Science Inquiry Skills

| Knowledge | Application |
| --- | --- |
| Scientific methods enable systematic investigation to obtain measurable evidence. | Deconstruct the parts of a problem to determine the most appropriate method for investigation.  Design investigations, including:   * hypothesis or inquiry question * types of variables * dependent * independent * factors held constant (how and why they are controlled) * factors that may not be able to be controlled (and why not) * materials required * the procedure to be followed * the type and amount of data to be collected   identification of ethical and safety considerations. |
| Obtaining meaningful data depends on conducting investigations using appropriate procedures and safe, ethical working practices. | Conduct investigations, including:   * selection and safe use of appropriate materials, apparatus, and equipment * collection of appropriate primary or secondary data (numerical, visual, descriptive) * individual and collaborative work. |
| Results of investigations are represented in a well-organised way to allow them to be interpreted. | Represent results of investigations in appropriate ways, including:   * use of appropriate SI units, symbols * construction of appropriately labelled tables * drawing of graphs: linear, non-linear, lines of best fit * use of significant figures. |
| Scientific information can be presented using different types of symbols and representations. | Select, use, and interpret appropriate representations, including:   * mathematical relationships, including direct or inverse proportion and exponential relationships * diagrams and multi-image representations * formulae   to explain concepts, solve problems, and make predictions. |
| Analysis of the results of investigations allows them to be interpreted in a meaningful way. | Analyse data, including:   * multi-image representations * identification and discussion of trends, patterns, and relationships * interpolation or extrapolation through the axes where appropriate * selection and use of evidence and scientific understanding to make and justify conclusions. |
| Critical evaluation of procedures and outcomes can determine the meaningfulness of conclusions. | Evaluate the procedures and results to identify sources of uncertainty, including:   * random and systematic errors * replication * sample size * accuracy * reliability * precision * validity * effective control of variables.   Discuss the impact that sources of uncertainty have on experimental results.  Recognise the limitations of conclusions. |
| Effective scientific communication is clear and concise. | Communicate to specific audiences and for specific purposes using:   * appropriate language * terminology * conventions. |

Topic 1: Linear Motion and Forces

Subtopic 1.1: Motion under Constant Acceleration

| Knowledge | Application |
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| Linear motion with constant velocity is described in terms of relationships between measurable scalar and vector quantities, including displacement, distance, speed, and velocity.  Acceleration is a change in motion.  Uniformly accelerated motion is described in terms of relationships between measurable scalar and vector quantities, including displacement, speed, velocity, and acceleration. | Solve problems using .  Interpret solutions to problems in a variety of contexts.  Explain and solve problems involving the instantaneous velocity of an object.  Solve problems using equations for constant acceleration and .  Interpret solutions to problems in a variety of contexts.  Make reasonable and appropriate estimations of physical quantities in a variety of contexts. |
| Graphical representations can be used qualitatively and quantitatively to describe and predict aspects of linear motion. | Use graphical methods to represent linear motion, including the construction of graphs showing:   * position vs time * velocity vs time * acceleration vs time.   Use graphical representations to determine quantities such as position, displacement, distance, velocity, and acceleration.  Use graphical techniques to calculate the instantaneous velocity and instantaneous acceleration of an object. |
| Equations of motion quantitatively describe and predict aspects of linear motion.  Vertical motion is analysed by assuming that the acceleration due to gravity is constant near Earth’s surface.  The constant acceleration due to gravity near the surface of the Earth is approximately . | Solve and interpret problems using the equations of motion:        Solve problems for objects undergoing vertical motion because of the acceleration due to gravity in the absence of air resistance.  Explain the concept of free-falling objects and the conditions under which free-falling motion may be approximated.  Describe qualitatively the effects that air resistance has on vertical motion.  Use equations of motion and graphical representations to determine the acceleration due to gravity. |

Subtopic 1.2 on next page.

