West Kirby Grammar School

Curriculum Map – Year 9 - Physics

Topic Name	Term	Skills Developed	Link to NC Subject Content	Next link in curriculum	Other Notes
Density and states of matter	Autumn	MS 1a, b, c, a Recognise and use expressions in decimal form b Recognise and use expressions in standard form c Use ratios, fractions and percentages MS 3b, c b Change the subject of an equation c Substitute numerical values into algebraic equations using appropriate units for physical quantities WS 1.2 – use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts.	**4.3.1.1 Density** The density of a material is defined by the equation: density = mass ÷ volume density, ρ, in kilograms per metre cubed, kg/m^3 mass, *m*, in kilograms, kg volume, *V*, in metres cubed, m^3 The particle model can be used to explain: • the different states of matter • differences in density. Students should be able to recognise/draw simple diagrams to model the difference between solids, liquids, and gases. Students should be able to explain the differences in density between the different states of matter in terms of the arrangement of atoms or molecules.	KS5 AQA A-level Physics 3.4.2.1 Bulk properties of solids	**Links from KS3:** States of matter **Required practical:** Use appropriate apparatus to make and record the measurements needed to determine the densities of regular and irregular solid objects and liquids. Volume should be determined from the dimensions of regularly shaped objects, and by a displacement technique for irregularly shaped objects. Dimensions to be measured using appropriate apparatus such as a ruler, micrometer, or Vernier callipers.

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Pressure in solids , liquids and gases	Autumn	MS 3b, c b Change the subject of an equation c Substitute numerical values into algebraic equations using appropriate units for physical quantities WS 1.2 – use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts.	**4.3.3.1 Particle motion in gases** The molecules of a gas are in constant random motion. The temperature of the gas is related to the average kinetic energy of the molecules. Changing the temperature of a gas, held at constant volume, changes the pressure exerted by the gas. A gas can be compressed or expanded by pressure changes. The pressure produces a net force at right angles to the wall of the gas container (or any surface). Students should be able to use the particle model to explain how increasing the volume in which a gas is contained, at constant temperature, can lead to a decrease in pressure. For a fixed mass of gas held at a constant temperature: pressure × volume = constant p V = constant pressure, p, in pascals, Pa volume, V, in metres cubed, m3 Students should be able to calculate the change in the pressure of a gas or the volume of a gas (a fixed mass held at constant temperature) when either the pressure or volume is increased or decreased. Work is the transfer of energy by a force. Doing work on a gas increases the internal energy of the gas and can cause an increase in the temperature of the gas.	KS5 AQA A-level Physics 3.6.2.2 Ideal gases	**Links from KS3:** Kinetic theory
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				curriculum	
Waves	Autumn	MS 1c, 3b, c, 5a, c 1c Use ratios, fractions and percentages 3b Change the subject of an equation 3c Substitute numerical values into algebraic equations using appropriate units for physical quantities 5 a Use angular measures in degrees 5 c Calculate areas of triangles and rectangles, surface areas and volumes of cubes WS 1.1 Understand how scientific methods and theories develop over time. WS 1.2 – use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts. WS 1.4 Explain everyday and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on the	**4.6.1 Waves in air, fluids and solids** Waves may be either transverse or longitudinal. The ripples on a water surface are an example of a transverse wave. Longitudinal waves show areas of compression and rarefaction. Sound waves travelling through air are longitudinal. Students should be able to describe the difference between longitudinal and transverse waves. Students should be able to describe evidence that, for both ripples on a water surface and sound waves in air, it is the wave and not the water or air itself that travels. Students should be able to describe wave motion in terms of their amplitude, wavelength, frequency and period. The amplitude of a wave is the maximum displacement of a point on a wave away from its undisturbed position. The wavelength of a wave is the distance from a point on one wave to the equivalent point on the adjacent wave. The frequency of a wave is the number of waves passing a point each second. period = 1 / frequency $T = 1/ f$ period, T, in seconds, s frequency, f, in hertz, Hz The wave speed is the speed at which the energy is transferred (or the wave moves) through the medium. All waves obey the wave equation:	KS5 AQA A-level Physics 3.3.1.1 Progressive waves 3.3.1.2 Longitudinal and transverse waves (links to A-level AT a and b). (links to A-level AT i and j).	**Links from KS3:** Waves topic **Required practical activity 8:** make observations to identify the suitability of apparatus to measure the frequency, wavelength and speed of waves in a ripple tank and waves in a solid and take appropriate measurements. **Required practical activity 9** (physics only): investigate the reflection of light by different types of surface and the refraction of light by different substances.

