ISS
SINGAPORE CAMPUS

Realising Potential

SCIENCE

K-12 LEARNING OUTCOMES & BENCHMARKS

Learning Outcomes and Benchmarks

Below you will find the Learning Outcomes and Benchmarks for the International Baccalaureate Primary Years Programme, Middle Years Programme and Diploma Programme at ISS.
This document covers the Learning Outcomes and Benchmarks that will be covered from Kindergarten to Grade 12 at ISS.

It is an important document in ensuring that the students at ISS have a World Class education. An education that provides an ever deepening level of understanding of the world from when they join us to when they leave.

Explanation of terms:

Different curriculum use the terms Outcomes and Benchmarks in slightly different ways. At ISS we use the terms to mean:

Learning Outcomes: the concepts, skills, attributes and knowledge that a student in the relevant Grade Level is expected to understand, demonstrate and apply.

Learning outcomes complete the statement: students will be able to .....

Benchmarks: specific performance indicators for each grade level

Benchmarks complete the statement: students will be able to show their understanding by .....

It is important to note that a Learning Outcome is not a limitation. Through differentiated teaching teachers ensure that all students are given the maximum opportunity to reach the Learning Outcomes for their Grade Level and to extend those who are capable of surpassing the Learning Outcomes.

Learning Outcomes and Benchmarks

Subject : SCIENCE

Strand : SCIENTIFIC LITERACY

Grade/ Phase	**Learning Outcomes:** ***Students will be able to...***	**Benchmarks:** ***Students will be able to show their understanding by….***
12	· Meet the expectations of the Criterion: Personal Engagement · Meet the expectations of the Criterion: Exploration · Meet the expectations of the Criterion: Analysis · Meet the expectations of the Criterion: Evaluation · Meet the expectations of the Criterion: Communication	Addressing personal interests or showing evidence of independent thinking, creativity or initiative in the designing, implementation or presentation of the investigation. Establishing the scientific context for the work, stating a clear and focused research question and using concepts and techniques appropriate to the Diploma Programme level Providing evidence that the student has selected, recorded, processed and **interpreted** the data in ways that are relevant to the research question and can support a conclusion. Evaluating the investigation and the results with regard to the research question and the accepted scientific context. Presenting and reporting in a way that supports effective communication of the focus, process and outcomes.
11	*Same as Grade 12*	*Same as Grade 12*

10	**Criterion B: Inquiring and designing** i. explain a problem or question to be tested by a ii. scientific investigation iii. formulate a testable hypothesis and explain it using scientific reasoning iv. explain how to manipulate the variables, and explain how data will be collected v. design scientific investigations. **Criterion C: Processing and Evaluating** i. present collected and transformed data ii. interpret data and explain results using scientific iii. reasoning iv. evaluate the validity of a hypothesis based on the v. outcome of the scientific investigation vi. evaluate the validity of the method vii. explain improvements or extensions to the method.	Demonstrating an understanding of the process of inquiry and design through explaining a problem, formulating hypotheses, explaining variables to be manipulated and designing an experiment independently. Demonstrating an understanding of processing and evaluating data by presenting collected and transformed data, interpreting and explaining results, evaluating the validity of a hypothesis and the method, and explaining improvements independently.
9	*Should be approaching the learning outcomes goals of Grade 10.*	*Should be approaching the benchmarks goals of Grade 10.*
8	**Criterion B: Inquiring and designing** i. describe a problem or question to be tested by a ii. scientific investigation iii. outline a testable hypothesis and explain it iv. using scientific reasoning v. describe how to manipulate the variables, and describe how data will be collected	Demonstrating an understanding of the process of inquiry and design through describing a problem, outlining a testable hypothesis, describing variables and designing an investigation with some assistance from peers and or teacher.

	vi. design scientific investigations. **Criterion C: Processing and Evaluating** i. present collected and transformed data ii. interpret data and describe results using scientific iii. reasoning iv. discuss the validity of a hypothesis based on the v. outcome of the scientific investigation vi. iv. discuss the validity of the method vii. describe improvements or extensions to the method. **More specific Learning Outcomes for the Unit:** · Identify outliers calculate mean, median, and mode. · Identify reliable and unreliable data and what that means when planning an experiment. · Draw scientific drawings properly so they can draw an apparatus · Review how to write a hypothesis, aim, and materials/procedure, effectively. · Understand and apply proper lab safety procedures.	Demonstrating an understanding of the processing and evaluating data by presenting data, interpreting and describing results using scientific reasoning, discussing the validity of the hypothesis and method, as well as describing improvements **with some assistance** from peers and/or teacher. Applying statistics to data collected during investigations in order to demonstrate an understanding of reliable data. Producing scientific drawings that represent a set of methods accurately.
7	*Should be approaching the learning outcomes of Grade 8.*	*Should be approaching the benchmarks of Grade 8.*
6	**Criterion B: Inquiring and designing** i. outline an appropriate problem or research question to be tested by a scientific investigation	Demonstrating an understanding of the process of inquiry and design through outlining a problem, outlining a testable hypothesis, outlining variables and designing an investigation **with assistance** from peers

	ii. outline a testable prediction using scientific reasoning iii. outline how to manipulate the variables, and outline how data will be collected iv. design scientific investigations. **Criterion C: Processing and Evaluating** i. present collected and transformed data ii. interpret data and outline results using scientific reasoning iii. discuss the validity of a prediction based on the iv. outcome of the scientific investigation v. discuss the validity of the method vi. describe improvements or extensions to the method. **More specific Learning Outcomes for the Unit:** Calculate the average for a set of data collected	and or teacher. Demonstrating an understanding of the processing and evaluating data by presenting data, interpreting and outline results using scientific reasoning, discussing the validity of the hypothesis and method, as well as describing improvements **with assistance** from peers and/or teacher.
5	**Students will be able to** · Observe carefully in order to gather data · Use a variety of instruments and tools to measure data accurately · Use scientific vocabulary to explain their observations and experiences · Identify or generate a question or problem to be explored · Plan and carry out systematic investigations,	**Students will show their understanding by** Recording observations in a systematic way Measuring, comparing and recording data with appropriately selected tool Recording and presenting findings and conclusions using a variety of strategies and appropriate scientific vocabulary Posing questions and defining problems that will facilitate effective investigations for inquiry Demonstrating the ways in which an experiment is unfair if the relevant variables are not controlled

	manipulating variables as necessary · Make and test predictions · Interpret, evaluate data gathered in order to draw conclusions · Consider scientific models and applications of these models (including limitations)	Reflecting on methods used in investigations and their effectiveness Making justified predictions Proposing ideas or simple theories that may be explored or tested Interpreting information and offer explanations from both observations and inferences Composing a Lab Report Applying scientific knowledge to reconstruct or refine their understanding Assessing their understanding in light of new data or reconsideration of existing data
4	**Students will be able to** · Observe carefully in order to gather data · Use a variety of instruments and tools to measure data accurately · Use scientific vocabulary to explain their observations and experiences · Identify or generate a question or problem to be explored · Plan and carry out systematic investigations, manipulating variables as necessary · Make and test predictions · Interpret, evaluate data gathered in order to draw conclusions	**Students will be able to show their understanding by** Distinguishing between significant and less significant observations Using standard and nonstandard units of measurement Recording and presenting findings and conclusions using a variety of strategies and appropriate scientific vocabulary Posing questions and defining problems that will facilitate effective investigations for inquiry Recognizing the ways in which an experiment is unfair if the relevant variables are not controlled Reflecting on methods used in investigations and their effectiveness Making justified predictions Proposing ideas or simple theories that may be explored or tested

	· Consider scientific models and applications of these models (including limitations)	Interpreting information and offering explanations from both observations and inferences Composing a Lab Report Applying scientific knowledge to reconstruct or refine their understanding
3	**Students will be able to** · Observe carefully in order to gather data · Use a variety of instruments and tools to measure data accurately · Use scientific vocabulary to explain their observations and experiences · Identify or generate a question or problem to be explored · Plan and carry out systematic investigations, manipulating variables as necessary · Make and test predictions · Interpret, evaluate data gathered in order to draw conclusions · Consider scientific models and applications of these models (including limitations)	**Students will be able to show their understanding by** Observing changes in living things, objects, and events over a period of time Using a range of tools and techniques to gather scientific data. Describing what is happening using an increasing scientific vocabulary Posing open questions that lead to investigations Creating variables relevant to the investigation. Suggesting and justifying predictions Interpreting information gathered Composing a Lab Report on an experiment.

2	**Students will be able to** · Observe carefully in order to gather data · Use a variety of instruments and tools to measure data accurately · Use scientific vocabulary to explain their observations and experiences · Identify or generate a question or problem to be explored · Plan and carry out systematic investigations, manipulating variables as necessary · Make and test predictions · Interpret, evaluate data gathered in order to draw conclusions · Consider scientific models and applications of these models (including limitations)	**Students will be able to show their understanding by** Including relevant details in observations Demonstrating use of tools can be used to gather information and extend senses Describing objects and events using scientific vocabulary Posing open and investigative questions Demonstrating scientific investigations generally work the same way in different places. Suggesting outcomes of an investigation. Synthesizing results of different investigations Sharing findings using models and pictures
1	**Students will be able to...** · Observe carefully in order to gather data · Use a variety of instruments and tools to measure data accurately · Use scientific vocabulary to explain their observations and experiences · Identify or generate a question or problem to be explored	**Students will be able to show their understanding by...** Demonstrating that learning can come from careful observations and simple experiments Demonstrating that tools can be used to gather information and extend senses Beginning to describe using scientific vocabulary Beginning to ask questions about the natural and physical environment

	· Plan and carry out systematic investigations, manipulating variables as necessary · Make and test predictions · Interpret, evaluate data gathered in order to draw conclusions · Consider scientific models and applications of these models (including limitations)	Demonstrating that scientific investigations generally work the same way in different places. Making predictions based on patterns. Looking for and recognize patterns from data Sharing findings with peers informally
K2	**Students will be able to** · Observe carefully in order to gather data · Use a variety of instruments and tools to measure data accurately · Use scientific vocabulary to explain their observations and experiences · Identify or generate a question or problem to be explored · Plan and carry out systematic investigations, manipulating variables as necessary · Make and test predictions · Interpret, evaluate data gathered in order to draw conclusions · Consider scientific models and applications of these models (including limitations)	**Students will be able to show their understanding by** Using sight, hearing, and touch to observe Recording information in drawings and simple data charts Using simple vocabulary to describe some observable properties such as color, shape, and size of objects Brainstorming questions in a group Developing predictions and explanations based on previous experiences Sorting and classifying gathered data

K1	**Students will be able to** · Observe carefully in order to gather data · Use a variety of instruments and tools to measure data accurately · Use scientific vocabulary to explain their observations and experiences · Identify or generate a question or problem to be explored · Plan and carry out systematic investigations, manipulating variables as necessary · Make and test predictions · Interpret, evaluate data gathered in order to draw conclusions · Consider scientific models and applications of these models (including limitations)	**Students will be able to show their understanding by** Using sight, hearing, and touch to observe Recording information in drawings and simple data charts Using simple vocabulary to describe some observable properties such as color, shape, and size of objects Brainstorming questions in a group Developing predictions and explanations based on previous experiences Sorting and classifying gathered data

Learning Outcomes and Benchmarks

Subject: SCIENCE

Strand: MATERIALS AND MATTER

Grade/ Phase	**Learning Outcomes** ***Students will be able to …..***	**Benchmarks** ***Students will be able to show their understanding by….***
11 / 12	**1.1 Introduction to the particulate nature of matter and chemical change** Students will be able to understand: · Atoms of different elements combine in fixed ratios to form compounds, which have different properties from their component elements. · Mixtures contain more than one element and/or compound that are not chemically bonded together and so retain their individual properties. · Mixtures are either homogeneous or heterogeneous. Application and Skills: · Deduction of chemical equations when reactants and products are specified. · Application of the state symbols (s), (l), (g) and (aq) in equations. · Explanation of observable changes in physical properties and temperature during changes of state. **1.2 The mole concept** Students will be able to understand:	Demonstrating an understanding that physical and chemical properties depend on the ways in which different atoms combine.

	· The mole is a fixed number of particles and refers to the amount, n, of substance. · Masses of atoms are compared on a scale relative to 12C and are expressed as relative atomic mass (Ar) and relative formula/molecular mass (Mr). · Molar mass (M) has the units g mol-1. · The empirical formula and molecular formula of a compound give the simplest ratio and the actual number of atoms present in a molecule respectively. Applications and skills: · Calculation of the molar masses of atoms, ions, molecules and formula units. · Solution of problems involving the relationships between the number of particles, the amount of substance in moles and the mass in grams. · Inter-conversion of the percentage composition by mass and the empirical formula. · Determination of the molecular formula of a compound from its empirical formula and molar mass. · Obtaining and using experimental data for deriving empirical formulas from reactions involving mass changes **1.3 Reacting masses and volumes** Students will be able to understand: · Reactants can be either limiting or excess.	Demonstrating an understanding that the mole makes it possible to correlate the number of particles with the mass that can be measured.

	· The experimental yield can be different from the theoretical yield. · Avogadro's law enables the mole ratio of reacting gases to be determined from volumes of the gases. · The molar volume of an ideal gas is a constant at specified temperature and pressure. · The molar concentration of a solution is determined by the amount of solute and the volume of solution. · A standard solution is one of known concentration. Applications and skills: · Solution of problems relating to reacting quantities, limiting and excess reactants, theoretical, experimental and percentage yields. · Calculation of reacting volumes of gases using Avogadro's law. · Solution of problems and analysis of graphs involving the relationship between temperature, pressure and volume for a fixed mass of an ideal gas. · Solution of problems relating to the ideal gas equation. · Explanation of the deviation of real gases from ideal behaviour at low temperature and high pressure. · Obtaining and using experimental values to calculate the molar mass of a gas from the ideal gas equation. · Solution of problems involving molar concentration, amount of solute and volume of solution. · Use of the experimental method of titration to calculate the concentration of a solution by reference to a standard solution	Demonstrating an understanding that mole ratios in chemical equations can be used to calculate reacting ratios by mass and gas volume.

	· _____ **2.1 The nuclear atom** Students will be able to understand: · Atoms contain a positively charged dense nucleus composed of protons and neutrons (nucleons). · Negatively charged electrons occupy the space outside the nucleus. · The mass spectrometer is used to determine the relative atomic mass of an element from its isotopic composition. Applications and skills: · Use of the nuclear symbol notation $XX\ ZZ\ AA$ to deduce the number of protons, neutrons and electrons in atoms and ions. · Calculations involving non-integer relative atomic masses and abundance of isotopes from given data, including mass spectra. **2.2 Electron configuration** Students will be able to understand: · Emission spectra are produced when photons are emitted from atoms as excited electrons return to a lower energy level. · The line emission spectrum of hydrogen provides evidence for the existence of electrons in discrete energy levels, which converge at higher energies. · The main energy level or shell is given an integer number, n, and can hold a maximum number of electrons, $2n^2$. · A more detailed model of the atom describes the division of the main energy level into s, p, d and f sub-levels of successively higher energies.	_____ Demonstrating an understanding that the mass of an atom is concentrated in its minute, positively charged nucleus Topic 2: Atomic structure Demonstrating an understanding that the electron configuration of an atom can be deduced from its atomic number

	· Sub-levels contain a fixed number of orbitals, regions of space where there is a high probability of finding an electron. · Each orbital has a defined energy state for a given electronic configuration and chemical environment and can hold two electrons of opposite spin. Applications and skills: · Description of the relationship between colour, wavelength, frequency and energy across the electromagnetic spectrum. · Distinction between a continuous spectrum and a line spectrum. · Description of the emission spectrum of the hydrogen atom, including the relationships between the lines and energy transitions to the first, second and third energy levels. · Recognition of the shape of an s atomic orbital and the px, py and pz atomic orbitals. · Application of the Aufbau principle, Hund's rule and the Pauli Exclusion Principle to write electron configurations for atoms and ions up to Z = 36. _____ **3.1 Periodic table** Students will be able to understand:	_____

	· The periodic table is arranged into four blocks associated with the four sublevels— s, p, d, and f. · The periodic table consists of groups (vertical columns) and periods (horizontal rows). · The period number (n) is the outer energy level that is occupied by electrons. · The number of the principal energy level and the number of the valence electrons in an atom can be deduced from its position on the periodic table. · The periodic table shows the positions of metals, non-metals and metalloids. Applications and skills: · Deduction of the electron configuration of an atom from the element's position on the periodic table, and vice versa. **3.2 Periodic trends** Students will be able to understand: · Vertical and horizontal trends in the periodic table exist for atomic radius, ionic radius, ionization energy, electron affinity and electronegativity. · Trends in metallic and non-metallic behaviour are due to the trends above. · Oxides change from basic through amphoteric to acidic across a period. Applications and skills: · Prediction and explanation of the metallic and non-metallic behaviour of an element based on its position in the periodic table. · Discussion of the similarities and differences in the properties of elements in the same group, with reference to alkali metals (group 1) and halogens (group17).	Demonstrating an understanding that the arrangement of elements in the periodic table helps to predict their electron configuration Demonstrating an understanding that elements show trends in their physical and chemical properties across periods and down groups.

	· Construction of equations to explain the pH changes for reactions of Na2O, MgO, P4O10, and the oxides of nitrogen and sulfur with water. _____ **4.1 Ionic bonding and structure** Students will be able to understand: · Positive ions (cations) form by metals losing valence electrons. · Negative ions (anions) form by non-metals gaining electrons. · The number of electrons lost or gained is determined by the electron configuration of the atom. · The ionic bond is due to electrostatic attraction between oppositely charged ions. · Under normal conditions, ionic compounds are usually solids with lattice structures. Applications and skills: · Deduction of the formula and name of an ionic compound from its component ions, including polyatomic ions. · Explanation of the physical properties of ionic compounds (volatility, electrical conductivity and solubility) in terms of their structure. **4.2. Covalent bonding** Students will be able to understand: · A covalent bond is formed by the electrostatic attraction between a shared pair of electrons and the positively charged nuclei. · Single, double and triple covalent bonds involve one, two and three shared pairs of electrons respectively. · Bond length decreases and bond strength increases as the number of shared electrons increases.	_____ Demonstrating an understanding that Ionic compounds consist of ions held together in lattice structures by ionic bonds. Demonstrating an understanding that covalent compounds form by the sharing of electrons.