Subtopic 1.2: Forces

| Knowledge | Application |
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| A force,  is any action which causes motion to change,  Uniform motion is a state of motion in which the body travels with a constant speed (in a straight line).  Rest is a state of uniform motion in which the speed of the body is zero.  To change the state of motion of an object, a net force must be applied. |  |
| Newton’s Three Laws of Motion describe the relationship between the force or forces acting on an object, modelled as a point mass, and the motion of the object due to the application of the force or forces.  Newton’s First Law: An object will remain at rest, or continue in its motion, unless acted upon by an unbalanced force:  Newton’s Second Law: If an unbalanced force acts upon an object, the object will accelerate in the direction of the net force.  This can be given mathematically as: . | Explain Newton’s First Law using the concept of inertia.  Use Newton’s First Law to explain the motion of objects in a variety of contexts.  Describe and explain the motion of an object falling in a uniform gravitational field with air resistance.  Solve problems involving .  Explain the difference between mass and weight. |
| Newton’s Third Law: When two objects interact, they exert forces on each other equal in magnitude and opposite in direction.  The forces are identified in pairs, and the accelerations of each object will differ if the objects differ in mass. | Use Newton’s Third Law to solve problems.  Identify pairs of forces in a variety of contexts, including the normal reaction force.  Describe and explain motion where Newton’s Third Law occurs.  Use Newton’s Laws to explain the motion of spacecraft.  Undertake experiments to investigate the relationship between acceleration and either force or mass. |

Topic 2: Electric Circuits

Subtopic 2.1: Potential Difference and Electric Current

| Knowledge | Application |
| --- | --- |
| Atoms contain positively charged protons and negatively charged electrons.  Objects become charged when electrons are transferred from one object to another or redistributed on one object.  Two like charges exert repulsive forces on each other, whereas two opposite charges exert attractive forces on each other.  Energy is required to separate positive and negative charges and this charge separation produces an electrical potential difference that can be used to drive current in circuits.  The energy available to charges moving in an electrical circuit is measured using electric potential difference (voltage). This is defined as the change in potential energy per unit charge between two defined points in the circuit and is measured using a voltmeter. | Describe electric forces between like charges and between opposite charges.  Explain various phenomena involving interactions of charge.  Explain how electrical conductors allow charges to move freely through them, whereas insulators do not.  Describe how a voltmeter is used in an electric circuit.  Explain the purpose of measuring potential difference in electric circuit.  Describe how electrical safety is increased through the use of:   * fuses or circuit breakers * residual current devices. |
| Electric current is carried by discrete charge carriers. Charge is conserved at all points in an electrical circuit.  Electric current is the rate of flow of charge.  An ammeter is used to measure the electric current at a point in a circuit. It is placed in series with the electrical component through which the current is to be measured. | Distinguish between electron current and conventional current.  Solve problems involving . |

Subtopic 2.2: Resistance

| Knowledge | Application |
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| Resistance for ohmic and non-ohmic components is defined as the ratio of potential difference across the component to the current in the component.  The resistance of a conductor depends on its length, area of cross-section, temperature, and the type of the material of which it is composed.  Resistance is constant for ohmic resistors, which conform to Ohm’s Law.  Ohm’s Law states that current is directly proportional to the potential difference providing the temperature of the conductor remains constant. | Solve problems involving . |

Subtopics 2.3 and 2.4 on next page.

Subtopic 2.3: Circuit Analysis

| Knowledge | Application |
| --- | --- |
| Circuit analysis and circuit design involve calculation of the potential difference across, the current in, and the power supplied to components in series, parallel, and composite circuits.  The current is equal in each series component.  The potential difference is equal across each parallel component. | Solve problems involving    and    for components in series.  Solve problems involving    and    for components in parallel.  Undertake experiments to investigate current, resistance, or potential difference in series and parallel circuits using various circuit elements. |

Subtopic 2.4: Electrical Power

| Knowledge | Application |
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| Power is the rate at which energy is transformed by a circuit component.  Electric circuits enable electrical energy to be transferred efficiently over large distances and transformed into a range of other useful forms of energy including thermal and kinetic energy, and light. | Solve problems involving:       and the use of Ohm’s Law formula.  Solve problems involving the cost of electrical energy, using kilowatt-hours.  Solve problems involving:    or |