		evaluation of evidence and arguments. WS 2.2 – plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena. WS 2.3 – apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment. WS 2.4 – carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations. WS 2.6 – make and record observations and measurements using a range of apparatus and methods. WS 2.7 – evaluate methods and suggest possible improvements and further investigations. WS 3.1 – present observations and other data using appropriate methods. WS 3.5 – interpret observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form),	wave speed = frequency × wavelength wave speed, v, in metres per second, m/s frequency, f, in hertz, Hz wavelength, λ, in metres, m Students should be able to: • identify amplitude and wavelength from given diagrams • describe a method to measure the speed of sound waves in air • describe a method to measure the speed of ripples on a water surface. Students should be able to show how changes in velocity, frequency and wavelength, in transmission of sound waves from one medium to another, are inter-related. Waves can be reflected at the boundary between two different materials. Waves can be absorbed or transmitted at the boundary between two different materials. Students should be able to construct ray diagrams to illustrate the reflection of a wave at a surface. Students should be able to describe the effects of reflection, transmission and absorption of waves at material interfaces. Sound waves can travel through solids causing vibrations in the solid. Within the ear, sound waves cause the ear drum and other parts to vibrate which causes the sensation of sound. The conversion of sound waves to vibrations of solids works over a limited frequency range. This restricts the limits of human hearing. Students		

		including identifying patterns and trends, making inferences and drawing conclusions. AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects AT 4 Making observations of waves in fluids and solids to identify the suitability of apparatus to measure speed/frequency/wavelength. Making observations of the effects of the interaction of electromagnetic waves with matter AT 8 (physics only) Making observations of waves in fluids and solids to identify the suitability of apparatus to measure the effects of the interaction of waves with matter (links to A-level AT h, j).	should be able to: • describe, with examples, processes which convert wave disturbances between sound waves and vibrations in solids. Examples may include the effect of sound waves on the ear drum • explain why such processes only work over a limited frequency range and the relevance of this to human hearing. Students should know that the range of normal human hearing is from 20 Hz to 20 kHz. Students should be able to explain in qualitative terms, how the differences in velocity, absorption and reflection between different types of wave in solids and liquids can be used both for detection and exploration of structures which are hidden from direct observation. Ultrasound waves have a frequency higher than the upper limit of hearing for humans. Ultrasound waves are partially reflected when they meet a boundary between two different media. The time taken for the reflections to reach a detector can be used to determine how far away such a boundary is. This allows ultrasound waves to be used for both medical and industrial imaging. Seismic waves are produced by earthquakes. P-waves are longitudinal, seismic waves. P-waves travel at different speeds through solids and liquids. S-waves are transverse, seismic waves. S-waves cannot travel through a liquid. P-waves and S-waves provide evidence for the structure and size of the Earth's core.		

			Echo sounding, using high frequency sound waves is used to detect objects in deep water and measure water depth. Students should be aware that the study of seismic waves provided new evidence that led to discoveries about parts of the Earth which are not directly observable.		
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Electromagnetic waves	Spring	WS 1.2 – use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts. WS 1.4 Explain everyday and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on the evaluation of evidence and arguments. WS 1.5 Evaluate risks both in practical science and the wider societal context, including perception of risk in relation to data and consequences	**4.6.2.1 Types of electromagnetic waves** Electromagnetic waves are transverse waves that transfer energy from the source of the waves to an absorber. Electromagnetic waves form a continuous spectrum and all types of electromagnetic wave travel at the same velocity through a vacuum (space) or air. The waves that form the electromagnetic spectrum are grouped in terms of their wavelength and their frequency. Going from long to short wavelength (or from low to high frequency) the groups are: radio, microwave, infrared, visible light (red to violet), ultraviolet, Xrays and gamma rays. Our eyes only detect visible light and so detect a limited range of electromagnetic waves. Students should be able to give examples that illustrate the transfer of energy by electromagnetic waves. **4.6.2.2 Properties of electromagnetic waves 1**	KS5 AQA A-level Physics 3.3.2.1 Interference 3.8.1.2 α, β and γ radiation	**Links from KS3:** Y7 Energy Y8 Heating and Cooling **Links with KS4 topics:** 4.6.2.5 Lenses (physics only) 4.6.2.6 Visible light (physics only) 4.4.2 Atoms and nuclear radiation **Required practical**

		AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects AT 4 Making observations of waves in fluids and solids to identify the suitability of apparatus to measure speed/frequency/wavelength. Making observations of the effects of the interaction of electromagnetic waves with matter	(HT only) Different substances may absorb, transmit, refract or reflect electromagnetic waves in ways that vary with wavelength. (HT only) Some effects, for example refraction, are due to the difference in velocity of the waves in different substances. Students should be able to construct ray diagrams to illustrate the refraction of a wave at the boundary between two different media. (HT only) Different substances may absorb, transmit, refract or reflect electromagnetic waves in ways that vary with wavelength. (HT only) Some effects, for example refraction, are due to the difference in velocity of the waves in different substances. Students should be able to construct ray diagrams to illustrate the refraction of a wave at the boundary between two different media. **4.6.2.3 Properties of electromagnetic waves 2** (HT only) Radio waves can be produced by oscillations in electrical circuits. (HT only) When radio waves are absorbed, they may create an alternating current with the same frequency as the radio wave itself, so radio waves can themselves induce oscillations in an electrical circuit. Changes in atoms and the nuclei of atoms can result in electromagnetic waves being generated or absorbed over a wide frequency range. Gamma rays originate from changes in the nucleus of an atom. Ultraviolet waves, X-rays and gamma rays can have hazardous effects on human body tissue. The		**activity 10:** investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface.

			effects depend on the type of radiation and the size of the dose. Radiation dose (in sieverts) is a measure of the risk of harm resulting from an exposure of the body to the radiation. 1000 millisieverts (mSv) = 1 sievert (Sv) Students will not be required to recall the unit of radiation dose. Students should be able to draw conclusions from given data about the risks and consequences of exposure to radiation. Ultraviolet waves can cause skin to age prematurely and increase the risk of skin cancer. X-rays and gamma rays are ionising radiation that can cause the mutation of genes and cancer. **4.6.2.4 Uses and applications of electromagnetic waves** Electromagnetic waves have many practical applications. For example: • radio waves – television and radio • microwaves – satellite communications, cooking food • infrared – electrical heaters, cooking food, infrared cameras • visible light – fibre optic communications • ultraviolet – energy efficient lamps, sun tanning • X-rays and gamma rays – medical imaging and treatments (HT only) Students should be able to give brief explanations why each type of electromagnetic wave is suitable for the practical application.		
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Electricity	Spring / Summer	WS 1.2 – use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts. WS 1.4 Explain everyday and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on the evaluation of evidence and arguments. WS 1.5 Evaluate risks both in practical science and the wider societal context, including perception of risk in relation to data and consequences WS 4.5 Interconvert units MS 1c c Use ratios, fractions and percentages MS 3b, 3c, 3d 3b Change the subject of an equation	**4.2.5.1 Static charge** When certain insulating materials are rubbed against each other they become electrically charged. Negatively charged electrons are rubbed off one material and on to the other. The material that gains electrons becomes negatively charged. The material that loses electrons is left with an equal positive charge. When two electrically charged objects are brought close together, they exert a force on each other. Two objects that carry the same type of charge repel. Two objects that carry different types of charge attract. Attraction and repulsion between two charged objects are examples of non-contact force. Students should be able to: • describe the production of static electricity, and sparking, by rubbing surfaces • describe evidence that charged objects exert forces of attraction or repulsion on one another when not in contact • explain how the transfer of electrons between objects can explain the phenomena of static electricity. **4.2.5.2 Electric fields** A charged object creates an electric field around itself. The electric field is strongest close to the charged object. The further away from the charged object, the weaker the field.	KS5 AQA A-level Physics 3.5 Electricity (links to A-level AT a and b). (links to A-level AT f).	**Links from KS3:** Electricity **Links with KS4 topics:** 4.2.3.1 Direct and alternating potential difference 4.2.3.2 Mains electricity 4.2.4.3 The National Grid **Required practical activity 3:** Use circuit diagrams to set up and check appropriate circuits to investigate the factors affecting the resistance of electrical circuits. This should include: • the length of a wire at constant temperature • combinations of resistors in series and parallel.