	· Bond polarity results from the difference in electro negativities of the bonded atoms. Applications and skills: · Deduction of the polar nature of a covalent bond from electronegativity values **4.3 Covalent structures** Students will be able to understand: · Lewis (electron dot) structures show all the valence electrons in a covalently bonded species. · The “octet rule” refers to the tendency of atoms to gain a valence shell with a total of 8 electrons. · Some atoms, like Be and B, might form stable compounds with incomplete octets of electrons. · Resonance structures occur when there is more than one possible position for a double bond in a molecule. · Shapes of species are determined by the repulsion of electron pairs according to VSEPR theory. · Carbon and silicon form giant covalent/network covalent structures. Applications and skills: · Deduction of Lewis (electron dot) structure of molecules and ions showing all valence electrons for up to four electron pairs on each atom. · The use of VSEPR theory to predict the electron domain geometry and the molecular geometry for species with two, three and four	Demonstrating an understanding that Lewis (electron dot) structures show the electron domains in the valence shell and are used to predict molecular shape.

	electron domains. · Prediction of bond angles from molecular geometry and presence of nonbonding pairs of electrons. · Prediction of molecular polarity from bond polarity and molecular geometry. · Deduction of resonance structures, examples include but are not limited to C6H6, CO3 2- and O3. · Explanation of the properties of giant covalent compounds in terms of their structures. **4.4 Intermolecular forces** Students will be able to understand: · Intermolecular forces include London (dispersion) forces, dipole-dipole forces and hydrogen bonding. · The relative strengths of these interactions are London (dispersion) forces < dipole-dipole forces < hydrogen bonds. Applications and skills · Deduction of the types of intermolecular force present in substances, based on their structure and chemical formula. · Explanation of the physical properties of covalent compounds (volatility, electrical conductivity and solubility) in terms of their structure and intermolecular forces. **4.5 Metallic bonding** Students will be able to understand: · A metallic bond is the electrostatic attraction between a lattice of positive ions and delocalized electrons. · The strength of a metallic bond depends on the charge of the ions	Demonstrating an understanding that the physical properties of molecular substances result from different types of forces between their molecules.

	and the radius of the metal ion. · Alloys usually contain more than one metal and have enhanced properties. Applications and skills: · Explanation of electrical conductivity and malleability in metals. · Explanation of trends in melting points of metals. · Explanation of the properties of alloys in terms of non-directional bonding. _____ **5.1 Measuring energy changes** Students will be able to understand: · Heat is a form of energy. · Temperature is a measure of the average kinetic energy of the particles. · Total energy is conserved in chemical reactions. · Chemical reactions that involve transfer of heat between the system and the surroundings are described as endothermic or exothermic. · The enthalpy change (ΔH) for chemical reactions is indicated in kJ mol-1. · ΔH values are usually expressed under standard conditions, given by ΔH°, including standard states. Applications and skills: · Calculation of the heat change when the temperature of a pure substance is changed using $qq = mmmm\Delta TT$.	Demonstrating an understanding that metallic bonds involve a lattice of cations with delocalized electrons. _____ Demonstrating an understanding that enthalpy changes from chemical reactions can be calculated from their effect on the temperature of their surroundings.

	· A calorimetry experiment for an enthalpy of reaction should be covered and the results evaluated. **5.2 Hess's Law** Students will be able to understand: · The enthalpy change for a reaction that is carried out in a series of steps is equal to the sum of the enthalpy changes for the individual steps. Applications and skills: · Application of Hess's Law to calculate enthalpy changes. · Calculation of ΔHH reactions using ΔHf ° data. · Determination of the enthalpy change of a reaction that is the sum of multiple reactions with known enthalpy changes. **5.3 Bond enthalpies** Students will be able to understand: · Bond-forming releases energy and bond-breaking requires energy. · Average bond enthalpy is the energy needed to break one mole of a bond in a gaseous molecule averaged over similar compounds. Applications and skills: · Calculation of the enthalpy changes from known bond enthalpy values and comparison of these to experimentally measured values. · Sketching and evaluation of potential energy profiles in determining whether reactants or products are more stable and if the reaction is exothermic or endothermic. · Discussion of the bond strength in ozone relative to oxygen in its importance to the atmosphere _____	Demonstrating an understanding that in chemical transformations energy can neither be created nor destroyed (the first law of thermodynamics). Demonstrating an understanding that energy is absorbed when bonds are broken and is released when bonds are formed

	6.1 Collision theory and rates of reaction Students will be able to understand: · Species react as a result of collisions of sufficient energy and proper orientation. · The rate of reaction is expressed as the change in concentration of a particular reactant/product per unit time. · Concentration changes in a reaction can be followed indirectly by monitoring changes in mass, volume and colour. · Activation energy (Ea) is the minimum energy that colliding molecules need in order to have successful collisions leading to a reaction. · By decreasing Ea, a catalyst increases the rate of a chemical reaction, without itself being permanently chemically changed. Applications and skills: · Description of the kinetic theory in terms of the movement of particles whose average kinetic energy is proportional to temperature in Kelvin. · Analysis of graphical and numerical data from rate experiments · Explanation of the effects of temperature, pressure/concentration and particle size on rate of reaction. · Construction of Maxwell–Boltzmann energy distribution curves to account for the probability of successful collisions and factors affecting these, including the effect of a catalyst. · Investigation of rates of reaction experimentally and evaluation of the results. · Sketching and explanation of energy profiles with and without catalysts. _____	_____ Demonstrating an understanding that the greater the probability that molecules will collide with sufficient energy and proper orientation, the higher the rate of reaction.

	7.1 Equilibrium Students will be able to understand: · A state of equilibrium is reached in a closed system when the rates of the forward and reverse reactions are equal. · The equilibrium law describes how the equilibrium constant (Kc) can be determined for a particular chemical reaction. · The magnitude of the equilibrium constant indicates the extent of a reaction at equilibrium and is temperature dependent. · The reaction quotient (Q) measures the relative amount of products and reactants present during a reaction at a particular point in time. Q is the equilibrium expression with non-equilibrium concentrations. The position of the equilibrium changes with changes in concentration, pressure, and temperature. · A catalyst has no effect on the position of equilibrium or the equilibrium constant. Applications and skills: · The characteristics of chemical and physical systems in a state of equilibrium. · Deduction of the equilibrium constant expression (Kc) from an equation for a homogeneous reaction. · Determination of the relationship between different equilibrium constants (Kc) for the same reaction at the same temperature · Application of Le Châtelier's principle to predict the qualitative effects of changes of temperature, pressure and concentration on the position of equilibrium and on the value of the equilibrium constant. _____ **8.1 Theories of acids and bases** Students will be able to understand:	_____ Demonstrating an understanding that many reactions are reversible. These reactions will reach a state of equilibrium when the rates of the forward and reverse reaction are equal. The position of equilibrium can be controlled by changing the conditions.

	· A Brønsted–Lowry acid is a proton/H+ donor and a Brønsted–Lowry base is a proton/H+ acceptor. · Amphiprotic species can act as both Brønsted–Lowry acids and bases. · A pair of species differing by a single proton is called a conjugate acid-base pair. Applications and skills: · Deduction of the Brønsted–Lowry acid and base in a chemical reaction. · Deduction of the conjugate acid or conjugate base in a chemical reaction **8.2 Properties of acids and bases** Students will be able to understand: · Most acids have observable characteristic chemical reactions with reactive metals, metal oxides, metal hydroxides, hydrogen carbonates and carbonates. · Salt and water are produced in exothermic neutralization reactions. Applications and skills: · Balancing chemical equations for the reaction of acids. · Identification of the acid and base needed to make different salts. · Candidates should have experience of acid-base titrations with different indicators **8.3 The pH scale** Students will be able to understand: · pH = − log[H+(aq)] and [H+] = 10^{-pH}. · A change of one pH unit represents a 10-fold change in the hydrogen	_____ Demonstrating an understanding that many reactions involve the transfer of a proton from an acid to a base. Demonstrating an understanding that the characterization of an acid depends on empirical evidence such as the production of gases in reactions with metals, the colour changes of indicators or the release of heat in reactions with metal oxides and hydroxides.

	ion concentration [H+]. · pH values distinguish between acidic, neutral and alkaline solutions. · The ionic product constant, Kw = [H+][OH−] = 10^{-14} at 298 K. Applications and skills: · Solving problems involving pH, [H+] and [OH−]. · Students should be familiar with the use of a pH meter and universal indicator **8.4 Strong and weak acids and bases** Students will be able to understand: · Strong and weak acids and bases differ in the extent of ionization. · Strong acids and bases of equal concentrations have higher conductivities than weak acids and bases. · A strong acid is a good proton donor and has a weak conjugate base. · A strong base is a good proton acceptor and has a weak conjugate acid. Applications and skills: · Distinction between strong and weak acids and bases in terms of the rates of their reactions with metals, metal oxides, metal hydroxides, metal hydrogen carbonates and metal carbonates and their electrical conductivities for solutions of equal concentrations **8.5 Acid deposition** Students will be able to understand: · Rain is naturally acidic because of dissolved CO_2 and has a pH of 5.6. Acid deposition has a pH below 5.6. · Acid deposition is formed when nitrogen or sulfur oxides dissolve in	Demonstrating an understanding that the pH scale is an artificial scale used to distinguish between acid, neutral and basic/alkaline solutions Demonstrating an understanding that the pH depends on the concentration of the solution. The strength of acids or bases depends on the extent to which they dissociate in aqueous solution.

	water to form HNO_3, HNO_2, H_2SO_4 and H_2SO_3. · Sources of the oxides of sulfur and nitrogen and the effects of acid deposition should be covered. Applications and skills: · Balancing the equations that describe the combustion of sulfur and nitrogen to their oxides and the subsequent formation of HNO_3, HNO_2, H_2SO_4 and H_2SO_3. · Distinction between the pre-combustion and post-combustion methods of reducing sulfur oxides emissions. · Deduction of acid deposition equations for acid deposition with reactive metals and carbonates _____ **9.1 Oxidation and reduction** Students will be able to understand: · Oxidation and reduction can be considered in terms of oxygen gain/hydrogen loss, electron transfer or change in oxidation number. · An oxidizing agent is reduced and a reducing agent is oxidized. · Variable oxidation numbers exist for transition metals and for most main-group non-metals. · The activity series ranks metals according to the ease with which they undergo oxidation. · The Winkler Method can be used to measure biochemical oxygen demand (BOD), used as a measure of the degree of pollution in a water sample.	Demonstrating an understanding that increased industrialization has led to greater production of nitrogen and sulfur oxides leading to acid rain, which is damaging our environment. These problems can be reduced through collaboration with national and intergovernmental organizations. _____

	Applications and skills: · Deduction of the oxidation states of an atom in an ion or a compound. · Deduction of the name of a transition metal compound from a given formula, applying oxidation numbers represented by Roman numerals. · Identification of the species oxidized and reduced and the oxidizing and reducing agents, in redox reactions. · Deduction of redox reactions using half-equations in acidic or neutral solutions. · Deduction of the feasibility of a redox reaction from the activity series or reaction data. · Solution of a range of redox titration problems. · Application of the Winkler Method to calculate BOD. **9.2 Electrochemical cells** Students will be able to understand: Voltaic (Galvanic) cells: · Voltaic cells convert energy from spontaneous, exothermic chemical processes to electrical energy. · Oxidation occurs at the anode (negative electrode) and reduction occurs at the cathode (positive electrode) in a voltaic cell. Electrolytic cells: · Electrolytic cells convert electrical energy to chemical energy, by bringing about non-spontaneous processes. · Oxidation occurs at the anode (positive electrode) and reduction occurs at the cathode (negative electrode) in an electrolytic cell. Applications and skills: · Construction and annotation of both types of electrochemical cells.	Demonstrating an understanding that redox (reduction–oxidation) reactions play a key role in many chemical and biochemical processes

	· Explanation of how a redox reaction is used to produce electricity in a voltaic cell and how current is conducted in an electrolytic cell. · Distinction between electron and ion flow in both electrochemical cells. · Performance of laboratory experiments involving a typical voltaic cell using two metal/metal-ion half-cells. · Deduction of the products of the electrolysis of a molten salt _____ **10.1 Fundamentals of organic chemistry** Students will be able to understand: · A homologous series is a series of compounds of the same family, with the same general formula, which differ from each other by a common structural unit. · Structural formulas can be represented in full and condensed format. · Structural isomers are compounds with the same molecular formula but different arrangements of atoms. · Functional groups are the reactive parts of molecules. · Saturated compounds contain single bonds only and unsaturated compounds contain double or triple bonds. · Benzene is an aromatic, unsaturated hydrocarbon. Applications and skills: · Explanation of the trends in boiling points of members of a homologous series. · Distinction between empirical, molecular and structural formulas. · Identification of different classes: alkanes, alkenes, alkynes, halogenoalkanes, alcohols, ethers, aldehydes, ketones, esters,	Demonstrating an understanding that voltaic cells convert chemical energy to electrical energy and electrolytic cells convert electrical energy to chemical energy _____ Demonstrating an understanding that organic chemistry focuses on the chemistry of compounds containing carbon.

	carboxylic acids, amines, amides, nitriles and arenes. · Identification of typical functional groups in molecules e.g. phenyl, hydroxyl, carbonyl, carboxyl, carboxamide, aldehyde, ester, ether, amine, nitrile, alkyl, alkenyl and alkynyl. · Construction of 3-D models (real or virtual) of organic molecules. · Application of IUPAC rules in the nomenclature of straight-chain and branched chain isomers. · Identification of primary, secondary and tertiary carbon atoms in halogenoalkanes and alcohols and primary, secondary and tertiary nitrogen atoms in amines. · Discussion of the structure of benzene using physical and chemical evidence **10.2 Functional group chemistry** Students will be able to understand: Alkanes: · Alkanes have low reactivity and undergo free-radical substitution reactions. Alkenes: · Alkenes are more reactive than alkanes and undergo addition reactions. Bromine water can be used to distinguish between alkenes and alkanes. Alcohols: · Alcohols undergo nucleophilic substitution reactions with acids (also called esterification or condensation) and some undergo oxidation reactions. Halogenoalkanes: · Halogenoalkanes are more reactive than alkanes. They can undergo (nucleophilic) substitution reactions. A nucleophile is an electron-rich	

	species containing a lone pair that it donates to an electron-deficient carbon. Polymers: · Addition polymers consist of a wide range of monomers and form the basis of the plastics industry. Benzene: · Benzene does not readily undergo addition reactions but does undergo electrophilic substitution reactions Applications and skills: Alkanes: · Writing equations for the complete and incomplete combustion of hydrocarbons. · Explanation of the reaction of methane and ethane with halogens in terms of a free-radical substitution mechanism involving photochemical homolytic fission. Alkenes: · Writing equations for the reactions of alkenes with hydrogen and halogens and of symmetrical alkenes with hydrogen halides and water. · Outline of the addition polymerization of alkenes. · Relationship between the structure of the monomer to the polymer and repeating unit.	Demonstrating an understanding that structure, bonding and chemical reactions involving functional group interconversions are key strands in organic chemistry.

	Alcohols: · Writing equations for the complete combustion of alcohols. · Writing equations for the oxidation reactions of primary and secondary alcohols (using acidified potassium dichromate(VI) or potassium manganate(VII) as oxidizing agents). Explanation of distillation and reflux in the isolation of the aldehyde and carboxylic acid products. · Writing the equation for the condensation reaction of an alcohol with a carboxylic acid, in the presence of a catalyst (e.g. concentrated sulfuric acid) to form an ester. Halogenoalkanes: · Writing the equation for the substitution reactions of halogenoalkanes with aqueous sodium hydroxide. _____ **11.1 Uncertainties and errors in measurement and results** Students will be able to understand: · Qualitative data includes all non-numerical information obtained from observations not from measurement. · Quantitative data are obtained from measurements, and are always associated with random errors/uncertainties, determined by the apparatus, and by human limitations such as reaction times. · Propagation of random errors in data processing shows the impact of the uncertainties on the final result. · Experimental design and procedure usually lead to systematic errors in measurement, which cause a deviation in a particular direction. · Repeat trials and measurements will reduce random errors but not systematic errors. Applications and skills: · Distinction between random errors and systematic errors.	

	· Record uncertainties in all measurements as a range (+) to an appropriate precision. · Discussion of ways to reduce uncertainties in an experiment. · Propagation of uncertainties in processed data, including the use of percentage uncertainties. · Discussion of systematic errors in all experimental work, their impact on the results and how they can be reduced. · Estimation of whether a particular source of error is likely to have a major or 11.1 Uncertainties and errors in measurement and results minor effect on the final result. · Calculation of percentage error when the experimental result can be compared with a theoretical or accepted result. · Distinction between accuracy and precision in evaluating results. **11.2 Graphical techniques** Students will be able to understand: · Graphical techniques are an effective means of communicating the effect of an independent variable on a dependent variable, and can lead to determination of physical quantities. · Sketched graphs have labelled but unscaled axes, and are used to show qualitative trends, such as variables that are proportional or inversely proportional. · Drawn graphs have labelled and scaled axes, and are used in quantitative measurements. Applications and skills: · Drawing graphs of experimental results including the correct choice of	_____ Demonstrating an understanding that an measurement has a limit of precision and accuracy, and this must be taken into account when evaluating experimental results.

	axes and scale. · Interpretation of graphs in terms of the relationships of dependent and independent variables. · Production and interpretation of best-fit lines or curves through data points, including an assessment of when it can and cannot be considered as a linear function. · Calculation of quantities from graphs by measuring slope (gradient) and intercept, including appropriate units. **11.3 Spectroscopic identification of organic compounds** Students will be able to understand: · The degree of unsaturation or index of hydrogen deficiency (IHD) can be used to determine from a molecular formula the number of rings or multiple bonds in a molecule. · Mass spectrometry (MS), proton nuclear magnetic resonance spectroscopy (1HNMR) and infrared spectroscopy (IR) are techniques that can be used to help identify compounds and to determine their structure. Applications and skills: · Determination of the IHD from a molecular formula. · Deduction of information about the structural features of a compound from percentage composition data, MS, 1H NMR or IR. _____ **12.1 Electrons in atoms** Students will be able to understand:	Demonstrating an understanding that graphs are a visual representation of trends in data.