Topic 3: Heat

Subtopic 3.1: Heat and Temperature

| Knowledge | Application |
| --- | --- |
| Thermal energy is made up of the combined potential energy and the kinetic energy that is due to the vibration of the particles within the object.  The particles within objects with higher temperatures have a higher average kinetic energy.  An increase in the temperature of an object is due to an increase in its thermal energy.  Temperature can be measured with different scales (common ones being Celsius, Fahrenheit, and Kelvin).  As the temperature decreases, the average kinetic energy of the particles drops until the lower limit (known as ‘absolute zero’) is reached.  When a hotter object is put into contact with a cooler object, some of the thermal energy transfers from the hotter object to the cooler one. This flow of energy is referred to as ‘heat’.  If the objects remain in contact, then eventually the objects will reach the same temperature, putting the objects into ‘thermal equilibrium’. | Describe the links between temperature, vibrating particles, and thermal energy  Describe heat as the flow of energy from hotter to cooler objects.  Describe thermal equilibrium. |
| Heat transfer can occur through conduction, convection, and radiation.  Most solids, liquids, and gases expand when heated. | Explain how heat transfer can occur through conduction, convection, and radiation.  Describe examples of each heat-transfer process.  Describe applications of the expansion of matter due to heat transfer. |

Subtopic 3.2: Specific Heat Capacity

| Knowledge | Application |
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| Energy can be added to or removed from a system without causing a change of state. The energy that is added or removed causes a change in temperature,  The change in temperature depends on the mass of the object, m, the amount of heat transferred to or from the object, Q, and the nature of the material (its ‘specific heat capacity’, c). These variables are linked through the formula: | Describe and explain specific heat capacity.  Solve problems using the formula |

Subtopic 3.3: Change of State

| Knowledge | Application |
| --- | --- |
| Matter commonly exists in three states: solid, liquid, and gas.  To change a solid to a liquid (melting or fusion) and to change a liquid to a gas (boiling or vaporisation) requires the input of energy.  This energy breaks bonds between atoms or molecules but does not change the temperature and is thus known as *‘*latent heat’*.*  The amount of latent heat required (Q) depends upon the nature of the substance (specifically, its latent heat capacity (L)) and the mass of the substance m, and is calculated using  During the change of state from a gas to a liquid (condensation) or from a liquid to a solid (freezing or solidification), heat is released due to the formation of bonds between atoms or molecules.  Some substances change from solid to gas (sublimation) or from gas to solid (deposition) without going through a liquid phase. | Describe and explain latent heat.  Explain the difference between evaporation and boiling, using the particle model.  Solve problems using the formula  Undertake experiments to determine the specific heat capacity or latent heat of different materials. |

Topic 4: Energy and Momentum

Subtopic 4.1: Energy

| Knowledge | Application |
| --- | --- |
| The work done on an object is equivalent to the change in energy of that object. When a force is applied to an object causing a displacement over a distance, work is done.  Energy exists in a number of different forms.  Energy can be transferred from one object to another or transformed into different forms of energy.  Energy is conserved when transferred from one object to another in an isolated system.  Power is defined as the rate at which work is done and is equivalent to the rate at which energy is used. | Explain work in terms of an applied force.  Solve problems using  where the displacement is parallel to the force.  Describe different forms of energy including kinetic, elastic, gravitational potential, rotational kinetic, heat, and electrical.  Describe examples of energy being transferred from one object to another.  Describe examples of energy being transformed.  Explain qualitatively the meaning and some applications of various forms of energy, including kinetic energy and potential energy.  Solve problems using    Describe energy transfers between objects and within different mechanical systems.  Solve problems using the conservation of energy.  Describe and explain the energy losses that occur in systems involving energy transfers.  Solve problems using  Interpret solutions in context. |

Subtopic 4.2: Momentum

| Knowledge | Application |
| --- | --- |
| Momentum is a property of moving objects, which depends on their mass and velocity.  Momentum can be expressed mathematically as .  Momentum may be transferred from one object to another when a force acts over a time interval.  The rate of change of momentum of an object with respect to time is equal to the net force acting upon the object. This can be expressed mathematically as:    The impulse of an object is equal toand consequently equals the change in momentum. | Use Newton’s Second Law in the form  to derive the formula:  Solve problems involving changes in momentum and impulse (for one dimension).  Draw and interpret graphs of force vs time. |
| In an isolated system, the total momentum is conserved.  An elastic collision is one in which the total initial kinetic energy equals the total final kinetic energy. In an inelastic collision, some kinetic energy is transformed. | Use the conservation of momentum to solve problems in a variety of contexts.  Describe the difference between an elastic collision and an inelastic collision using examples.  Solve problems involving one-dimensional collisions, using  and  Describe the energy transformations during inelastic collisions.  Undertake experiments to investigate the conservation of energy or conservation of momentum. |