		3c Substitute numerical values into algebraic equations using appropriate units for physical quantities 3d Solve simple algebraic equations MS 4c, d, e c Plot two variables from experimental or other data d Determine the slope and intercept of a linear graph e Draw and use the slope of a tangent to a curve as a measure of rate of change AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects (links to A-level AT a and b). AT6 Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of	A second charged object placed in the field experiences a force. The force gets stronger as the distance between the objects decreases. Students should be able to: • draw the electric field pattern for an isolated charged sphere • explain the concept of an electric field • explain how the concept of an electric field helps to explain the non-contact force between charged objects as well as other electrostatic phenomena such as sparking. **4.2.1 Current, potential difference and resistance** 4.2.1.1 Standard circuit diagram symbols Students should be able to draw and interpret circuit diagrams. 4.2.1.2 Electrical charge and current For electrical charge to flow through a closed circuit the circuit must include a source of potential difference. Electric current is a flow of electrical charge. The size of the electric current is the rate of flow of electrical charge. Charge flow, current and time are linked by the equation: charge flow = current × time $Q = I\ t$ charge flow, Q, in coulombs, C current, I, in amperes, A (amp is acceptable for ampere)		**Required practical activity 4:** use circuit diagrams to construct appropriate circuits to investigate the I–V characteristics of a variety of circuit elements, including a filament lamp, a diode and a resistor at constant temperature.

		circuit elements (links to Alevel AT f). AT7 Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements (links to A-level AT g).	time, t, in seconds, s A current has the same value at any point in a single closed loop. 4.2.1.3 Current, resistance and potential difference The current (I) through a component depends on both the resistance (R) of the component and the potential difference (V) across the component. The greater the resistance of the component the smaller the current for a given potential difference (pd) across the component. Questions will be set using the term potential difference. Students will gain credit for the correct use of either potential difference or voltage. Current, potential difference or resistance can be calculated using the equation: potential difference = current × resistance $V = I R$ potential difference, V, in volts, V current, I, in amperes, A (amp is acceptable for ampere) resistance, R, in ohms, Ω 4.2.1.4 Resistors Students should be able to explain that, for some resistors, the value of R remains constant but that in others it can change as the current changes. The current through an ohmic conductor (at a constant temperature) is directly proportional to the potential difference across the resistor. This means that the resistance remains constant as the current changes.		

			The resistance of components such as lamps, diodes, thermistors and LDRs is not constant; it changes with the current through the component. The resistance of a filament lamp increases as the temperature of the filament increases. The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction. The resistance of a thermistor decreases as the temperature increases. The applications of thermistors in circuits eg a thermostat is required. The resistance of an LDR decreases as light intensity increases. The application of LDRs in circuits eg switching lights on when it gets dark is required. Students should be able to: • explain the design and use of a circuit to measure the resistance of a component by measuring the current through, and potential difference across, the component • draw an appropriate circuit diagram using correct circuit symbols. Students should be able to use graphs to explore whether circuit elements are linear or non-linear and relate the curves produced to their function and properties. 4.2.2 Series and parallel circuits There are two ways of joining electrical components, in series and in parallel. Some circuits include both series and parallel parts. For components connected in series: • there is the same current through each component • the total		

			potential difference of the power supply is shared between the components • the total resistance of two components is the sum of the resistance of each component. Rtotal = R1 + R2 resistance, R, in ohms, Ω For components connected in parallel: • the potential difference across each component is the same • the total current through the whole circuit is the sum of the currents through the separate components • the total resistance of two resistors is less than the resistance of the smallest individual resistor. Students should be able to: • use circuit diagrams to construct and check series and parallel circuits that include a variety of common circuit components • describe the difference between series and parallel circuits • explain qualitatively why adding resistors in series increases the total resistance whilst adding resistors in parallel decreases the total resistance • explain the design and use of dc series circuits for measurement and testing purposes • calculate the currents, potential differences and resistances in dc series circuits • solve problems for circuits which include resistors in series using the concept of equivalent resistance. 4.2.4.1 Power Students should be able to explain how the power transfer in any circuit device is related to the potential difference across it and the current		