	· In an emission spectrum, the limit of convergence at higher frequency corresponds to the first ionization energy. · Trends in first ionization energy across periods account for the existence of main energy levels and sub-levels in atoms. · Successive ionization energy data for an element give information that shows relations to electron configurations. Applications and skills: · Solving problems using $E = hv$. · Calculation of the value of the first ionization energy from spectral data which gives the wavelength or frequency of the convergence limit. · Deduction of the group of an element from its successive ionization energy data. · Explanation of the trends and discontinuities in first ionization energy across a period. _____ 1**3.1 First-row d-block elements** Students will be able to understand: · Transition elements have variable oxidation states, form complex ions with ligands, have coloured compounds, and display catalytic and magnetic properties. · Zn is not considered to be a transition element as it does not form ions with incomplete d-orbitals. · Transition elements show an oxidation state of +2 when the s-electrons are removed. Applications and skills:	Demonstrating an understanding that analytical techniques can be used to determine the structure of a compound, analyse the composition of a substance or determine the purity of a compound. Spectroscopic techniques are used in the structural identification of organic and inorganic compounds _____ Demonstrating an understanding that the quantized nature of energy transitions is related to the energy states of electrons in atoms and molecules.

	· Explanation of the ability of transition metals to form variable oxidation states from successive ionization energies. · Explanation of the nature of the coordinate bond within a complex ion. · Deduction of the total charge given the formula of the ion and ligands present. · Explanation of the magnetic properties in transition metals in terms of unpaired electrons. **13.2 Coloured complexes** Students will be able to understand: · The d sub-level splits into two sets of orbitals of different energy in a complex ion. · Complexes of d-block elements are coloured, as light is absorbed when an electron is excited between the d-orbitals. · The colour absorbed is complementary to the colour observed. Applications and skills: · Explanation of the effect of the identity of the metal ion, the oxidation number of the metal and the identity of the ligand on the colour of transition metal ion complexes. · Explanation of the effect of different ligands on the splitting of the d-orbitals in transition metal complexes and colour observed using the spectrochemical series _____ **14.1 Further aspects of covalent bonding and structure** Students will be able to understand: · Covalent bonds result from the overlap of atomic orbitals. A sigma bond (σ) is formed by the direct head-on/end-to-end overlap of	_____ Demonstrating an understanding that the transition elements have characteristic properties; these properties are related to their all having incomplete d sublevels.

	atomic orbitals, resulting in electron density concentrated between the nuclei of the bonding atoms. A pi bond (π) is formed by the sideways overlap of atomic orbitals, resulting in electron density above and below the plane of the nuclei of the bonding atoms. · Formal charge (FC) can be used to decide which Lewis (electron dot) structure is preferred from several. The FC is the charge an atom would have if all atoms in the molecule had the same electronegativity. FC = (Number of valence electrons)-ó(Number of bonding electrons)-(Number of non-bonding electrons). The Lewis (electron dot) structure with the atoms having FC values closest to zero is preferred. · Exceptions to the octet rule include some species having incomplete octets and expanded octets. · Delocalization involves electrons that are shared by/between all atoms in a molecule or ion as opposed to being localized between a pair of atoms. · Resonance involves using two or more Lewis (electron dot) structures to represent a particular molecule or ion. A resonance structure is one of two or more alternative Lewis (electron dot) structures for a molecule or ion that cannot be described fully with one Lewis (electron dot) structure alone. Applications and skills: · Prediction whether sigma (σ) or pi (π) bonds are formed from the linear combination of atomic orbitals. · Deduction of the Lewis (electron dot) structures of molecules and ions showing all valence electrons for up to six electron pairs on each atom. · Application of FC to ascertain which Lewis (electron dot) structure is preferred from different Lewis (electron dot) structures.	Demonstrating an understanding that d-orbitals have the same energy in an isolated atom, but split into two sub-levels in a complex ion. The electric field of ligands may cause the d-orbitals in complex ions to split so that the energy of an electron transition between them corresponds to a photon of visible light. _____ Demonstrating an understanding that larger structures and more in-depth explanations of bonding systems often require more sophisticated concepts and theories of bonding

	· Deduction using VSEPR theory of the electron domain geometry and molecular geometry with five and six electron domains and associated bond angles. · Explanation of the wavelength of light required to dissociate oxygen and ozone. · Description of the mechanism of the catalysis of ozone depletion when catalysed by CFCs and NOx **14.2 Hybridization** Students will be able to understand: · A hybrid orbital results from the mixing of different types of atomic orbitals on the same atom. Applications: · Explanation of the formation of sp^3, sp^2 and sp hybrid orbitals in methane, ethene and ethyne. · Identification and explanation of the relationships between Lewis (electron dot) structures, electron domains, molecular geometries and types of hybridization _____ **15.1 Energy cycles** Students will be able to understand: · Representative equations (e.g. M+(g) M+(aq)) can be used for enthalpy/energy of hydration, ionization, atomization, electron affinity, lattice, covalent bond and solution. · Enthalpy of solution, hydration enthalpy and lattice enthalpy are related in an energy cycle. Applications and skills: · Construction of Born-Haber cycles for group 1 and 2 oxides and chlorides.	Demonstrating an understanding that hybridization results from the mixing of atomic orbitals to form the same number of new equivalent hybrid orbitals that can have the same mean energy as the contributing atomic orbitals

	· Construction of energy cycles from hydration, lattice and solution enthalpy. For example dissolution of solid NaOH or NH_4Cl in water. · Calculation of enthalpy changes from Born-Haber or dissolution energy cycles. · Relate size and charge of ions to lattice and hydration enthalpies. · Perform lab experiments which could include single replacement reactions in aqueous solutions. **15.2 Entropy and spontaneity** Students will be able to understand: · Entropy (S) refers to the distribution of available energy among the particles. The more ways the energy can be distributed the higher the entropy. · Gibbs free energy (G) relates the energy that can be obtained from a chemical reaction to the change in enthalpy (ΔH), change in entropy (ΔS), and absolute temperature (T). · Entropy of gas>liquid>solid under same conditions. Applications and skills: · Prediction of whether a change will result in an increase or decrease in entropy by considering the states of the reactants and products. · Calculation of entropy changes (ΔS) from given standard entropy values (Sº). · Application of $\Delta GG° = \Delta HH° - TT\Delta SS°$ in predicting spontaneity and calculation of various conditions of enthalpy and temperature that	_____ Demonstrating an understanding that the concept of the energy change in a single step reaction being equivalent to the summation of smaller steps can be applied to changes involving ionic compounds

	will affect this. · Relation of ΔG to position of equilibrium _____ **16.1 Rate expression and reaction mechanism** Students will be able to understand: · Reactions may occur by more than one step and the slowest step determines the rate of reaction (rate determining step/RDS). · The molecularity of an elementary step is the number of reactant particles taking part in that step. · The order of a reaction can be either integer or fractional in nature. The order of a reaction can describe, with respect to a reactant, the number of particles taking part in the rate-determining step. · Rate equations can only be determined experimentally. · The value of the rate constant (k) is affected by temperature and its units are determined from the overall order of the reaction. · Catalysts alter a reaction mechanism, introducing a step with lower activation energy. Applications and skills: · Deduction of the rate expression for an equation from experimental data and solving problems involving the rate expression. · Sketching, identifying, and analysing graphical representations for zero, first and second order reactions. · Evaluation of proposed reaction mechanisms to be consistent with kinetic and stoichiometric data. **16.2 Activation energy** Students will be able to understand:	Demonstrating an understanding that a reaction is spontaneous if the overall transformation leads to an increase in total entropy (system plus surroundings). The direction of spontaneous change always increases the total entropy of the universe at the expense of energy available to do useful work. This is known as the second law of thermodynamics _____ Demonstrating an understanding that rate expressions can only be determined empirically and these limit possible reaction mechanisms. In particular cases, such as a linear chain of elementary reactions, no equilibria and only one significant activation barrier, the rate equation is equivalent to the slowest step of the reaction

	· The Arrhenius equation uses the temperature dependence of the rate constant to determine the activation energy. · A graph of 1/T against ln k is a linear plot with gradient – Ea / R and intercept, lnA. · The frequency factor (or pre-exponential factor) (A) takes into account the frequency of collisions with proper orientations. Applications and skills: · Analysing graphical representation of the Arrhenius equation in its linear form • ln kk = $-EEaa$ • $RRRR$ • + ln AA. · Using the Arrhenius equation kk = $AA\ ee$ • $-EEaa$ • $RRRR$. · Describing the relationships between temperature and rate constant; frequency factor and complexity of molecules colliding. · Determining and evaluating values of activation energy and frequency factors from data. _____ **17.1 The equilibrium law** Students will be able to understand: · Le Châtelier's principle for changes in concentration can be explained by the equilibrium law. · The position of equilibrium corresponds to a maximum value of entropy and a minimum in the value of the Gibbs free energy. · The Gibbs free energy change of a reaction and the equilibrium	Demonstrating an understanding that the activation energy of a reaction can be determined from the effect of temperature on reaction rate.

	constant can both be used to measure the position of an equilibrium reaction and are related by the equation, $\Delta GG = -RRRR \ln KK$. Applications and skills: · Solution of homogeneous equilibrium problems using the expression for Kc. · Relationship between ΔG and the equilibrium constant. · Calculations using the equation $\Delta GG = -RRRR \ln KK$. _____ **18.1 Lewis acids and bases** Students will be able to understand: · A Lewis acid is a lone pair acceptor and a Lewis base is a lone pair donor. · When a Lewis base reacts with a Lewis acid a coordinate bond is formed. · A nucleophile is a Lewis base and an electrophile is a Lewis acid. Applications and skills: · Application of Lewis' acid–base theory to inorganic and organic chemistry to identify the role of the reacting species. **18.2 Calculations involving acids and bases** Students will be able to understand: · The expression for the dissociation constant of a weak acid (Ka) and a weak base (Kb). · For a conjugate acid base pair, Ka x Kb = Kw. · The relationship between Ka and pKa is (pKa = -log Ka), and between Kb and pKb is (pKb = -log Kb).	_____ Demonstrating an understanding that the position of equilibrium can be quantified by the equilibrium law. The equilibrium constant for a particular reaction only depends on the temperature _____

	Applications and skills: · Solution of problems involving [H+ (aq)], [OH–(aq)], pH, pOH, Ka, pKa, Kb and pKb. · Discussion of the relative strengths of acids and bases using values of Ka, pKa, Kb and pKb	Demonstrating an understanding that the acid–base concept can be extended to reactions that do not involve proton transfer
	18.3 pH curves Students will be able to understand: · The characteristics of the pH curves produced by the different combinations of strong and weak acids and bases. · An acid–base indicator is a weak acid or a weak base where the components of the conjugate acid–base pair have different colours. · The relationship between the pH range of an acid–base indicator, which is a weak acid, and its pKa value. · The buffer region on the pH curve represents the region where small additions of acid or base result in little or no change in pH. · The composition and action of a buffer solution. Applications and skills: · The general shapes of graphs of pH against volume for titrations involving strong and weak acids and bases with an explanation of their important features. · Selection of an appropriate indicator for a titration, given the equivalence point of the titration and the end point of the indicator. · While the nature of the acid–base buffer always remains the same,	Demonstrating an understanding that the equilibrium law can be applied to acid–base reactions. Numerical problems can be simplified by making assumptions about the relative concentrations of the species involved. The use of logarithms is also significant here.

	buffer solutions can be prepared by either mixing a weak acid/base with a solution of a salt containing its conjugate, or by partial neutralization of a weak acid/base with a strong acid/base. · Prediction of the relative pH of aqueous salt solutions formed by the different combinations of _____ **19.1 Electrochemical cell** Students will be able to understand: · A voltaic cell generates an electromotive force (EMF) resulting in the movement of electrons from the anode (negative electrode) to the cathode (positive electrode) via the external circuit. The EMF is termed the cell potential (Eº). · The standard hydrogen electrode (SHE) consists of an inert platinum electrode in contact with 1 mol dm-3 hydrogen ion and hydrogen gas at 100 kPa and 298K. The standard electrode potential (Eº) is the potential (voltage) of the reduction half-equation under standard conditions measured relative to the SHE. Solute concentration is 1 mol dm-3 or 100 kPa for gases. Eº of the SHE is 0 V. · When aqueous solutions are electrolysed, water can be oxidized to oxygen at the anode and reduced to hydrogen at the cathode. · □□° □ □ □□□□°.When Eº is positive, Gº is negative indicative of a spontaneous process. When Eº is negative, Gº is positive indicative of a non-spontaneous process. When Eº is 0, then Gº is 0. · Current, duration of electrolysis and charge on the ion affect the amount of product formed at the electrodes during electrolysis. · Electroplating involves the electrolytic coating of an object with a metallic thin layer	Demonstrating an understanding that pH curves can be investigated experimentally but are mathematically determined by the dissociation constants of the acid and base. An indicator with an appropriate end point can be used to determine the equivalence point of the reaction

	Applications and skills: · Calculation of cell potentials using standard electrode potentials. · Prediction of whether a reaction is spontaneous or not using Eo values. · Determination of standard free-energy changes (ΔGo) using standard electrode potentials. · Explanation of the products formed during the electrolysis of aqueous solutions. · Perform lab experiments that could include single replacement reactions in aqueous solutions. · Determination of the relative amounts of products formed during electrolytic processes. · Explanation of the process of electroplating _____ **20.1 Types of organic reactions** Students will be able to understand: Nucleophilic Substitution Reactions: · SN1 represents a nucleophilic unimolecular substitution reaction and SN2 represents a nucleophilic bimolecular substitution reaction. SN1 involves a carbocation intermediate. SN2 involves a concerted reaction with a transition state. · For tertiary halogenoalkanes the predominant mechanism is SN1 and for primary halogenoalkanes it is SN2. Both mechanisms occur for secondary halogenoalkanes. · The rate determining step (slow step) in an SN1 reaction depends only on the concentration of the halogenoalkane, rate = k[halogenoalkane]. For SN2, rate =	Demonstrating an understanding that energy conversions between electrical and chemical energy lie at the core of electrochemical cells

	k[halogenoalkane][nucleophile]. SN2 is stereospecific with an inversion of configuration at the carbon. · SN2 reactions are best conducted using aprotic, non-polar solvents and SN1 reactions are best conducted using protic, polar solvents. Electrophilic Addition Reactions: · An electrophile is an electron-deficient species that can accept electron pairs from a nucleophile. Electrophiles are Lewis acids. · Markovnikov's rule can be applied to predict the major product in electrophilic addition reactions of unsymmetrical alkenes with hydrogen halides and interhalogens. The formation of the major product can be explained in terms of the relative stability of possible carbocations in the reaction mechanism. Electrophilic Substitution Reactions: · Benzene is the simplest aromatic hydrocarbon compound (or arene) and has a delocalized structure of π bonds around its ring. Each carbon to carbon bond has a bond order of 1.5. Benzene is susceptible to attack by electrophiles. Reduction Reactions: · Carboxylic acids can be reduced to primary alcohols (via the aldehyde). Ketones can be reduced to secondary alcohols. Typical reducing agents are lithium aluminium hydride (used to reduce carboxylic acids) and sodium borohydride. Applications and skills: Nucleophilic Substitution Reactions: · Explanation of why hydroxide is a better nucleophile than water. · Deduction of the mechanism of the nucleophilic substitution reactions of halogenoalkanes with aqueous sodium hydroxide in	_____ Demonstrating an understanding that key organic reaction types include nucleophilic substitution, electrophilic addition, and electrophilic substitution and redox reactions. Reaction mechanisms vary and help in understanding the different types of reaction taking place

	terms of SN1 and SN2 mechanisms. Explanation of how the rate depends on the identity of the halogen (i.e. the leaving group), whether the halogenoalkane is primary, secondary or tertiary and the choice of solvent. · Outline of the difference between protic and aprotic solvents. Electrophilic Addition Reactions: · Deduction of the mechanism of the electrophilic addition reactions of alkenes with halogens/interhalogens and hydrogen halides Electrophilic Substitution Reactions: · Deduction of the mechanism of the nitration (electrophilic substitution) reaction of benzene (using a mixture of concentrated nitric acid and sulfuric acid). Reduction Reactions: · Writing reduction reactions of carbonyl containing compounds: aldehydes and ketones to primary and secondary alcohols and carboxylic acids to aldehydes, using suitable reducing agents. · Conversion of nitrobenzene to phenylamine via a two-stage reaction **20.2 Synthetic routes** Students will be able to understand: · The synthesis of an organic compound stems from a readily available starting material via a series of discrete steps. Functional group interconversions are the basis of such synthetic routes. · Retro-synthesis of organic compounds. Applications and skills: · Deduction of multi-step synthetic routes given starting reagents and the product	

	20.3 Stereoisomerism Students will be able to understand: · Stereoisomers are subdivided into two classes—conformational isomers, which interconvert by rotation about a σ bond and configurational isomers that interconvert only by breaking and reforming a bond. Configurational isomers are further subdivided into cis-trans and E/Z isomers and optical isomers. Cis-trans isomers can occur in alkenes or cycloalkanes (or heteroanalogues) and differ in the positions of atoms (or groups) relative to a reference plane. According to IUPAC, E/Z isomers refer to alkenes of the form R1R2C=CR3R4 (R1 ≠ R2, R3 ≠ R4) where neither R1 nor R2 need be different from R3 or R4. · A chiral carbon is a carbon joined to four different atoms or groups. · An optically active compound can rotate the plane of polarized light as it passes through a solution of the compound. Optical isomers are enantiomers. Enantiomers are non-superimposable mirror images of each other. Diastereomers are not mirror images of each other. · A racemic mixture (or racemate) is a mixture of two enantiomers in equal amounts and is optically inactive. Applications and skills: · Construction of 3-D models (real or virtual) of a wide range of stereoisomers. · Explanation of stereoisomerism in non-cyclic alkenes and C3 and C4	Demonstrating an understanding that organic synthesis is the systematic preparation of a compound from a widely available starting material or the synthesis of a compound via a synthetic route that often can involve a series of different steps.

	cycloalkanes · Comparison between the physical and chemical properties of enantiomers. · Description and explanation of optical isomers in simple organic molecules. · Distinction between optical isomers using a polarimeter _____ **21.1 Spectroscopic identification of organic compounds** Students will be able to understand: · Structural identification of compounds involves several different analytical techniques including IR, 1H NMR and MS. · In a high resolution 1H NMR spectrum, single peaks present in low resolution can split into further clusters of peaks. · The structural technique of single crystal X-ray crystallography can be used to identify the bond lengths and bond angles of crystalline compounds. Applications and skills: · Explanation of the use of tetramethylsilane (TMS) as the reference standard. · Deduction of the structure of a compound given information from a range of analytical characterization techniques (X-ray crystallography, IR, 1H NMR and MS).	Demonstrating an understanding that stereoisomerism involves isomers which have different arrangements of atoms in space but do not differ in connectivity or bond multiplicity (i.e. whether single, double or triple) between the isomers themselves.