Topic 5: Waves

Subtopic 5.1: Wave Model

| Knowledge | Application |
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| Waves are periodic oscillations that transfer energy from one point to another.  In longitudinal waves, the direction of oscillation is parallel to the direction of travel of the wave.  In transverse waves, the direction of oscillation is perpendicular to the direction of travel of the wave. | Represent transverse waves graphically and analyse the graphs.  Describe waves in terms of measurable quantities, including amplitude, wavelength , frequency , period , and velocity .  Solve problems using: |

Subtopic 5.2: Mechanical Waves

| Knowledge | Application |
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| Mechanical waves, such as sound and seismic waves, transfer energy through a physical medium.  The natural frequency is the rate at which an object vibrates when it is disturbed by an outside force.  A forced vibration occurs when a wave forces an object to vibrate at the same frequency as the wave.  Resonance is the large-amplitude vibration that occurs in the object when the forced vibration is the same as its natural frequency. | Explain a range of wave-related phenomena, including echoes, refraction, and resonance, using the mechanical wave model.  Use the principle of superposition of waves to explain a range of interference phenomena, including standing waves and beats. |

Subtopic 5.3: Light

| Knowledge | Application |
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| Light is the visible part of the electromagnetic spectrum — a spectrum that also includes radio waves, microwaves, infrared and ultraviolet radiations, X-rays, and gamma rays.  Electromagnetic waves can be modelled as a transverse wave that can travel through a vacuum.  Refraction is the change in direction of propagation of a wave as its speed changes.  Diffraction is the bending/spreading of waves as they pass through an aperture or past a sharp edge.  The plane of polarisation of an electromagnetic wave is the plane defined by the direction of travel and the oscillating electric field. | Describe reflection and refraction, using the ray model of light.  Explain a range of light-related phenomena, including reflection, refraction, total internal reflection, diffraction, and polarisation, using the wave model.  Undertake experiments to investigate reflection or refraction of light using different media. |

Topic 6: Nuclear Models and Radioactivity

Subtopic 6.1: The Nucleus

| Knowledge | Application |
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| The basic structure of an atom comprises a small central nucleus consisting of protons and neutrons (nucleons) surrounded by electrons.  Atomic nuclei can be described using their chemical symbol  mass number  atomic number  and number of neutrons  A common representation is: .  Isotopes are atoms of the same element that have different mass numbers.  The nucleus is held together by a strong, attractive nuclear force. | Describe the structure of an atom, including the relative size and location of the nucleons and electrons.  Describe the structure of various nuclei from their symbol and vice versa.  Identify isotopes of an element based on their composition.  Explain why isotopes of the same element are chemically identical but have different physical properties.  Describe the properties of the strong nuclear force, including its short range.  Describe the balance between the electrostatic force and the strong nuclear force in stable nuclei.  Use the properties of the electrostatic force and the strong nuclear force to explain why some isotopes are unstable.  Locate stable and unstable nuclei on an N vs Z graph. |

Subtopic 6.2: Radioactive decay

| Knowledge | Application |
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| Unstable nuclei will undergo radioactive decay in which particles and/or electromagnetic radiation are emitted. |  |
| In alpha decay, an unstable nucleus emits an alpha particle,  Alpha decay typically occurs for nuclei with .  The general equation for an alpha decay is given by: . | Write equations for the decay of heavy nuclei by alpha decay. |
| In beta minus decay, an unstable nucleus emits an electron, .  Beta minus decay occurs when a nucleus has an excess of neutrons, and involves the decay of a neutron into a proton, electron, and antineutrino. This is shown by the equation:    The general equation for beta minus decay of an unstable nucleus is shown by the equation:  .  In beta plus decay, an unstable nucleus emits a positron, .  Beta plus decay occurs when a nucleus has an excess of protons, and involves the decay of a proton into a neutron, positron, and neutrino. This is shown by the equation:    The general equation for beta plus decay of an unstable nucleus is given by:  . | Describe the structure of unstable nuclei that causes each type of beta decay.  Write the equations for the decay of nuclei by beta minus and beta plus decay.  Use the conservation of charge to explain the emission of an electron in the decay of a neutron into a proton.  Use the conservation of charge to explain the emission of a positron in the decay of a proton into a neutron. |

Subtopics 6.2 (continued) to 6.3 on next page.

