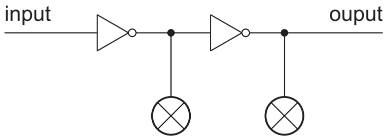
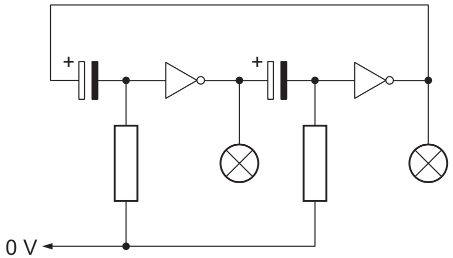
10 hours		SUPPORTING STANDARDS		CORE STANDARDS Grade 11 standards	EXTENSION STANDARDS
4 hours **Potential dividers and variable resistors** **2 hours** **Capacitors** **4 hours** **Logic gates and switches**	10F.25.2	Know that ... opposite charges attract but like charges repel each other.	11F.24.1	Demonstrate an understanding of the construction of capacitors and their use in electrical circuits.	
	10F.25.1	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.	11F.24.2	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.			
			11F.24.3	Use logic gates in practical circuits (AND, OR, NAND, NOR) and determine truth tables for the gates, individually and in combination.	
			11F.24.4	Understand and use bistable and astable switches and know how these can constitute memory circuits.	

Objectives	Possible teaching activities	Notes	School resources
4 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 11F.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 11F.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. 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.	 Enquiry skills 11F.4.1, 11F.4.2 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 11F.1.1, 11F.1.3–11F.1.5, 11F.3.4, 11F.4.1, 11F.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.		
2 hours **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 11F.1.1, 11F.1.3, 11F.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.)	Enquiry skills 11F.4.1, 11F.4.2	
	Discuss with students how the charge or discharge of a capacitor might be exploited in a delayed-action switching circuit. 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).	Prepare a suitable handout.	
4 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 11F.1.2, 11F.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.	