		_____ Demonstrating an understanding that although spectroscopic characterization techniques form the backbone of structural identification of compounds, typically no one technique results in a full structural identification of a molecule. Stereoisomerism involves isomers which have different arrangements of atoms in space but do not differ in connectivity or bond multiplicity (i.e. whether single, double or triple) between the isomers themselves.
10	**1.A Rates of Reaction** **Students will be able to…** Understand the collision theory as applied to the rate of reactions. Particles must: · collide with each other · collide with the correct orientation (that is at the correct angle) · collide with sufficient energy to overcome the 'activation energy'. · Use and label an energy diagram to show that the reacting particles (reactants) must overcome an energy barrier (the activation energy) before they can form products. · The slope of a graph can be used to determine the rate of a reaction.	**Students will show their understanding by...** Demonstrating an understanding that the greater the probability that molecules will collide with sufficient energy and proper orientation the higher the rate of reaction Calculating the rate at different stages of a chemical reaction using data collected or date given.

	· Explain how the factors of concentration, temperature, surface area and catalysts affect the rate of chemical reactions. · Outline and investigate one factor that affects the rate of reaction. (Prac 1)	Demonstrating an understanding of the factors involved together with their effects on altering the rate of a reaction.
	1.B Reactivity of Metals	
	Students will be able to… · Recall that metals can be placed in order of their reactivity by reference to their reaction with water/steam or dilute acid. · Recall that metals can be placed in order of their reactivity by reference to displacement reactions. · Explain the apparent unreactive nature of aluminium. · Appreciate the significance of position of Hydrogen in the reactivity series as related to reaction of metals with water and dilute acid. · Write word and balanced symbol equations for the reactions of metals with water and dilute acid. · Describe rusting as a reaction that involves iron reacting with air and water. · Describe methods of rust prevention, including using sacrificial protection. · Appreciate the significance of position of Carbon in the reactivity series as related to methods of metal extraction, e.g. the extraction of iron from iron oxide. · Appreciate that the method of extraction of metals from their ores is related to their position on the reactivity series.	**Students will show their understanding by...** Demonstrating an understanding that the extraction of metals, and their properties and uses, are related to their reactivity. Identifying through observation which metals can displace hydrogen. Demonstrating an understanding of the ability to identify products from a reaction and to write a balanced equation for the reaction. Creating a labeled drawing of the blast furnace and showing how it is used to extract iron.

	· Apply their understanding of metals in order to investigate the effect of metals on human health and the environment	
	1.C Electrolysis **Students will be able to…** · Recall the use of electrolysis in extracting reactive metals from their ores. · Draw and label an electrolysis cells to show the electrolysis of molten sodium chloride and aqueous copper (II) chloride. · Set up an electrolysis (electrolytic) cell for the electrolysis of aqueous copper (II) chloride. · Explain the processes at each electrode in an electrolysis cell in terms of oxidation and reduction. · Write half equations for the reactions occurring at the electrodes in an electrolysis cell.	**Students will show their understanding by...** Demonstrating an understanding that electrolytic cells convert electrical energy to chemical energy Demonstrating an understanding of the basic principles of oxidation and reduction
	4. Chemicals of Life 1 **Students will be able to…** · Recognize that Carbon is a unique atom which is able to bond to four other atoms and form chains and rings. · Recall that hydrocarbons are composed of the elements carbon and hydrogen only. · Recall that alkanes are saturated hydrocarbons with a general formula C_nH_{2n+2}. · Name and draw the structural formula of some straight chain alkanes. · Draw isomers for hydrocarbons (names not necessary).	**Students will show their understanding by...** Demonstrating an understanding that organic chemistry focuses on the chemistry of compounds containing carbon.

	· Recall the prefix of the names of the first six hydrocarbons. · Recall the characteristics of an homologous series. · Appreciate that the physical properties of hydrocarbons such as melting and boiling point depend on the size of the molecule. · Understand the principles, and recall the need for, the process of fractional distillation · Recall the need for and importance of cracking. · Name and identify simple straight chain alkanes, alkenes, alcohols and carboxylic acids · Appreciate the difference between complete and incomplete combustion. · Write and balance complete combustion reactions. · Compare the reactivity of alkanes and alkenes. · Identify uses and importance of hydrocarbons: (i) alkanes as fuels and lubricants (ii) alkenes as precursors for making other organic molecules such as alcohols and polymers · Write the equations for the production of ethanol: (i) the catalytic addition of water to ethanol (ii) the fermentation of sugar by yeast	Demonstrating an ability to relate physical properties of hydrocarbons listed in tables and graphs to the size of the molecule. Creating a labeled diagram to show the process of fractional distillation. Demonstrating an ability to distinguish between complete and incomplete combustion from products formed.

	6. Chemicals of Life 2 **Students will be able to….** · Demonstrate linking in simple addition polymers starting with monomers e.g. polyethene, polyvinyl chloride, polystyrene, polypropene · Outline some uses of each addition polymer · Demonstrate linking in simple condensation polymers starting with monomers e.g. carbohydrates *(*polysaccharides) peptides, proteins and enzymes, and nylon · Apply their understanding of polymers in order to research the use of polymers in industry to solve human health and environmental problems. · Recognise the structure of glucose and an amino acid · Draw diagrams of condensation polymers using simplified notation · Recall that artificial condensation polymers such as nylon are copies of natural polymers such as silk · Draw a simplified diagram of a fat molecule · Draw a simplified diagram of a soap molecule · Explain the action of soap · Compare the action of soaps and detergents	**Students will show their understanding by...** Demonstrating an understanding that polymers play an important role in biochemistry and technology Recognizing the difference between an addition polymer and condensation polymer through drawing and identifying unknown structures.

9	**5. Acids, Bases and Salts** **Students will be able to….** · Describe properties and uses of acids. · Describe properties and uses of bases. · Use the pH scale to identify the acidity or alkalinity of aqueous substances. · Carry out a neutralization reaction between an acid and a base. · Understand the reactions of acids with · metals, bases/alkalis, carbonates · Balance chemical equations. · Explore various implications of acids in the environment · Describe the properties of salts. · Investigate the solubility of salts. _____ **2. Atoms and Bonding** **Students will be able to…….** · Discuss evidence for atoms and main subatomic particles and scientist involved · Know the relative charge of a proton, a neutron and an electron · Represent the simplified structure of atoms based on the atomic and mass number · Explain that atoms have a tendency to fill their outer valence 'shell' when gaining or losing electrons	**Students will show their understanding by...** Demonstrating an understanding that the characterization of an acid depends on empirical observation such as the production of gases in reactions with metals, the colour changes of indicators or the release of heat in reactions with metal oxides and hydroxides. _____ **Students will show their understanding by...** Demonstrating an understanding that the mass of an atom is concentrated in its minute, positively charged nucleus Demonstrating an understanding that the electron configuration of an atom can be deduced from its atomic number Demonstrating an understanding that the properties of substances are related to their bonding

	· Recall bonds are formed by sharing or transferring electrons (covalent bonding or ionic bonding) · Explain that molecules are formed by atoms sharing electrons · Appreciate that the number of bonds formed by an atom in a molecule can be explained in terms of atomic structure (Bohr model of the atom will help to determine this number) · Practise writing formulae of simple ionic compounds using a periodic table as a reference · Practise writing balanced chemical equations · Represent the states of matter using diagrams · Explain inter-conversion of states of matter in terms of kinetic energy and examine heating and cooling curves · Infer whether a reaction is exothermic or endothermic given information such as change in temperature, or other relevant information · Recall pure substances have characteristic melting and boiling points	Demonstrating an understanding how ions combine to form ionic compounds.
8	**2. Chemical Reactions** **Students will be able to:** · Use appropriate terminology related to chemical reactions, including, but not limited to: *compounds, product,* and *reactant* · Construct molecular models to illustrate the structure of molecules in simple chemical reactions (e.g., $C + O_2 \rightarrow CO_2$; $2H_2 + O_2 \rightarrow 2H_2O$), and produce diagrams of these models · Recognize how coefficients are used when balancing an equation.	**Students will show their understanding by...** Demonstrating an understanding of atoms and their arrangement to form molecules and compounds.

	· Investigate simple chemical reactions, including synthesis, decomposition, and displacement reactions and combustion and acid base reaction, and represent them using a variety of formats (e.g., molecular models, word equations, balanced chemical equations) · Describe the relationships between chemical formulae, composition, and names of binary compounds (e.g., carbon dioxide, CO_2, has two oxygen atoms and one carbon atom) · Explain, using the law of conservation of mass and atomic theory, the rationale for balancing chemical equations · Describe the types of evidence that indicate chemical change (e.g., changes in colour, the production of a gas, the formation of a precipitate, the production or absorption of heat, the production of light)	Demonstrating an understanding of the Law of Conservation of Matter when applied to a chemical reaction. Demonstrating an understanding of the evidence of a chemical change (e.g., the formation of a gas or precipitate, a change in colour or odour, a change in temperature).
7	**5. Periodic Table** **Students will be able to...** · Describe the characteristics of neutrons, protons, and electrons including charge, location and relative mass. · Distinguish between atoms and compounds. · Identify common elements and compounds. · Explain the relationships between the atomic structure of an element and the position of that element in the periodic table. · Compare and contrast the different properties of elements within a group (alkali metals vs. halogens). · Identify and use the symbols of common elements (C, Cl, S, N) and the formula for common substances (Glucose, CO_2, O_2, H_2O) etc.	**Students will show their understanding by...** Demonstrating an understanding of the structure and evolution of the atom model Demonstrating an understanding of the terminology involved and the characteristics of atoms, elements, molecules and compounds Demonstrating an understanding of the periodic table based on the behaviour, properties, and atomic structure of elements

	· Explain how different atomic models evolved as a result of experimental evidence (how the Thompson model changed as a result of the Rutherford Gold Foil experiment). · Describe the patterns and arrangements of electrons of the first 20 elements of the periodic table using the Bohr-Rutherford model. · Describe the characteristic physical and chemical properties of common elements and compounds (ex. Al is a good conductor of heat, Cu reacts to moist air by developing a greenish surface of CuCO3 (penny in vinegar experiment), Sodium carbonate is a white odourless powder that dissolves in water, water has unique physical properties that allows it to support life).	Demonstrating an understanding of some physical and chemical properties of some chemicals
6	**2. What's the Matter?** **Students will be able to…** · Understand that all substances are made up of atoms and molecules in relation to the particle theory of matter. · Know the properties of matter, changes of state, and physical and chemical change. · Investigate the properties of matter and changes in matter. · Describe the characteristics of neutrons, protons, and electrons including charge, location and relative mass. · Show an understanding of models of solids, liquids and gases, in terms of arrangement and movement of the particles. · Explain melting, boiling, evaporation, condensation and sublimation in terms of conversion of the states of matter.	**Students will show their understanding by...** Demonstrating an understanding of the particle theory of matter. Demonstrating that different states of matter have different physical properties.

	· Scientific skills developed in data recording, data presentation and analysis. (i) Explain what is density, with reference to (ii) mass and volume. (iii) Explain how density can be calculated by (iv) the formula: Density = Mass/Volume. · Explain how: (i) density of a liquid may be altered with dissolved substances (ii) density of different liquids/solids may differ even with same volume (iii) density of solids can be changed by altering its volume. · Draw correlation to real life situations or phenomena where density plays an important role in the environment.	Demonstrating the relationship between density, mass and volume. Demonstrating an understanding that different factors affect density.
5	**Students will be able to** · Understand that heat can move from one object to another by conduction and that some materials conduct heat better than others. · Understand that heat is often produced as a byproduct when one form of energy is converted to another.	**Students will be able to show their understanding by** Demonstrating an understanding that energy can come from many sources Demonstrating an understanding of how energy is stored and used in different ways
4	**Students will be able to** · Understand that materials can be manipulated to be used and reused to suit a purpose. · Understand that things can be done to materials to change some of their properties (physical and chemical)	**Students will be able to show their understanding by** Demonstrating an understanding of the recycling process

3	**Students will be able to** · Understand that matter can be in the form of a liquid, a solid or a gas and can be made to change from one to the other but the amount of matter stays the same. · Understand that water exists in the air in different forms and changes from one form to another through the various processes (water cycle) · Understand that things can be done to materials to change some of their properties. · Identify substances by their physical and chemical properties. · Understand that matter can be made of particles that are too small to be seen. · Understand that solids can be understood as having a fixed shape and having a definite volume. · Understand that liquids can be understood as having no fixed shape but having a definite volume. · Understand that gases can be understood as having no fixed shape and no definite volume.	**Students will be able to show their understanding by** Demonstrating the process of changes in states of matter using water and transform that learning to other states of matter. Demonstrate an understanding of the physical and chemical properties of materials and the changes that they can go through under specific conditions.
2		
1		

K2	**Students will be able to** · Identify the source that materials come from. · Identify the properties of different materials. · Understands the suitability of materials for specific purposes	**Students will be able to show their understanding by** Demonstrating how different materials can be used for different purposes.
K1	**Students will be able to** · Understand that light comes from different sources · Understand that light can be used in different ways and for different purposes	**Students will be able to show their understanding by** Demonstrating an understanding of how light can be used in different ways.

Learning Outcomes and Benchmarks

Subject: SCIENCE

Strand: EARTH AND SPACE

Grade/ Phase	**Learning Outcomes** ***Students will be able to …..***	**Benchmarks** ***Students will be able to show their understanding by***
12		
11		
10		
9		
8		
7	Understand that space can only be understood through scaling and modeling. Recognize different level of scale related the size of the universe. Outline the generally accepted Big Bang Theory of the formation of the solar system. Differentiate between the two historical theories as to how our solar system is organized; Geocentric and Heliocentric.	Demonstrating an ability to compare different sizes based on the scale of the universe. Demonstrating that our scientific understanding changes throughout history and that some theories about the solar system must be rewritten.

	Identify the different types of galaxies as elliptical, irregular, and spiral. Describe the physical characteristics of components of the solar system – the sun, planets, natural satellites, comets, asteroids, and meteoroids (e.g., relative size compared to earth, surface temperature, ability to support life, and distance from the sun.) Identify the bodies in space that emit light (stars) and those that reflect light (e.g., moons, planets).	Demonstrate an understanding of the basic components of the solar system.
	Identify cycles in nature (e.g., cycle of day and night, cycle of seasons) and describe the changes within the cycles (e.g., observe the phases of the moon over several months to determine the pattern of change, and record these observations).	Explaining why there are different biomes on the earth which are influenced by seasons, with reference to the cycle of day and night and changes in weather patterns.
	Describe, using models or simulations, the changes that occur when the moon and sun change positions around the earth (e.g., solar and lunar eclipses, tides, phases of the moon).	Explaining the 30-day cycle of the moon and why we only see one side of the moon.
	Describe major humans' contributions that have improved space exploration. (e.g., Canadarm, Hubble telescope, Lunar Rover, ISS)	
	Explain how astronauts meet their basic needs in space on the International Space Station (e.g., through the use of dehydrated foods, backpacks with an oxygen supply, a hermetically sealed cabin with temperature, gold in helmets to protect from the sun)	Demonstrating an understanding that space exploration has improved life on planet Earth. *possibly robotics*
	Describe the challenges astronauts face when travelling to distant planets (not enough oxygen or fuel, effects of microgravity)	**Discussing** and **evaluating** the implications of using science and its application to solve the problem of space travel through writing a reflective essay. (Criterion D)

6		
5		
4		
3	Students will be able to Understand the concept that resources can be renewable or reused.	Students will be able to show their understanding by Explain the scientific process of reusing water through Singapore's NeWater phases.
2	Students will be able to Understand Earth's place in the universe and the solar system. Understand that the earth is one of several planets that orbit the sun and that the moon orbits the earth Understand that night and day are caused by the earth's rotation on its axis Understand that the features on the earth's surface are constantly changed by the combination of slow and rapid processes. Identify the composition of our atmosphere	Students will be able to show their understanding by Demonstrating the physical qualities of earth that can support life Creating a visual that shows an understanding of the relationship between planets and the sun and moon.
1		
K2		
K1		

Learning Outcomes and Benchmarks

Subject : SCIENCE
Strand : LIVING THINGS

Grade/Phase	Learning Outcome Students will be to understand and apply...	Benchmarks Students will be able to show their understanding by….
12 DP Biology	A gene is a heritable factor that consists of a length of DNA and influences a specific characteristic. A gene occupies a specific position on a chromosome. The various specific forms of a gene are alleles. Alleles differ from each other by one or only a few bases. New alleles are formed by mutation. The genome is the whole of the genetic information of an organism. The entire base sequence of human genes was sequenced in the Human Genome Project. Prokaryotes have one chromosome consisting of a circular DNA molecule. Some prokaryotes also have plasmids but eukaryotes do not. Eukaryote chromosomes are linear DNA molecules associated with histone proteins. In a eukaryote species there are different chromosomes that carry different genes.	Demonstrating that every living organism inherits a blueprint for life from its parents. Demonstrating that chromosomes carry genes in a linear sequence that is shared by members of a species.