Subtopic 6.2: Radioactive decay (continued)

| Knowledge | Application |
| --- | --- |
| In gamma decay, an unstable nucleus emits high-energy gamma rays,  Gamma decay occurs when a nucleus is left with excess energy after an alpha or beta decay.  The general equation for a gamma decay is given by:    where n is the number of high-energy gamma rays emitted. | Write equations for the decay of unstable nuclei involving the emission of gamma rays. |
| The type of decay an unstable nucleus will undergo can be predicted based on the number of protons and neutrons within the nucleus. | Use the atomic and mass numbers to predict the type of decay for an unstable nucleus.  Use the location on an N vs Z graph to predict the type of decay for an unstable nucleus. |
| The particles emitted in radioactive decay have sufficient energy to ionise atoms.  The properties of the particles and/or radiation emitted in the different types of radioactive decay result in different penetration of matter. | Describe the effects of ionising radiation on living matter.  Describe methods of minimising exposure to ionising radiation.  Compare and contrast the ionising ability and penetration through matter of alpha, beta, and gamma radiations. |

Subtopic 6.3: Radioactive Half-life

| Knowledge | Application |
| --- | --- |
| The number of radioactive nuclei in a sample of a given isotope decreases exponentially with time.  Half-life is the time required for half of the radioactive nuclei in a sample to decay.  The half-life of radioactive nuclei is independent of both the physical state and the chemical state of the material.  The activity of a radioactive substance is the number of radioactive nuclei that decay per unit time.  The range of products of nuclear decay, some with long half-lives, means that nuclear waste must be stored for long periods. | Relate the activity of a sample to the number of radioactive nuclei present, and hence explain how it decreases exponentially with time.  Use data to estimate the half-life of radioactive nuclei.  Use data to estimate the activity or number of radioactive nuclei of a sample at different times.  Estimate the age of a sample based on the relative activity or the relative amounts of radioactive nuclei or their decay products.  Explain the requirements for the safe storage of nuclear waste. |

Subtopic 6.4 on next page.

Subtopic 6.4: Induced Nuclear Reactions

| Knowledge | Application |
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| Nuclear fission can be induced in some heavy nuclei by the capture of a neutron.  The nucleus splits into two nuclei and several neutrons.  The total mass of the reactants in a fission reaction is greater than that of the products, releasing energy given by , where  is the mass of the reactants minus the mass of the products.  On average, more than one neutron is emitted in nuclear fission. This leads to the possibility that these neutrons will induce further fissions, resulting in a chain reaction.  The neutrons emitted as a result of nuclear fission have high speeds.  undergoes fission with slow neutrons. Hence to induce fission in these nuclei the neutrons must be slowed down.  Many neutrons are absorbed by surrounding nuclei, or escape and cause no further fissions. | Calculate the energy released per fission reaction, given the relevant masses (in kg).  Relate the starting, normal operation, and stopping of a nuclear reactor to the nature of the chain reaction.  Explain why neutrons have to be slowed down in order to produce fission in . |
| Enrichment increases the proportion of  in uranium fuel. | Describe how enrichment enables a chain reaction to proceed.  Use a diagram of a reactor to locate and discuss the function of the principal components of a water-moderated fission power reactor. |
| Energy released during nuclear fission reactions can be harnessed for use in power generation. | Explain the use of nuclear fission in power production.  Describe some of the risks associated with the use of nuclear energy for power production. |
| Nuclear fusion is the process in which two nuclei combine into a single nucleus.  The energy absorbed or released is given by , where is the difference in mass between the reactants and the products. | Explain why high temperatures are needed for nuclear fusion to occur.  Calculate the energy released per fusion reaction, given the relevant masses (in kg). |