			through it, and to the energy changes over time: power = potential difference × current $P = V I$ power = current ^{2} × resistance $P = I^2 R$ power, P, in watts, W potential difference, V, in volts, V current, I, in amperes, A (amp is acceptable for ampere) resistance, R, in ohms, Ω 4.2.4.2 Energy transfers in everyday appliances Everyday electrical appliances are designed to bring about energy transfers. The amount of energy an appliance transfers depends on how long the appliance is switched on for and the power of the appliance. Students should be able to describe how different domestic appliances transfer energy from batteries or ac mains to the kinetic energy of electric motors or the energy of heating devices. Work is done when charge flows in a circuit. The amount of energy transferred by electrical work can be calculated using the equation: energy transferred = power × time $E = P t$ energy transferred = charge flow × potential difference $E = Q V$ energy transferred, E, in joules, J power, P, in watts, W time, t, in seconds, s charge flow, Q, in coulombs, C		

			potential difference, V, in volts, V Students should be able to explain how the power of a circuit device is related to: • the potential difference across it and the current through it • the energy transferred over a given time. Students should be able to describe, with examples, the relationship between the power ratings for domestic electrical appliances and the changes in stored energy when they are in use.		

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Forces and motion	Summer Completed in Autumn Y10	MS 1a,b,c,d a Recognise and use expressions in decimal form b Recognise and use expressions in standard form c Use ratios, fractions and percentages d Make estimates of the results of simple calculations MS 2c,d,f,h c Construct and interpret frequency tables and diagrams, bar charts and histograms d Understand the principles of sampling as applied to scientific data f Understand the terms mean, mode and median h Make order of magnitude	**4.5.6 Forces and motion** 4.5.6.1.2 Speed Speed does not involve direction. Speed is a scalar quantity. The speed of a moving object is rarely constant. When people walk, run or travel in a car their speed is constantly changing. The speed at which a person can walk, run or cycle depends on many factors including: age, terrain, fitness and distance travelled. Typical values may be taken as: walking ~ 1.5 m/s running ~ 3 m/s cycling ~ 6 m/s. Students should be able to recall typical values of speed for a person walking, running and cycling as well as the typical values of speed for different types of transportation systems. It is not only moving objects that have varying speed. The speed of sound and the speed of the wind also vary. A typical value for the speed of sound in air is	KS5 AQA A-level Physics 3.4.1 Force, energy and momentum (links to A-level AT a, b and d).	**Links from KS3:** Forces unit Energy unit **Links with KS4 topics:** 4.5.3 Forces and elasticity 4.5.4 Moments, levers and gears (physics only) 4.5.7 Momentum 4.1.1 Energy changes in a system, and the ways energy is stored before and after such changes

		calculations MS 3a,b,c a Understand and use the symbols: =, <>, >, ∝ , ~ b Change the subject of an equation c Substitute numerical values into algebraic equations using appropriate units for physical quantities MS 4a,b,c,d,f a Translate information between graphical and numeric form b Understand that y = mx + c represents a linear relationship c Plot two variables from experimental or other data d Determine the slope and intercept of a linear graph f Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate MS 5a,b a Use angular measures in degrees b Visualise and represent 2D and 3D forms including two dimensional representations of 3D objects WS 1.2 Use a variety of models	330 m/s. Students should be able to make measurements of distance and time and then calculate speeds of objects. For an object moving at constant speed the distance travelled in a specific time can be calculated using the equation: distance travelled = speed × time $s = v\,t$ distance, s, in metres, m speed, v, in metres per second, m/s time, t, in seconds, s Students should be able to calculate average speed for non-uniform motion. 4.5.6.1.3 Velocity The velocity of an object is its speed in a given direction. Velocity is a vector quantity. Students should be able to explain the vector–scalar distinction as it applies to displacement, distance, velocity and speed. 4.5.6.1.4 The distance–time relationship If an object moves along a straight line, the distance travelled can be represented by a distance–time graph. The speed of an object can be calculated from the gradient of its distance–time graph. (HT only) If an object is accelerating, its speed at any particular time can be determined by drawing a tangent and measuring the gradient of the distance–time graph at that time. Students should be able to draw distance–time graphs from measurements and extract and		Required practical activity 7: investigate the effect of varying the force on the acceleration of an object of constant mass, and the effect of varying the mass of an object on the acceleration produced by a constant force.