	Homologous chromosomes carry the same sequence of genes but not necessarily the same alleles of those genes. Diploid nuclei have pairs of homologous chromosomes. Haploid nuclei have one chromosome of each pair. The number of chromosomes is a characteristic feature of members of a species. A karyogram shows the chromosomes of an organism in homologous pairs of decreasing length. Sex is determined by sex chromosomes and autosomes are chromosomes that do not determine sex. ***Students will be able to understand and apply:*** One diploid nucleus divides by meiosis to produce four haploid nuclei. The halving of the chromosome number allows a sexual life cycle with fusion of gametes. DNA is replicated before meiosis so that all chromosomes consist of two sister chromatids. The early stages of meiosis involve pairing of homologous chromosomes and crossing over followed by condensation. Orientation of pairs of homologous chromosomes prior to separation is random. Separation of pairs of homologous chromosomes in the first division of meiosis halves the chromosome number.	Demonstrating that alleles segregate during meiosis allowing new combinations to be formed by the fusion of gametes producing variation.

	Crossing over and random orientation promotes genetic variation. Fusion of gametes from different parents promotes genetic variation ***Students will be able to understand and apply:*** Mendel discovered the principles of inheritance with experiments in which large numbers of pea plants were crossed. Gametes are haploid so contain only one allele of each gene. The two alleles of each gene separate into different haploid daughter nuclei during meiosis. Fusion of gametes results in diploid zygotes with two alleles of each gene that may be the same allele or different alleles. Dominant alleles mask the effects of recessive alleles but co-dominant alleles have joint effects. Many genetic diseases in humans are due to recessive alleles of autosomal genes, although some genetic diseases are due to dominant or co-dominant alleles. Some genetic diseases are sex-linked. The pattern of inheritance is different with sex-linked genes due to their location on sex chromosomes. Many genetic diseases have been identified in humans but most are very rare. Radiation and mutagenic chemicals increase the mutation rate and can cause genetic diseases and cancer	Demonstrating that the inheritance of genes follows patterns and many diseases are related to these patterns.

	Students will be able to understand and apply: Gel electrophoresis is used to separate proteins or fragments of DNA according to size. PCR can be used to amplify small amounts of DNA. DNA profiling involves comparison of DNA. Genetic modification is carried out by gene transfer between species. Clones are groups of genetically identical organisms, derived from a single original parent cell. Many plant species and some animal species have natural methods of cloning. Animals can be cloned at the embryo stage by breaking up the embryo into more than one group of cells. Methods have been developed for cloning adult animals using differentiated cells.	Demonstrating that biologist have developed techniques for artificial manipulation of DNA, cells and organisms.
	Students will be able to understand and apply: Evolution occurs when heritable characteristics of a species change. The fossil record provides evidence for evolution. Selective breeding of domesticated animals shows that artificial selection can cause evolution. Evolution of homologous structures by adaptive radiation explains similarities in structure when there are differences in function.	Demonstrating that there is overwhelming evidence for the evolution of life on Earth.

	Populations of a species can gradually diverge into separate species by evolution. Continuous variation across the geographical range of related populations matches the concept of gradual divergence. ***Students will be able to understand and apply:*** Natural selection can only occur if there is variation among members of the same species. Mutation, meiosis and sexual reproduction cause variation between individuals in a species. Adaptations are characteristics that make an individual suited to its environment and way of life. Species tend to produce more offspring than the environment can support. Individuals that are better adapted tend to survive and produce more offspring while the less well adapted tend to die or produce fewer offspring. Individuals that reproduce pass on characteristics to their offspring. Natural selection increases the frequency of characteristics that make individuals better adapted and decreases the frequency of other characteristics leading to changes within the species.	Demonstrating that the diversity of life has evolved and continues to evolve by natural selection.
	Students will be able to understand and apply: The binomial system of names for species is universal among biologists and has been agreed and developed at a series of congresses. When species are discovered they are given scientific names using the	Demonstrating how species are named and classified using an internationally agreed system.

	binomial system. Taxonomists classify species using a hierarchy of taxa. All organisms are classified into three domains. The principal taxa for classifying eukaryotes are kingdom, phylum, class, order, family, genus and species. In a natural classification, the genus and accompanying higher taxa consist of all the species that have evolved from one common ancestral species. Taxonomists sometimes reclassify groups of species when new evidence shows that a previous taxon contains species that have evolved from different ancestral species. Natural classifications help in identification of species and allow the prediction of characteristics shared by species within a group. ***Students will be able to understand and apply:*** A clade is a group of organisms that have evolved from a common ancestor. Evidence for which species are part of a clade can be obtained from the base sequences of a gene or the corresponding amino acid sequence of a protein. Sequence differences accumulate gradually so there is a positive correlation between the number of differences between two species and the time since they diverged from a common ancestor.	Demonstrating how the ancestry of groups of species can be deduced by comparing their base or amino acid sequences.

	Students will be able to understand and apply: Traits can be analogous or homologous. Cladograms are tree diagrams that show the most probable sequence of divergence in clades. Evidence from cladistics has shown that classifications of some groups based on structure did not correspond with the evolutionary origins of a group or species. ***Students will be able to understand and apply:*** The contraction of circular and longitudinal muscle of the small intestine mixes the food with enzymes and moves it along the gut. The pancreas secretes enzymes into the lumen of the small intestine. Enzymes digest most macromolecules in food into monomers in the small intestine. Villi increase the surface area of epithelium over which absorption is carried out. Villi absorb monomers formed by digestion as well as mineral ions and vitamins. Different methods of membrane transport are required to absorb different nutrients. ***Students will be able to understand and apply:*** Arteries convey blood at high pressure from the ventricles to the tissues of the body.	Demonstrating how the structure of the wall of the small intestine allows it to move, digest and absorb food.

	Arteries have muscle cells and elastic fibres in their walls. The muscle and elastic fibres assist in maintaining blood pressure between pump cycles. Blood flows through tissues in capillaries. Capillaries have permeable walls that allow exchange of materials between cells in the tissue and the blood in the capillary. Veins collect blood at low pressure from the tissues of the body and return it to the atria of the heart. Valves in veins and the heart ensure circulation of blood by preventing backflow. There is a separate circulation for the lungs. The heart beat is initiated by a group of specialized muscle cells in the right atrium called the sinoatrial node. The sinoatrial node acts as a pacemaker. The sinoatrial node sends out an electrical signal that stimulates contraction as it is propagated through the walls of the atria and then the walls of the ventricles. The heart rate can be increased or decreased by impulses brought to the heart through two nerves from the medulla of the brain. Epinephrine increases the heart rate to prepare for vigorous physical activity.	Demonstrating that the blood system continuously transports substances to cells and simultaneously collects waste products.

	Students will be able to understand and apply: The skin and mucous membranes form a primary defence against pathogens that cause infectious disease. Cuts in the skin are sealed by blood clotting. Clotting factors are released from platelets. The cascade results in the rapid conversion of fibrinogen to fibrin by thrombin. Ingestion of pathogens by phagocytic white blood cells gives non-specific immunity to diseases. Production of antibodies by lymphocytes in response to particular pathogens gives specific immunity. Antibiotics block processes that occur in prokaryotic cells but not in eukaryotic cells. Viruses lack a metabolism and cannot therefore be treated with antibiotics. Some strains of bacteria have evolved with genes that confer resistance to antibiotics and some strains of bacteria have multiple resistance.	Demonstrating that the human body has structures and processes that resist the continuous threat by invasion by pathogens.
	Students will be able to understand and apply: Ventilation maintains concentration gradients of oxygen and carbon dioxide between air in alveoli and blood flowing in adjacent capillaries. Type I pneumocytes are extremely thin alveolar cells that are adapted to carry out gas exchange. Type II pneumocytes secrete a solution containing surfactant that	Demonstrating how the lungs are actively ventilated to ensure that gas exchange can occur passively.

	creates a moist surface inside the alveoli to prevent the sides of the alveolus adhering to each other by reducing surface tension. Air is carried to the lungs in the trachea and bronchi and then to the alveoli in bronchioles. Muscle contractions cause the pressure changes inside the thorax that force air in and out of the lungs to ventilate them. Different muscles are required for inspiration and expiration because muscles only do work when they contract. ***Students will be able to understand and apply:*** Neurons transmit electrical impulses. The myelination of nerve fibres allows for saltatory conduction. Neurons pump sodium and potassium ions across their membranes to generate a resting potential An action potential consists of depolarization and repolarization of the neuron. Nerve impulses are action potentials propagated along the axons of neurons. Propagation of nerve impulses is the result of local currents that cause each successive part of the axon to reach the threshold potential. Synapses are junctions between neurons and between neurons and receptor or effector cells. When presynaptic neurons are depolarized they release a neurotransmitter into the synapse.	Demonstrating that within the nervous system the neurons transmit the message, and the synapses modulate the message.

	A nerve impulse is only initiated if the threshold potential is reached. ***Students will be able to understand and apply:*** Insulin and glucagon are secreted by β and α cells of the pancreas respectively to control blood glucose concentration. Thyroxin is secreted by the thyroid gland to regulate the metabolic rate and help control body temperature. Leptin is secreted by cells in adipose tissue and acts on the hypothalamus of the brain to inhibit appetite. Melatonin is secreted by the pineal gland to control circadian rhythms. A gene on the Y chromosome causes embryonic gonads to develop as testes and secrete testosterone. Testosterone causes pre-natal development of male genitalia and both sperm production and development of male secondary sexual characteristics. Estrogen and progesterone cause pre-natal development of female reproductive organs and female secondary characteristics during puberty The menstrual cycle is controlled by negative and positive feedback mechanisms involving ovarian and pituitary hormones.	Demonstrating and understanding of the relationship between hormones and tissues, and understand that specific hormones are used when signals need to be widely distributed. Demonstrating an understanding of how male and female secondary sexual characteristics are regulated by hormones during puberty.
12 DP ESS	***Students will be able to understand and apply:*** The mechanism of natural selection (evolution) and speciation; The role of abiotic factors to the formation of new species (see plate tectonics); The process of succession (and its types);	Demonstrating an understanding that ecosystems are different in terms of their biodiversity.

	The factors that lead to loss of biodiversity; Factors that make species prone to extinction; The concepts will focus on *biodiversity, types of diversity (genetic, species and habitat), natural selection, isolation and species, diversity, vulnerability and succession*. The different types of pollutions (soil, water, air); Eutrophication and explain its effects on biotic components; Acid deposition and its management strategies; The depletion of stratospheric ozone and its management strategies; Solid domestic waste and its management strategies; Urban air pollution (photochemical smog) and its effects on living organisms. The effect and origin of greenhouse gases (applied to our planet); The effects of the Kyoto Protocol The concepts will focus on *pollution, eutrophication, acid deposition, domestic waste, depletion of stratospheric ozone and pollution management strategies*. Global Warming and their effects on living organisms. The concepts will focus on *GW, climate change, El Nino/La Nina phenomena, greenhouse gas, CFCs, Kyoto Protocol and diming*.	Demonstrating an understanding of pollution in the form of air, water and soil and the management strategies to control these forms of pollution.

12DP SEHS	***Students will be able to understand and apply:*** The macronutrients and micronutrients and their main functions including macronutrients; lipid (fat), carbohydrate, water and protein and micronutrients; vitamins, minerals and fibre. Chemical composition of glucose, triglycerides, and protein. Saturated fats and unsaturated fats. Essential and non-essential amino acids. Recommendations for a healthy diet including relative contributions of carbohydrates, lipids, and protein. Approximate energy content of carbohydrates (1760 kJ), lipids (4000 kJ) and protein (1720 kJ) per 100 g. Different forms of metabolism including; anabolism, aerobic catabolism and anaerobic catabolism. Glycogen is and its major storage sites. Major sites of triglyceride storage. Role of insulin in the formation of glycogen and the accumulation of body fat. Glycogenolysis and lipolysis. Functions of glucagon and adrenaline during fasting and exercise. Role of insulin and muscle contraction on glucose uptake during exercise.	Demonstrating an understanding of the role of nutrition in maintaining a balanced and healthy diet. Demonstrating an understanding of the process of metabolism as it relates to carbohydrates and fats.

	Ultrastructure of a generalized animal cell (ribosomes, rough endoplasmic reticulum, lysosomes, Golgi apparatus, mitochondrion and nucleus). Ultrastructure of a mitochondrion showing the cristae, inner matrix and outer smooth membrane Cell respiration. Adenosine can gain and lose a phosphate molecule. Role of ATP in muscle contraction. Re-synthesis of ATP by the ATP–CP system. Describe the production of ATP by the lactic acid system. Explain the phenomena of oxygen deficit and oxygen debt. Production of ATP from glucose and fatty acids by the aerobic system. Relative contributions of the three energy systems during different types of exercise. Different types of exercise (endurance athlete, games player, and sprinter) should be considered.	Demonstrating an understanding of the cellular processes involved in converting energy within living systems as it relates to both aerobic and anaerobic pathways.
11 DP Biology	***Students will be able to understand and apply:*** According to the cell theory, living organisms are composed of cells. Organisms consisting of only one cell carry out all functions of life in that cell.	Demonstrating an understanding that the evolution of multicellular organisms allowed cell specialization and cell replacement.

	Surface area to volume ratio is important in the limitation of cell size. Multicellular organisms have properties that emerge from the interaction of their cellular components. Specialized tissues can develop by cell differentiation in multicellular organisms. Differentiation involves the expression of some genes and not others in a cell's genome. The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development and also makes stem cells suitable for therapeutic uses. ***Students will be able to understand and apply:*** Prokaryotes have a simple cell structure without compartmentalization. Eukaryotes have a compartmentalized cell structure. Electron microscopes have a much higher resolution than light microscopes ***Students will be able to understand and apply:*** Phospholipids form bilayers in water due to the amphipathic properties of phospholipid molecules. Membrane proteins are diverse in terms of structure, position in the membrane and function. Cholesterol is a component of animal cell membranes.	Demonstrating an understanding that eukaryotes have a much more complex cell structure than prokaryotes. Demonstrating an understanding that the application of electron microscopy in furthering understanding of anatomy and physiology in living things. (JFitts**)** Demonstrating an understanding that the structures of biological membranes make them fluid and dynamic.

	Students will be able to understand and apply: Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport. The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis. Vesicles move materials within cells.	Demonstrating an understanding that membranes control the composition of cells by active and passive transport.
	Students will be able to understand and apply: Cells can only be formed by division of pre-existing cells. The first cells must have arisen from non-living material. The origin of eukaryotic cells can be explained by the endosymbiotic theory	Demonstrating an understanding that there is an unbroken chain of life from the first cells on Earth to all cells in organisms alive today.
	Students will be able to understand and apply: Mitosis is division of the nucleus into two genetically identical daughter nuclei. Chromosomes condense by supercoiling during mitosis. Cytokinesis occurs after mitosis and is different in plant and animal cells. Interphase is a very active phase of the cell cycle with many processes occurring in the nucleus and cytoplasm. Cyclins are involved in the control of the cell cycle.	Demonstrating an understanding that cell division is essential but must be controlled, otherwise disease such as cancer can arise.

	Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours. ***Students will be able to understand and apply:*** Molecular biology explains living processes in terms of the chemical substances involved. Carbon atoms can form four covalent bonds allowing a diversity of stable compounds to exist. Life is based on carbon compounds including carbohydrates, lipids, proteins and nucleic acids. Metabolism is the web of all the enzyme-catalysed reactions in a cell or organism. Anabolism is the synthesis of complex molecules from simpler molecules including the formation of macromolecules from monomers by condensation reactions. Catabolism is the breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers.	Demonstrating an understanding that living organisms control their composition by a complex web of chemical reactions, including anabolism and catabolism.
	Students will be able to understand and apply: Water molecules are polar and hydrogen bonds form between them. Hydrogen bonding and dipolarity explain the cohesive, adhesive, thermal and solvent properties of water. Substances can be hydrophilic or hydrophobic.	Demonstrating an understanding that water is the medium of life, and its chemical bonding explains its unique properties.

	Students will be able to understand and apply: Monosaccharide monomers are linked together by condensation reactions to form disaccharides and polysaccharide polymers. Fatty acids can be saturated, monounsaturated or polyunsaturated. Unsaturated fatty acids can be cis or trans isomers. Triglycerides are formed by condensation from three fatty acids and one glycerol.	Demonstrating an understanding that compounds of carbon, hydrogen and oxygen are used to supply and store energy.
	Students will be able to understand and apply: Amino acids are linked together by condensation to form polypeptides. There are 20 different amino acids in polypeptides synthesized on ribosomes. Amino acids can be linked together in any sequence giving a huge range of possible polypeptides. The amino acid sequence of polypeptides is coded for by genes. A protein may consist of a single polypeptide or more than one polypeptide linked together. The amino acid sequence determines the three-dimensional conformation of a protein. Living organisms synthesize many different proteins with a wide range of functions. Every individual has a unique proteome.	Demonstrating an understanding of the structure of protein and how this structure is related to its function. (J Fitts) Demonstrating an understanding that proteins have a very wide range of functions in living organisms.

	Students will be able to understand and apply: Enzymes have an active site to which specific substrates bind. Enzyme catalysis involves molecular motion and the collision of substrates with the active site. Temperature, pH and substrate concentration affect the rate of activity of enzymes. Enzymes can be denatured. Immobilized enzymes are widely used in industry.	Demonstrating an understanding that enzymes control the metabolism of the cell through specificity with a substrate, and are affected by various environmental factors. *(modified by J. Fittts)*
	Students will be able to understand and apply: The nucleic acids DNA and RNA are polymers of nucleotides. DNA differs from RNA in the number of strands present, the base composition and the type of pentose. DNA is a double helix made of two antiparallel strands of nucleotides linked by hydrogen bonding between complementary base pairs.	Demonstrating an understanding that the structure of DNA allows efficient storage of genetic information**.**
	Students will be able to understand and apply: The replication of DNA is semi-conservative and depends on complementary base pairing. Helicase unwinds the double helix and separates the two strands by breaking hydrogen bonds. DNA polymerase links nucleotides together to form a new strand,	Demonstrating an understanding that genetic information in DNA can be accurately copied and can be translated to make the proteins needed by the cell.

	using the pre-existing strand as a template. Transcription is the synthesis of mRNA copied from the DNA base sequences by RNA polymerase. Translation is the synthesis of polypeptides on ribosomes. The amino acid sequence of polypeptides is determined by mRNA according to the genetic code. Codons of three bases on mRNA correspond to one amino acid in a polypeptide. Translation depends on complementary base pairing between codons on mRNA and anticodons on tRNA. ***Students will be able to understand and apply:*** Cell respiration is the controlled release of energy from organic compounds to produce ATP. ATP from cell respiration is immediately available as a source of energy in the cell. Anaerobic cell respiration gives a small yield of ATP from glucose. Aerobic cell respiration requires oxygen and gives a large yield of ATP from glucose.	Demonstrating an understanding that cell respiration supplies ATP energy for the functions of life.

	Students will be able to understand and apply:	
	Photosynthesis is the production of carbon compounds in cells using light energy.	Demonstrating an understanding that photosynthesis uses the energy in sunlight to produce the chemical energy needed for life in the form of glucose.
	Visible light has a range of wavelengths with violet the shortest wavelength and red the longest.	
	Chlorophyll absorbs red and blue light most effectively and reflects green light more than other colours.	
	Oxygen is produced in photosynthesis from the photolysis of water.	
	Energy is needed to produce carbohydrates and other carbon compounds from carbon dioxide.	
	Temperature, light intensity and carbon dioxide concentration are possible limiting factors on the rate of photosynthesis.	Demonstrating an understanding that various factors have an effect of various factors on the rate of photosynthesis (J Fitts)
	Students will be able to understand and apply:	
	Species are groups of organisms that can potentially interbreed to produce fertile offspring.	Demonstrating an understanding that the different levels of complexity within an ecosystem (J Fitts)
	Members of a species may be reproductively isolated in separate populations.	
	Species have either an autotrophic or heterotrophic method of nutrition (a few species have both methods).	Demonstrating an understanding of trophic levels and be able to describe the relationship between different trophic levels. (JFitts)
	Consumers are heterotrophs that feed on living organisms by ingestion.	Demonstrating an understanding that the continued survival of living organisms including humans depends on sustainable communities.

	Detritivores are heterotrophs that obtain organic nutrients from detritus by internal digestion. Saprotrophs are heterotrophs that obtain organic nutrients from dead organisms by external digestion. A community is formed by populations of different species living together and interacting with each other. A community forms an ecosystem by its interactions with the abiotic environment. Autotrophs obtain inorganic nutrients from the abiotic environment. The supply of inorganic nutrients is maintained by nutrient cycling. Ecosystems have the potential to be sustainable over long periods of time. ***Students will be able to understand and apply:*** Most ecosystems rely on a supply of energy from sunlight. Light energy is converted to chemical energy in carbon compounds by photosynthesis. Chemical energy in carbon compounds flows through food chains by means of feeding. Energy released from carbon compounds by respiration is used in living organisms and converted to heat. Living organisms cannot convert heat to other forms of energy.	Demonstrating an understanding that ecosystems require a continuous supply of energy to fuel life processes and to replace energy lost as heat.

	Heat is lost from ecosystems. Energy losses between trophic levels restrict the length of food chains and the biomass of higher trophic levels. ***Students will be able to understand and apply:*** Autotrophs convert carbon dioxide into carbohydrates and other carbon compounds. In aquatic ecosystems carbon is present as dissolved carbon dioxide and hydrogen carbonate ions. Carbon dioxide diffuses from the atmosphere or water into autotrophs. Carbon dioxide is produced by respiration and diffuses out of organisms into water or the atmosphere. Methane is produced from organic matter in anaerobic conditions by methanogenic archaeans and some diffuses into the atmosphere or accumulates in the ground. Methane is oxidized to carbon dioxide and water in the atmosphere. Peat forms when organic matter is not fully decomposed because of acidic and/or anaerobic conditions in waterlogged soils. Partially decomposed organic matter from past geological eras was converted either into coal or into oil and gas that accumulate in porous rocks.	Demonstrating an understanding that continued availability of carbon in ecosystems depends on carbon cycling.

	Carbon dioxide is produced by the combustion of biomass and fossilized organic matter. Animals such as reef-building corals and mollusca have hard parts that are composed of calcium carbonate and can become fossilized in limestone. ***Students will be able to understand and apply:*** Carbon dioxide and water vapour are the most significant greenhouse gases. Other gases including methane and nitrogen oxides have less impact. The impact of a gas depends on its ability to absorb long wave radiation as well as on its concentration in the atmosphere. The warmed Earth emits longer wavelength radiation (heat). Longer wave radiation is absorbed by greenhouse gases that retain the heat in the atmosphere. Global temperatures and climate patterns are influenced by concentrations of greenhouse gases. There is a correlation between rising atmospheric concentrations of carbon dioxide since the start of the industrial revolution 200 years ago and average global temperatures. Recent increases in atmospheric carbon dioxide are largely due to increases in the combustion of fossilized organic matter.	Demonstrating an understanding that concentrations of gases in the atmosphere affect climates experienced at the Earth's surface.

11 DP ESS	***Students will be able to understand and apply:*** Trophic levels in food chains and food webs selected (producers, consumers, decomposers herbivores, carnivores, top carnivores). Describe and explain population interactions - competition, parasitism, mutualism/commensalism, predation and herbivory. Use methods for measuring any three significant abiotic factors and how these may vary in a given ecosystem with depth, time or distance (marine - pH, salinity, and wave action etc.; freshwater - pH, total hardness, turbidity etc.; terrestrial - temperature, light intensity etc.) Methods should include capture–mark–release–recapture (Lincoln index) and quadrats for measuring population density, percentage frequency and percentage cover; Simpson's diversity index. Know the distribution, structure and relative productivity of tropical rainforests, deserts, tundra and aher biome. Describe photosynthesis and respiration in terms of inputs, outputs and energy transformations.	Demonstrating and understanding that Use relevant terms (for example,) and apply them to local, named examples, food chains and food webs. Demonstrating an understanding that population of species interacts with other species for food, space, and partner. Demonstrating an understanding of how to describe and evaluate at least three methods of measuring the abiotic (physical) factors within an ecosystem. (the original is below) Describing and evaluating methods for measuring at least three abiotic (physical) factors within an ecosystem. Demonstrating an understanding of how to describe and evaluate methods for estimating abundance and diversity of organisms. Demonstrating an understanding of photosynthesis as a process that requires carbon dioxide, water, chlorophyll and certain visible wavelengths of light to produce organic matter and oxygen
11 DP **SEHS**	Distinguish anatomically between the axial and appendicular skeleton. Distinguish between the axial and appendicular skeleton in terms of function. State the four types of bone (long, short, flat, irregular). Draw and annotate the structure of a long bone (epiphysis, spongy bone, articular cartilage, diaphysis, compact bone, bone marrow, marrow cavity, blood vessel and periosteum).	Demonstrating an understanding of the main structures of the skeletal system.

	Distinguish between the different types of joint in relation to movement permitted. (fibrous, cartilaginous, synovial joints) (hinge, ball and socket, condyloid, pivot, glidding and saddle). Include smooth, cardiac and skeletal. Limit to epimysium, perimysium, endomysium,muscle fibre, myofibril, sarcomere, actin and myosin. Include the muscles from: the anterior—deltoid, pectoralis, iliopsoas,sartorius, quadriceps femoris (rectus femoris, vastus intermedialis, vastus medialis, vastus lateralis), tibialis anterior, abdominus rectus, external obliques and biceps brachii, the posterior-trapezius, triceps brachii,latissimus dorsi, gluteus maximus,hamstrings (biceps femoris, semitendinosus,semimembranosus), gastrocnemius, soleus,erector spinae	Demonstrating an understanding of the main characteristics of the muscular system.
	Nose, mouth, pharynx, larynx, trachea, bronchi,bronchioles, lungs and alveoli. Limit to low resistance pathway for air flow,defence against chemicals and other harmfulsubstances that are inhaled, warming andmoistening the air.Include the actions of the diaphragm and the intercostal muscles, and the relationship between volume and pressure. Students should be aware that accessory muscles are also important during strenuous exercise Blood is composed of cells (erythrocytes, leucocytes and platelets) and plasma. Blood is also the transport vehicle for electrolytes, proteins,gases, nutrients, waste products and hormones. -The HEART, names of the four chambers, four valves (bicuspid, tricuspid, aortic and pulmonary valve) and the four major blood vessels (vena cava, pulmonary vein, the aorta and pulmonary artery) of the pulmonary and systemic circulation are required.	Demonstrating an understanding of the main structures and functions of the ventilatory system.

	-Cardiac output = stroke volume × heart rate. Stroke volume expands and heart rate increases during exercise. Systolic: the force exerted by blood on arterial walls during ventricular contraction. Diastolic: the force exerted by blood on arterial walls during ventricular relaxation. Maximal oxygen consumption (VO2max) represents the functional capacity of the oxygen transport system and is sometimes referred to asmaximal aerobic power or aerobic capacity. MOTOR UNIT- Limit to dendrite, cell body, nucleus, axon, motor end plate, synapse and muscle. SKELETAL MUSCLE CONTRACTION-Includ the terms myofibril, myofilament, sarcomere, actin and myosin, H zone, A band,Z line, tropomyosin, troponin, sarcoplasmic reticulum, calcium ions and ATP. Limit fibre types to slow twitch (type I) and fast twitch (type IIa and type IIb).Type IIa and IIb are high in glycogen content depending on training status. Consider flexion, extension, abduction, adduction, pronation, supination, elevation, depression, rotation, circumduction, dorsi flexion, plantar flexion, eversion and inversion. Consider isotonic, isometric, isokinetic, concentric and eccentric. Consider agonist and antagonist. muscles	Demonstrating an understanding of the main structures and functions of the cardiovascular system. Demonstrating an understanding of the main functions of the neuromuscular system. Demonstrating an understanding of the types of synovial joints and their movements.
10	**7. Homeostasis** **Students will be able to...** State that 'homeostasis' means the maintenance of the internal environment (of the body)	**Students will be able to show their understanding by...** Demonstrating an understanding of how negative feedback functions through the release of hormones, and how this mechanism is involved in thermoregulation, osmoregulation and blood glucose regulation.

	Explain how temperature, water and glucose concentration are actively maintained in the human body. Realize that mammals maintain a constant internal body temperature despite fluctuations in environmental temperature. State that the nervous system and the endocrine system are involved in maintaining homeostasis. Explain how negative feedback loops control the mechanism of maintaining homeostasis Explain how sweating, vasodilation and vasoconstriction help in regulating body temperature Know that mammals regulate the concentration of glucose in the blood State that the secretion of insulin by the pancreas reduces high blood glucose levels and that failure of this mechanism may lead to diabetes Know that urea is a nitrogenous waste product formed in the liver from excess proteins and is excreted by the kidneys in urine Label the position of the kidneys in the mammalian body and their relationship to the renal artery, renal vein, ureter, bladder and urethra Explain how the kidneys remove excess water and urea from the blood plasma and know that urine is produced and stored in the bladder Understand that the amount of water in urine can be varied by the	Demonstrating an understanding of the different parts of the nephron and explain how various substances are controlled within the kidney.

	kidney, in response to changes in the water content of the blood Identify the location and function of the pituitary gland as a means of controlling water content within the body	
	3. <u>Ecosystems:</u> ***Students will be able to...*** Understand that an ecosystem is the result of abiotic and biotic factors interacting and be able to state examples of each of these factors. Identify the major biomes on the planet and describe the abiotic and biotic factors for each one. Define species, habitat, population, community, ecosystem and ecology and be able to understand their different levels of complexity. Define adaptation and give examples of how organisms have evolved, through natural selection, adaptations to various environmental conditions. Define niche and using a named example describe the niche of that species. Distinguish between producer/autotroph and consumer/heterotroph giving examples. Classify consumers as herbivores, omnivores, carnivores or saprotrophs. Be able to arrange organisms based on their trophic level into a food chain.	***Students will be able to show their understanding by...*** Demonstrating an understanding of how abiotic and biotic factors interact within specific ecosystems and identify the characteristics of the biomes these ecosystems make up. Demonstrating an understanding that the living environment is composed of different levels of organisation and are the result of living and non-living factors. Demonstrating an understanding of adaptations in living things and how environmental conditions cause evolutionary changes. Demonstrating an understanding of the specific roles and relationships that exist within an ecosystem. Demonstrating an understanding of trophic levels and types of consumers and explain how organisms interact with each other in food chains and food webs. Demonstrating an understanding that energy is lost through the trophic levels and that nutrients are recycled within an ecosystem.

	Be able to combine several food chains into a food web in order to show interdependent relationships in a community. Interpret the three types of ecological pyramids (numbers, biomass and energy) and describe how energy flows in an ecosystem. Understand the role of decomposers in nutrient cycling. Identify limiting factors to population growth in an ecosystem and be able to graph an s-curve and a j-curve to show contrasting population trends. Describe the predator-prey relationship using a named example. Describe some of the impacts humans have had on the diversity of living things.	Demonstrating an understanding of the transfer of energy in trophic levels and be able to explain energy flow using ecological pyramids.
9	**5A. Photosynthesis and Cellular Respiration** ***Students will be able to...*** Recall the balanced chemical reaction for photosynthesis using carbon dioxide, water, glucose and oxygen. Explain how photosynthesis transfers energy from sunlight into energy in chemical bonds such as glucose and starch. State that light from the sun is composed of a range of wavelengths and that chlorophyll is the main plant pigment, which captures the red and blue wavelengths of light. Diagram and explain the structure of a chloroplast found within photosynthesizing organisms.	***Students will be able to show their understanding by...*** Demonstrating an understanding of the reactants, products and processes involved in photosynthesis, including the roles of light and chlorophyll.

	Explain how leaf structure enables it to carry out photosynthesis efficiently including reference to the epidermis, palisade mesophyll, spongy mesophyll, cuticle and stomata.	Demonstrating an understanding of how the structure of a leaf is adapted to maximise photosynthesis.
	Explain how photosynthesis affects the concentration of carbon dioxide and oxygen in the atmosphere.	Demonstrating an understanding of the role of photosynthesis in affecting the concentrations of oxygen and carbon dioxide gases in the atmosphere.
	Outline and investigate the effect of temperature, light intensity or carbon dioxide concentration on the rate of photosynthesis.	Demonstrating an understanding of the reactants, products and processes involved in cellular respiration, both aerobically and anaerobically.
	State that in cellular respiration glucose is broken down to produce ATP.	Demonstrating an understanding of the similarities and differences between the processes of photosynthesis and respiration. Demonstrating an understanding that the process of cellular respiration makes energy for all cells.
	Understand the relationship between the reactions of photosynthesis and cellular respiration.	
	Identify that aerobic cellular respiration has several steps occurring in both the cytoplasm and the mitochondria of both plant and animal cells.	Demonstrating an understanding of the products of anaerobic respiration in human cells as well as yeast cells.
	Explain that during anaerobic cellular respiration lactic acid is produced in humans while ethanol is produced in yeast.	
	<u>5B. Human Respiratory System</u> ***Students will be able to...*** Describe the structure of the human ventilation system, including the movement of the intercostal muscles, the diaphragm and the rib cage.	***Students will be able to show their understanding by…*** Demonstrating an understanding of the human ventilation system at the macroscopic, cellular and molecular levels, and the harmful effects of pollutants on this system.
	Explain how the structure of the alveoli and blood capillaries enable gaseous exchange to occur and the importance of diffusion.	

	Explain the role of hemoglobin found in red blood cells. Discuss the effects of air pollution and smoking on the structure and function of the respiratory system.	
8	**3. Human Variation and Genetics** ***Students will be able to...*** Know that the human body is a machine with many functional parts and the entire body must work together to maintain life. Identify that there are many systems in the body including digestive system, circulatory system, nervous system, excretory system, respiratory system. Draw a basic model of the DNA molecule. Understand the base pairing rule as it applies to the universal code of DNA in all living organisms. Understand that DNA codes for proteins. Understand what a trait is and how it is passed on from generation to generation. Understand what is chromosome is and why it is necessary to form in the process of mitosis. Understand that DNA organises itself into a coiled structure called a chromosome that forms before cell division.	***Students will be able to show their understanding by...*** Demonstrating and Understand using appropriate science and technology vocabulary that organ systems are a component of a larger system (the body) and as such they work together and affect one another. Demonstrating and understanding that the complexity of life is based on a simple code. Demonstrating an understanding that through cell division we create a pattern of inheritance and variation. Presenting their family traits as the result of inheritance patterns.

	Explain what a gene is and the difference between an allele and a gene. Understand the basic steps of mitosis and meiosis. Random combination of chromosomes leads to variation within the offspring of living organisms. Define genotype and understand that an individual can be heterozygous or homozygous for a trait. Show inheritance patterns in a family based on a visible trait. Use a Punnett Square to show how genes can be combined to form new variation in offspring. Look at a karyotype and identify the sex of the individual and see any abnormalities.	
7	**2. Cells and Microscopes** ***Students will be able to...*** Describe the postulates of the cell theory. (e.g., the cell is the basic unit of life; all cells come from pre-existing cells; all living things are made up of one or more cells) Know that cells are organised into tissues, which are organised into organs, which are organised into organ systems. Identify that organisms can be organised into seven main Kingdoms (Plantae, Fungi, Protista, Animalia, Archaebacteria, and Eubacteria), which can be further divided into Phylum, Class, Order, Family, Genus, and Species.	***Students will be able to show their understanding by...*** Demonstrating an understanding of the basic structure and function of plant and animal cells and cell processes and identify the differences between the two. Demonstrating an understanding of the cell theory through an examination of a virus. Demonstrating an understanding of the use of a microscope correctly and safely to find and observe components of plant and animal cell.

	Show how to use a dissecting and compound light microscope correctly and safely to find and observe components of plant and animal cells (e.g., using an onion slice or a prepared slide of a protist) and make accurate scientific drawings of their observation. Identify and label the various organelles found in plant and animal cells(including the nucleus, chromosomes, cytoplasm, cell membrane, cell wall, chloroplasts, lysosomes mitochondria, vacuole, golgi apparatus, and ribosomes), and explain their basic functions within the cell. (i.e.mitochondria are the “powerhouses” of the cell, cell membrane can control the substances that move into or out of a cell because the membrane is selectively permeable, etc) Explain how diffusion and osmosis are important processes for cell survival, and describe using appropriate scientific vocabulary how they can be applied Investigate using scientific inquiry/experimentation skills the processes of osmosis and diffusion.	Demonstrating an understanding of the functions of dissection, compound light, and electron microscopes and their uses in cell biology. Preparing dry and wet mount slides of a variety of objects for use with a compound light microscope.

6	**4. Environmental Science** ***Students will be able to...***	***Students will be able to show their understanding by...***
	Recognize biodiversity as the variety of life on earth, including variety within each species of plant and animal, among species of plants and animals in communities, and among communities and the physical landscapes that support them.	With reference to a selected biome, demonstrating an understanding of adaptive features of animals to its specific environment through the creation of a hybrid creature and it's associated food web.
	Identify how ecosystems are made up of biotic (living) and abiotic (non-living) elements, which depend on each other to survive.	Demonstrating an understanding of an ecosystem (e.g. wetland, a pond, a forest, a log. etc) as system of interactions between living organisms and the environment.
	Describe the roles and interactions of producers, consumers, and decomposers within an ecosystem.	Demonstrating an understanding of the transfer of energy in a food chain and explain the effects of the elimination of any part of the chain.
	Explain the differences between trophic levels and interrelationship between organisms within a food chain and food web as well as concept of predator-prey relationship.	Demonstrating an understanding of how ecosystems are in a constant state of change and the changes may be caused by human intervention such as deforestation, oil spills, eutrophication, industrialization and nuclear plant leaks.
	Describe the general characteristics of phylum Chordata (vertebrates-invertebrates) and Classes mammals, fish, amphibians, birds and insects.	
	Describe ways in which human activities and technologies alter balances and interactions in the environment	Demonstrating an understanding of negative impact of human actions on living things [plants] through experiment planning and execution, data collection, data processing, and analysis.
	Use scientific inquiry/research skills and knowledge acquired from previous investigations, to investigate the basic needs, characteristics, behaviour, and adaptations of an animal of their choice	

5	***Students will be able to*** Identify the characteristics of pubertal change and why they occur. Understand factors that affect personal, physical, social and emotional growth. Understand how growth and development of your body are influenced by nutrition and lifestyle choices and that these occur in different ways.	***Students will be able to show their understanding by*** Demonstrating how bodies change due to puberty and how puberty impacts personal growth and development. Demonstrating how bodies are affected by lifestyle and nutrition.
4	***Students will be able to*** Understand the structure and function of human body systems Understand interactions within and between body systems. Understand how the systems in the human body work together to meet our basic health needs.	***Students will be able to show their understanding by*** Demonstrating how systems in our body interact and work together to maintain good health. Presenting information on individual's responsibility in maintaining good health.
3	***Students will be able to*** Know the importance of fresh water to living things.	***Students will be able to show their understanding by*** Demonstrating the consequences of our actions on the availability of water for living things.
2	***Students will be able to*** Understand the components of an ecosystem, including living and nonliving factors. Understands the basic needs of plants.	***Students will be able to show their understanding by*** Creating an ecosystem using the Sungei Buloh Reserve Wetlands. Presenting factors that can impact on the balance within an ecosystem.

	Understand the requirements of a healthy ecosystem: change in habitat, number of animals per layer, invasive species.	
1	***Students will be able to*** Identify the five senses. Understand how people interact with the environment through their senses of sight, hearing, touch, smell, and taste. Understand life cycles of different living things and the changes they go through. Understand the stages of development and interruptions to life cycles	***Students will be able to show their understanding by*** Demonstrating how our senses work together in our daily lives. Demonstrating similarities and differences in life cycles and the factors that can interrupt life cycles.
K2	***Students will be able to*** Understands that all animals have certain requirements so they can stay alive Understands the impact that different kinds of human actions have on animals and their environment.	***Students will be able to show their understanding by*** Demonstrating ways we need to care for animals.
K1	***Students will be able to*** Identify how & why we move and the importance of movement in our lives. Understand that we (animals) closely resemble our parents. Understands that differences exist among individuals.	***Students will be able to show their understanding by*** Demonstrating their own movement in different ways. Creating realistic replicas of themselves with different materials.

Learning Outcomes and Benchmarks

Subject: SCIENCE

Strand: FORCES AND ENERGY

Grade / Phase	**Learning Outcomes** ***Students will be able to understand and apply***	**Benchmarks** ***Students will be able to show their understanding by….***
12	***Students will be able to understand and apply*** · Specific energy and energy density of fuel sources · Sankey diagrams · Primary energy sources · Electricity as a secondary and versatile form of energy · Renewable and non-renewable energy sources · Solving specific energy and energy density problems · Sketching and interpreting Sankey diagrams · Describing the basic features of fossil fuel power stations, nuclear power stations, wind generators, pumped storage hydroelectric systems and solar power cells · Solving problems relevant to energy transformations in the context of these generating systems · Discussing safety issues and risks associated with the production of nuclear power · Describing the differences between photovoltaic cells	Demonstrating an understanding that the constant need for new energy sources implies decisions that may have a serious effect on the environment, the finite quantity of fossil fuels and their implication in global warming has led to the development of alternative sources of energy, and that this continues to be an area of rapidly changing technological innovation.

	and solar heating panels	
	Students will be able to understand and apply · Conduction, convection and thermal radiation · Black-body radiation · Albedo and emissivity · The solar constant · The greenhouse effect · Energy balance in the Earth surface–atmosphere system · Sketching and interpreting graphs showing the variation of intensity with wavelength for bodies emitting thermal radiation at different temperatures · Solving problems involving the Stefan–Boltzmann law and Wien's displacement law · Describing the effects of the Earth's atmosphere on the mean surface temperature · Solving problems involving albedo, emissivity, solar constant and the Earth's average temperature	Demonstrating an understanding that for simplified modelling purposes the Earth can be treated as a black-body radiator and the atmosphere treated as a grey-body.
	Students will be able to understand and apply · The defining equation of SHM · Energy changes · Solving problems involving acceleration, velocity and displacement during simple harmonic motion, both graphically and algebraically · Describing the interchange of kinetic and potential	Demonstrating an understanding that the solution of the harmonic oscillator can be framed around the variation of kinetic and potential energy in the system.

	energy during simple harmonic motion · Solving problems involving energy transfer during simple harmonic motion, both graphically and algebraically	
	Students will be able to understand and apply · The nature of single-slit diffraction · Describing the effect of slit width on the diffraction pattern · Determining the position of first interference minimum · Qualitatively describing single-slit diffraction patterns produced from white light and from a range of monochromatic light frequencies · Students will be expected to be aware of the approximate ratios of successive intensity maxima for single-slit interference patterns · Calculations will be limited to a determination of the position of the first minimum for single-slit interference patterns using the approximation equation	Demonstrating an understanding that single-slit diffraction occurs when a wave is incident upon a slit of approximately the same size as the wavelength.
	Students will be able to understand and apply · Young's double-slit experiment · Modulation of two-slit interference pattern by one-slit diffraction effect · Multiple slit and diffraction grating interference patterns · Thin film interference · Qualitatively describing two-slit interference patterns, including modulation by one-slit diffraction effect	Demonstrating an understanding that interference patterns from multiple slits and thin films produce accurately repeatable patterns.

	· Investigating Young's double-slit experimentally · Sketching and interpreting intensity graphs of double-slit interference patterns · Solving problems involving the diffraction grating equation · Describing conditions necessary for constructive and destructive interference from thin films, including phase change at interface and effect of refractive index · Solving problems involving interference from thin films	
	Students will be able to understand and apply · The size of a diffracting aperture · The resolution of simple monochromatic two-source systems · Solving problems involving the Rayleigh criterion for light emitted by two sources diffracted at a single slit · Resolvance of diffraction gratings	Demonstrating an understanding that resolution places an absolute limit on the extent to which an optical or other system can separate images of objects.
	Students will be able to understand and apply · The Doppler effect for sound waves and light waves · Sketching and interpreting the Doppler effect when there is relative motion between source and observer · Describing situations where the Doppler effect can be utilized · Solving problems involving the change in frequency or wavelength observed due to the Doppler effect to determine the velocity of the source/observer	Demonstrating an understanding that the Doppler effect describes the phenomenon of wavelength/frequency shift when relative motion occurs.

	Students will be able to understand and apply · Gravitational fields · Electrostatic fields · Electric potential and gravitational potential · Field lines · Equipotential surfaces · Representing sources of mass and charge, lines of electric and gravitational force, and field patterns using an appropriate symbolism · Mapping fields using potential · Describing the connection between equipotential surfaces and field lines	Demonstrating an understanding that electric charges and masses each influence the space around them and that this influence can be represented through the concept of fields.
	Students will be able to understand and apply · Potential and potential energy · Potential gradient · Potential difference · Escape speed · Orbital motion, orbital speed and orbital energy · Forces and inverse-square law behaviour · Determining the potential energy of a point mass and the potential energy of a point charge · Solving problems involving potential energy	Demonstrating an understanding that similar approaches can be taken in analysing electrical and gravitational potential problems.

	· Determining the potential inside a charged sphere · Solving problems involving the speed required for an object to go into orbit around a planet and for an object to escape the gravitational field of a planet · Solving problems involving orbital energy of charged particles in circular orbital motion and masses in circular orbital motion · Solving problems involving forces on charges and masses in radial and uniform fields	
	Students will be able to understand and apply · Electromotive force (EMF) · Magnetic flux and magnetic flux linkage · Faraday's law of induction · Lenz's law · Describing the production of an induced EMF by a changing magnetic flux and within a uniform magnetic field · Solving problems involving magnetic flux, magnetic flux linkage and · Faraday's law · Explaining Lenz's law through the conservation of energy	Demonstrating an understanding that the majority of electricity generated throughout the world is generated by machines that were designed to operate using the principles of electromagnetic induction.
	Students will be able to understand and apply · Alternating current (ac) generators	Demonstrating an understanding that generation and transmission of alternating current (ac) electricity has transformed the world.

	· Average power and root mean square (rms) values of current and voltage · Transformers · Diode bridges · Half-wave and full-wave rectification · Explaining the operation of a basic ac generator, including the effect of changing the generator frequency · Solving problems involving the average power in an AC circuit · Solving problems involving step-up and step-down transformers · Describing the use of transformers in AC electrical power distribution · Investigating a diode bridge rectification circuit experimentally · Qualitatively describing the effect of adding a capacitor to a diode bridge rectification circuit	
	Students will be able to understand and apply · Capacitance · Dielectric materials · Capacitors in series and parallel · Resistor-capacitor (RC) series circuits · Time constant · Describing the effect of different dielectric materials on	Demonstrating an understanding that capacitors can be used to store electrical energy for later use.

	capacitance · Solving problems involving parallel-plate capacitors · Investigating combinations of capacitors in series or parallel circuits · Determining the energy stored in a charged capacitor · Describing the nature of the exponential discharge of a capacitor · Solving problems involving the discharge of a capacitor through a fixed resistor · Solving problems involving the time constant of an RC circuit for charge, voltage and current	
	Students will be able to understand and apply · Photons · The photoelectric effect · Matter waves · Pair production and pair annihilation · Quantization of angular momentum in the Bohr model for hydrogen · The wave function · The uncertainty principle for energy and time and position and momentum	Demonstrating an understanding that the microscopic quantum world offers a range of phenomena, the interpretation and explanation of which require new ideas and concepts not found in the classical world.

	· Tunnelling, potential barrier and factors affecting tunnelling probability · Discussing the photoelectric effect experiment and explaining which features of the experiment cannot be explained by the classical wave theory of light · Solving photoelectric problems both graphically and algebraically · Discussing experimental evidence for matter waves, including an experiment in which the wave nature of electrons is evident · Stating order of magnitude estimates from the uncertainty principle	
	Students will be able to understand and apply · Rutherford scattering and nuclear radius · Nuclear energy levels · The neutrino · The law of radioactive decay and the decay constant · Describing a scattering experiment including location of minimum intensity for the diffracted particles based on their de Broglie wavelength · Explaining deviations from Rutherford scattering in high energy experiments	Demonstrating an understanding that the idea of discreteness that we met in the atomic world continues to exist in the nuclear world as well.

	· Describing experimental evidence for nuclear energy levels · Solving problems involving the radioactive decay law for arbitrary time intervals · Explaining the methods for measuring short and long half-lives	
	Students will be able to understand and apply · Torque · Moment of inertia · Rotational and translational equilibrium · Angular acceleration · Equations of rotational motion for uniform angular acceleration · Newton's second law applied to angular motion · Conservation of angular momentum · Calculating torque for single forces and couples · Solving problems involving moment of inertia, torque and angular acceleration · Solving problems in which objects are in both rotational and translational equilibrium · Solving problems using rotational quantities analogous	Demonstrating an understanding that the basic laws of mechanics have an extension when equivalent principles are applied to rotation. That actual objects have dimensions and they require the expansion of the point particle model to consider the possibility of different points on an object having different states of motion and/or different velocities.

	to linear quantities · Sketching and interpreting graphs of rotational motion · Solving problems involving rolling without slipping	
	Students will be able to understand and apply · The first law of thermodynamics · The second law of thermodynamics · Entropy · Cyclic processes and pV diagrams · Isovolumetric, isobaric, isothermal and adiabatic processes · Carnot cycle · Thermal efficiency · Describing the first law of thermodynamics as a statement of conservation of energy · Explaining sign convention used when stating the first law of thermodynamics a Q = U + W · Solving problems involving the first law of thermodynamics · Describing the second law of thermodynamics in Clausius form, Kelvin form and as a consequence of entropy	Demonstrating an understanding that the first law of thermodynamics relates the change in internal energy of a system to the energy transferred and the work done. The entropy of the universe tends to a maximum.

	· Describing examples of processes in terms of entropy change · Solving problems involving entropy changes · Sketching and interpreting cyclic processes · Solving problems for adiabatic processes for monatomic gases using $PV^{5/3}$ = constant · Solving problems involving thermal efficiency	
	Students will be able to understand and apply · Density and pressure · Buoyancy and Archimedes' principle · Pascal's principle · Hydrostatic equilibrium · The ideal fluid · Streamlines · The continuity equation · The Bernoulli equation and the Bernoulli effect · Stokes' law and viscosity · Laminar and turbulent flow and the Reynolds number · Determining buoyancy forces using Archimedes'	Demonstrating an understanding that fluids cannot be modelled as point particles. Their distinguishable response to compression from solids creates a set of characteristics that require an in-depth study.

	principle · Solving problems involving pressure, density and Pascal's principle · Solving problems using the Bernoulli equation and the continuity equation	
	Students will be able to understand and apply · Natural frequency of vibration · Q factor and damping · Periodic stimulus and the driving frequency · Resonance	
11	***Students will be able to understand and apply*** · Represent forces as vectors. · Sketch and interpret free-body diagrams. · Describe the consequences of Newton's first law for translational equilibrium. · Use Newton's second law quantitatively and qualitatively. · Identify force pairs in the context of Newton's third law. · Solve problems involving forces and determine resultant	Demonstrating an understanding that classical physics requires a force to change a state of motion, as suggested by Newton in his laws of motion.

	force. · Describe solid friction (static and dynamic) by coefficients of friction.	
	Students will be able to understand and apply... Define each of the following with units: · Kinetic energy · Gravitational potential energy · Elastic potential energy · Work done · Power · Efficiency · Discuss the conservation of total energy within energy transformations. · Sketch and interpret force–distance graphs. · Determine work done including cases where a resistive force acts. · Solve problems involving power. · Quantitatively describe efficiency in energy transfers.	Demonstrating an understanding that 'energy' is a fundamental concept that lays the basis upon which much of science is built.
	Students will be able to understand and apply	

	Apply conservation of momentum in simple isolated systems including (but not limited to) collisions, explosions, or water jets. · Use Newton's second law quantitatively and qualitatively in cases where mass is not constant · Sketch and interpreting force–time graphs · Determine impulse in various contexts including (but not limited to) car safety and sports · Qualitatively and quantitatively comparing situations involving elastic collisions, inelastic collisions and explosions	
	Students will be able to understand and apply Define each of the following: · Temperature and absolute temperature · Internal energy · Specific heat capacity · Phase change · Specific latent heat · Describe temperature change in terms of internal energy. · Use Kelvin and Celsius temperature scales and convert between them. · Apply the calorimetric techniques of specific heat	Demonstrating an understanding of the links between the macroscopic measurements essential to many scientific models and the microscopic properties that underlie these models.

	capacity or specific latent heat experimentally. · Describe phase change in terms of molecular behaviour. · Sketch and interpret phase change graphs. · Calculate energy changes involving specific heat capacity and specific latent heat of fusion and vaporization.	
	Students will be able to understand and apply · *Pressure* · *Equation of state for an ideal gas* · *Kinetic model of an ideal gas* · *Mole, molar mass and the Avogadro constant* · *Differences between real and ideal gases* · *Solving problems using the equation of state for an ideal gas and gas laws* · *Sketching and interpreting changes of state of an ideal gas on pressure– volume, pressure–temperature and volume–temperature diagrams* · *Investigating at least one gas law experimentally*	Demonstrating an understanding that properties of ideal gases allow scientists to make predictions of the behaviour of real gases.
	Students will be able to understand and apply Simple harmonic oscillations · Time period, frequency, amplitude, displacement and	Demonstrating an understanding of how oscillations underpin many areas of physics with simple harmonic motion (shm), a fundamental oscillation that appears in various natural

	phase difference · Conditions for simple harmonic motion · Qualitatively describing the energy changes taking place during one cycle of an oscillation · Sketching and interpreting graphs of simple harmonic motion examples	phenomena.
	Students will be able to understand and apply · Travelling waves · Wavelength, frequency, period and wave speed · Transverse and longitudinal waves · The nature of electromagnetic waves · The nature of sound waves Applications and skills: · Explaining the motion of particles of a medium when a wave passes through it for both transverse and longitudinal cases · Sketching and interpreting displacement–distance graphs and displacement– time graphs for transverse and longitudinal waves · Solving problems involving wave speed, frequency and wavelength · Investigating the speed of sound experimentally	Demonstrating an understanding that there are many forms of waves available to be studied, and that a common characteristic of all travelling waves is that they carry energy, but generally the medium through which they travel will not be permanently disturbed.
	Students will be able to understand and apply · Wavefronts and rays · Amplitude and intensity	Demonstrating an understanding that all waves can be described by the same sets of mathematical ideas, and that detailed knowledge of one area leads to the possibility of prediction in another.

	· Superposition · Polarization · Sketching and interpreting diagrams involving wavefronts and rays · Solving problems involving amplitude, intensity and the inverse square law · Sketching and interpreting the superposition of pulses and waves · Describing methods of polarization · Sketching and interpreting diagrams illustrating polarized, reflected and transmitted beams · Solving problems involving Malus's law	
	Students will be able to understand and apply · Reflection and refraction · Snell's law, critical angle and total internal reflection · Diffraction through a single-slit and around objects · Interference patterns · Double-slit interference · Path difference · Sketching and interpreting incident, reflected and	Demonstrating an understanding that waves interact with media and each other in a number of ways that can be unexpected and useful.

	transmitted waves at boundaries between media · Solving problems involving reflection at a plane interface · Solving problems involving Snell's law, critical angle and total internal reflection · Determining refractive index experimentally · Qualitatively describing the diffraction pattern formed when plane waves are incident normally on a single-slit · Quantitatively describing double-slit interference intensity patterns	
	Students will be able to understand and apply · The nature of standing waves · Boundary conditions · Nodes and antinodes · Describing the nature and formation of standing waves in terms of superposition · Distinguishing between standing and travelling waves · Observing, sketching and interpreting standing wave patterns in strings and pipes · Solving problems involving the frequency of a harmonic, length of the standing wave and the speed of the wave	Demonstrating an understanding that travelling waves meet they can superpose to form standing waves in which energy may not be transferred.
	Students will be able to understand and apply · Charge	Demonstrating an understanding that when charges move an electric current is created.

	· Electric field · Coulomb's law · Electric current · Direct current (dc) · Potential difference · Identifying two forms of charge and the direction of the forces between them · Solving problems involving electric fields and Coulomb's law · Calculating work done in an electric field in both joules and electronvolts · Identifying sign and nature of charge carriers in a metal · Identifying drift speed of charge carriers · Solving problems using the drift speed equation · Solving problems involving current, potential difference and charge	
	Students will be able to understand and apply · Circuit diagrams · Kirchhoff's circuit laws	Demonstrating an understanding that one of the earliest uses for electricity was to produce light and heat, and that this technology continues to have a major impact on the lives of people around the world.

	· Heating effect of current and its consequences · Resistance expressed as R I = V · Ohm's law · Resistivity · Power dissipation · Drawing and interpreting circuit diagrams · Identifying ohmic and non-ohmic conductors through a consideration of the V/I characteristic graph · Solving problems involving potential difference, current, charge, Kirchhoff's circuit laws, power, resistance and resistivity · Investigating combinations of resistors in parallel and series circuits · Describing ideal and non-ideal ammeters and voltmeters · Describing practical uses of potential divider circuits, including the advantages of a potential divider over a series resistor in controlling a simple circuit · Investigating one or more of the factors that affect resistance experimentally	
	Students will be able to understand and apply · Cells	Demonstrating an understanding that electric cells allow us to store energy in a chemical form.

	· Internal resistance · Secondary cells · Terminal potential difference · Electromotive force (EMF) · Investigating practical electric cells (both primary and secondary) · Describing the discharge characteristic of a simple cell (variation of terminal potential difference with time) · Identifying the direction of current flow required to recharge a cell · Determining internal resistance experimentally · Solving problems involving EMF, internal resistance and other electrical quantities	
	Students will be able to understand and apply · Magnetic fields · Magnetic force · Determining the direction of force on a charge moving in a magnetic field · Determining the direction of force on a current-carrying conductor in a magnetic field	Demonstrating an understanding that the effect scientists call magnetism arises when one charge moves in the vicinity of another moving charge.

	· Sketching and interpreting magnetic field patterns · Determining the direction of the magnetic field based on current direction · Solving problems involving magnetic forces, fields, current and charges	
	Students will be able to understand and apply · Period, frequency, angular displacement and angular velocity · Centripetal force · Centripetal acceleration · Identifying the forces providing the centripetal forces such as tension, friction, gravitational, electrical, or magnetic · Solving problems involving centripetal force, centripetal acceleration, period, frequency, angular displacement, linear speed and angular velocity · Qualitatively and quantitatively describing examples of circular motion including cases of vertical and horizontal circular motion	Demonstrating an understanding that a force applied perpendicular to its displacement can result in circular motion.
	Students will be able to understand and apply · Newton's law of gravitation	Demonstrating an understanding that the newtonian idea of gravitational force acting between two spherical bodies and the laws of

	· Gravitational field strength · Describing the relationship between gravitational force and centripetal force · Applying Newton's law of gravitation to the motion of an object in circular orbit around a point mass · Solving problems involving gravitational force, gravitational field strength, orbital speed and orbital period · Determining the resultant gravitational field strength due to two bodies	mechanics create a model that can be used to calculate the motion of planets.
	Students will be able to understand and apply · Discrete energy and discrete energy levels · Transitions between energy levels · Radioactive decay · Fundamental forces and their properties · Alpha particles, beta particles and gamma rays · Half-life · Absorption characteristics of decay particles · Isotopes · Background radiation · Describing the emission and absorption spectrum of common gases	Demonstrating an understanding that in the microscopic world energy is discrete.

	· Solving problems involving atomic spectra, including calculating the wavelength of photons emitted during atomic transitions · Completing decay equations for alpha and beta decay · Determining the half-life of a nuclide from a decay curve · Investigating half-life experimentally (or by simulation)	
	Students will be able to understand and apply · The unified atomic mass unit · Mass defect and nuclear binding energy · Nuclear fission and nuclear fusion · Solving problems involving mass defect and binding energy · Solving problems involving the energy released in radioactive decay, nuclear fission and nuclear fusion · Sketching and interpreting the general shape of the curve of average binding energy per nucleon against nucleon number	Demonstrating an understanding that Energy can be released in nuclear decays and reactions as a result of the relationship between mass and energy.
	Students will be able to understand and apply · Quarks, leptons and their antiparticles	Demonstrating an understanding that It is believed that all the matter around us is made up of fundamental particles called quarks and leptons, and that it is known that matter has a hierarchical

	· Hadrons, baryons and mesons · The conservation laws of charge, baryon number, lepton number and strangeness · The nature and range of the strong nuclear force, weak nuclear force and electromagnetic force · Exchange particles · Feynman diagrams · Confinement · The Higgs boson · Describing the Rutherford-Geiger-Marsden experiment that led to the discovery of the nucleus · Applying conservation laws in particle reactions · Describing protons and neutrons in terms of quarks · Comparing the interaction strengths of the fundamental forces, including gravity · Describing the mediation of the fundamental forces through exchange particles · Sketching and interpreting simple Feynman diagrams · Describing why free quarks are not observed	structure with quarks making up nucleons, nucleons making up nuclei, nuclei and electrons making up atoms and atoms making up molecules. In this hierarchical structure, the smallest scale is seen for quarks and leptons (10^{-18}m).
10	**2. Work, Power and Energy** ***Students will be able to understand and apply*** · State the names, symbols and the units for the quantities energy, work, power, force, mass, speed and acceleration.	***Students will be able to show their understanding by….*** Demonstrating an understanding of SI units and their symbols.

	· Energy can be changed from one form to another, but cannot be created or destroyed (Principle of Conservation of Energy) · Understand the difference between potential and kinetic energy · Use the formula for gravitational potential energy: · Ep = mgh · Differentiate between mass and weight and that weight = mass x gravity · Recall and apply the formula for kinetic energy: Ek = ½ mv^2 · State that 'work' involves a transfer of energy · Recall and apply the formula for work done: W = Fd · State that 'power' is the rate at which energy is transferred · Apply the formula for power: P = W/t **5. Electric Circuits** ***Students will be able to understand and apply*** · Describe an electric circuit and define electric current · Explain the difference between conductors and insulators	Demonstrating an understanding of potential and kinetic energies, and be able to apply the formulae to solve problems. Demonstrating an understanding of the relationship between work, energy and power, and be able to apply the formulae to solve problems. ***Students will be able to show their understanding by….*** Demonstrating an understanding of the terminology, SI units, and circuit symbols in translating and constructing simple electric circuits. Demonstrating an understanding how series and parallel circuits can affect current, voltage and resistance.

	· Recall the units for measuring electric current · Recall some things that can change the size of current in a circuit · Explain the difference between resistors connected in series and in parallel · Describe how resistors connected in series and parallel affect the current in a circuit · Describe how to calculate resistance using ammeters and voltmeters · Recall and apply the formula: resistance = voltage/current to calculate resistance. R = V/I · Be able to use the formulae to calculate resistance in series and parallel circuits understand that voltage (potential difference) is a measure of how much energy is transferred when charge (current) moves between two points in a circuit · Recall what happens to current and voltage in a series circuit · Recall what happens to current and voltage in a parallel circuit · Recall and be able to use the formula: power = voltage x current. P = V.I · Be able to convert power from units of kilowatt hours to joules. · Apply understanding of all learning objectives by constructing a circuit and testing the resistance in wires.	Demonstrating an understanding of R = V/I and P = VI to solve applied problems. Demonstrating an understanding of the factors affecting resistance in an electric circuit. Explaining and applying power usage in the home.

9	**3. Forces and Momentum** **Students will be able to understand and apply…** · Understand that a force is a push or pull of one body acting on another, and that unbalanced forces always change the motion of an object. · Identify contact forces (normal to surface, tension in string, frictional) and non-contact forces (gravitational, electrostatic, and magnetic). · Label simple free body diagrams with correct force and magnitude as well as calculate total net force acting upon an object. · Relate the resultant force on an object to the sum of all the individual forces acting on it. · Describe Newton's first, second, and third laws of motion, and identify examples of these laws at work in the world around them. · Apply Newton's Laws of Motion to solve problems. · Describe and use the equation for momentum. · State that an object's momentum changes when a force is applied to it. **6. Waves** **Students will be able to:** · Explain that waves transfer energy without	**Students will be able to show their understanding by...** Demonstrate an understanding that forces include pushes or pulls or twists, and that they can change the direction, speed, or shape of an object. Demonstrating an understanding of balanced forces and unbalanced forces. (Balanced forces result in objects remaining stationary. Unbalanced forces can get something moving) Investigating the relationship between force, mass and acceleration (Newton's Second Law). **Students will be able to show their understanding by…**

	transferring matter. · Differentiate between transverse and longitudinal waves. · Describe the nature of sound, water, earthquake (P and S) and electromagnetic waves. Define with units / recognize from a diagram (or graph) the properties: · Wavelength, amplitude and period of a wave. · Identify the standard symbols for the wave properties: T, f, λ · Explain the term 'frequency' of a wave. · Explain the relationship between frequency and period of a wave. 'f = 1/T' · State the formula c = fλ and calculate wave speed using the formula. · Explain the relationship between wavelength and colour of visible light. · Identify the position of general components of the EM spectrum from radio waves to gamma rays. · Explain how loudness and pitch of sounds is related to the wave characteristics.	Describing the motion of particles in a medium when a wave passes through it for both longitudinal and transverse waves. Determining amplitude, period and wavelength from a graph/diagram of a transverse wave. Calculating wave period, frequency, wavelength or speed using the wave relationships. Describing the production of sound by vibrating sources. Demonstrating understanding that a medium is needed to transmit sound waves. Describing and interpreting an experiment to determine the speed of sound in air. Explaining reflection of waves using a wave front diagram. Describing diffraction effects for sound, radio and water waves. Performing an experiment to calculate the speed of waves in a guitar string by measuring the string length and its natural frequency.

	· Define the terms ‘compression’ and ‘rarefaction’ in the context of sound waves.	
8	**Students will be able to…** **Kinematics–Motion** · Use the terms vector and scalar when describing distance, displacement, speed, velocity. · Describe and use the equation for velocity, when given the equation. · Calculate acceleration, given final and initial velocity and time and the equations. · Explain the difference between average speed and instantaneous speed. · Describe the velocity of an object when given a distance/time graph. · Describe the acceleration of an object when given a velocity/time graph.	**Students will be able to show their understanding by….** Demonstrating an understanding of the relationships between distance, time and speed and acceleration. Calculating velocity from the slope of a distance–time graph. Calculating acceleration from the slope of a velocity-time graph.
7	**Unit Heat and Energy:** **Student will be able to…** · Define energy is the ability to do work and identify many forms of energy. · Understand that energy can be changed from one form to another through a transformation which can be shown graphically. · Distinguish between the three different temperature scales: Celsius, Fahrenheit, and Kelvin.	**Students will be able to show their understanding by….** Completing energy transfer diagrams to demonstrate heat transfer. Demonstrating the ability convert between Celsius and Fahrenheit

	· Be able to convert Celsius to Fahrenheit. · Know that temperature is the measure of the average kinetic energy of particles in a sample of matter, and that dissolves substances can affect the freezing temperature. · Understand that heat is the thermal energy transferred from an area of higher temperature to an area of lower temperature. · Describe the particle theory as related to particles of solids, liquids, and gases. · Define the Specific Heat Capacity (SPC) of a solid, liquid, or gas. · Understand that heat can be transferred through the environment through conduction (touching), convection (air currents), and radiation (from the sun**)** · Explain the role of Insulators as having the ability to trap heat and prevent it from escaping. · Design an experiment to test insulation properties.	
6	**5. Sound and Light:** **Students will be able to…** · Investigate the basic properties of light. · Identify a variety of natural light sources (e.g., the sun, a firefly) and artificial light sources (e.g., a candle, fireworks, a light bulb.) · Distinguish between objects that emit their own light	**Students will be able to show their understanding by...** Demonstrating an understanding of the properties of sound and investigate light through scientific reasoning (e.g. why do we see planes before we hear them? how do speakers work?)

	(e.g., stars, candles, light bulbs) and those that reflect light from other sources (e.g., the moon, safety reflectors, minerals) · Describe properties of light, including that light travels in a straight path; light can be absorbed, reflected and refracted. (to create shadows, to make veins blue, mirrors etc) · Describe the properties of sound, including that sound travels, the speed at which sound travels, sound can be absorbed, reflected, amplified, and modified. · Know examples of longitudinal (sound) and transverse waves (light). · Explain how vibrations cause sound. · Identify devices that make use of the properties of sound and light (e.g telescope, microscope, and motion detector- light; microphone, hearing aid, telephone- sound)	
	· Conduct experiments to show that light travels in a straight path, that light reflects off of shiny surfaces, that light refracts [bends] when passing from one medium to another, that white light is made up of many colours, that light diffracts [bends and spreads out] when passing through an opening)	Demonstrating an understanding of the behavior of light in different medium.
	· Conduct experiments to show that sound travels, that sound can be absorbed or reflected, that sound can be modified [pitch, volume], that there is a relationship between vibrations and sound)	Constructing a model of an atom to better understand the special distribution of the components in an atom.
	3. Electricity Unit · Describe the components of an atom. (electrons,	

	nucleus, neutrons, protons) · Understand that static electricity is a result of unbalanced distribution of electrons on different objects. · Explain static electricity is the imbalance of electrical charges between two objects. · Explain what is current and voltage and stating their units · Draw and interpret circuit diagrams and set up circuits containing electrical sources, light bulbs, wires, switches, resistors, ammeters and voltmeters. · Describe electricity as the movement of electrons in a closed circuit. · Draw and set up series and parallel circuits in practical sessions. · Compare the effect of current and voltage of fixed power source in series and parallel circuits. · State some electrical hazards and precautionary measures to ensure the safe use of electricity · Recognize that resistance of a circuit can be varied by quantity, types and arrangement of resistors used.	Demonstrating an understanding of proper construction of an electric circuit first on paper then using wires and components. Demonstrating an understanding of resistance without using formula to perform calculations.
5	**Students will be able to** · Identify and describe everyday examples of sources of energy.	**Students will be able to show their understanding by** Demonstrating an understanding that energy can come from many sources.

	· Know that there are two forms of energy: stored versus used (potential versus kinetic). These forms are interchangeable. · Understand that forms of energy can produce light, heat, sound, and magnetic effects. · Explain how energy produces change. · Compare the following ways in which energy can be transformed, mechanical to electrical, electrical to thermal.	Demonstrate an understanding that energy can be stored and used in many ways.
4	**Student will be able to** · Identify contact/noncontact forces that affect motion of an object. i.e. gravity, magnetism, collision · Understand that the Earth's gravity pulls any object towards it without touching it. · Explain that the strength of a force and mass of an object influence the amount of change in an object's motion. · Understand Newton's 3 Laws and their relationship to everyday actions	**Students will be able to show their understanding by** Demonstrating how forces cause action and reaction in everyday situations.
3	**Students will be able to** Understand the relationship technology has played in society to improve a communication device and how it has changed throughout time.	**Students will be able to show their understanding by** Demonstrating an understanding of the importance of inventions and how they have improved life.
2	**Students will be able to** Understand that the sun supplies heat and light to the Earth	**Students will be able to show their understanding by** Demonstrating that life on earth is supported by energy from the sun.
1		

K2	**Students will be able to** Understand that magnets can be used to make some things move without being touched	**Students will be able to show their understanding by** Demonstrating how magnets make things move.
K1		