		such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts. WS 1.5 Evaluate risks both in practical science and the wider societal context, including perception of risk in relation to data and consequences. WS 2.2 Plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena. WS 3.3 Carrying out and represent mathematical and statistical analysis. WS 3.5 Interpreting observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions. WS 3.7 Being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of	interpret lines and slopes of distance–time graphs, translating information between graphical and numerical form. Students should be able to determine speed from a distance–time graph. 4.5.6.1.5 Acceleration The average acceleration of an object can be calculated using the equation: acceleration = change in velocity/time taken $a = \Delta v / t$ acceleration, a, in metres per second squared, m/s2 change in velocity, Δv, in metres per second, m/s time, t, in seconds, s An object that slows down is decelerating. Students should be able to estimate the magnitude of everyday accelerations. The acceleration of an object can be calculated from the gradient of a velocity–time graph. (HT only) The distance travelled by an object (or displacement of an object) can be calculated from the area under a velocity–time graph. Students should be able to: • draw velocity–time graphs from measurements and interpret lines and slopes to determine acceleration • (HT only) interpret enclosed areas in velocity–time graphs to determine distance travelled (or displacement) • (HT only) measure, when appropriate, the area under a velocity–time graph by counting squares.		

		random and systematic error. WS 4.2 Recognise the importance of scientific quantities and understand how they are determined. WS 4.5 Interconvert units. AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects (links to A-level AT a and b). AT 2 Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs (links to A-level AT a). AT 3 Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration) (links to A-level AT a, b and d).	4.5.6.1 Describing motion along a line Distance is how far an object moves. Distance does not involve direction. Distance is a scalar quantity. Displacement includes both the distance an object moves, measured in a straight line from the start point to the finish point and the direction of that straight line. Displacement is a vector quantity. Students should be able to express a displacement in terms of both the magnitude and direction. **4.5.1 Forces and their interactions** 4.5.1.1 Scalar and vector quantities Scalar quantities have magnitude only. Vector quantities have magnitude and an associated direction. A vector quantity may be represented by an arrow. The length of the arrow represents the magnitude, and the direction of the arrow the direction of the vector quantity. 4.5.1.2 Contact and non-contact forces A force is a push or pull that acts on an object due to the interaction with another object. All forces between objects are either: • contact forces – the objects are physically touching • non-contact forces – the objects are physically separated. Examples of contact forces include friction, air resistance, tension and normal contact force. Examples of non-contact forces are gravitational		

			force, electrostatic force and magnetic force. Force is a vector quantity. Students should be able to describe the interaction between pairs of objects which produce a force on each object. The forces to be represented as vectors. 4.5.1.4 Resultant forces A number of forces acting on an object may be replaced by a single force that has the same effect as all the original forces acting together. This single force is called the resultant force. Students should be able to calculate the resultant of two forces that act in a straight line. (HT only) Students should be able to: • describe examples of the forces acting on an isolated object or system • use free body diagrams to describe qualitatively examples where several forces lead to a resultant force on an object, including balanced forces when the resultant force is zero. (HT only) A single force can be resolved into two components acting at right angles to each other. The two component forces together have the same effect as the single force. (HT only) Students should be able to use vector diagrams to illustrate resolution of forces, equilibrium situations and determine the resultant of two forces, to include both magnitude and direction (scale drawings only). 4.5.6.2 Forces, accelerations and Newton's Laws of motion		

			4.5.6.2.1 Newton's First Law Newton's First Law: If the resultant force acting on an object is zero and: • the object is stationary, the object remains stationary • the object is moving, the object continues to move at the same speed and in the same direction. So the object continues to move at the same velocity. So, when a vehicle travels at a steady speed the resistive forces balance the driving force. So, the velocity (speed and/or direction) of an object will only change if a resultant force is acting on the object. Students should be able to apply Newton's First Law to explain the motion of objects moving with a uniform velocity and objects where the speed and/or direction changes. (HT only) The tendency of objects to continue in their state of rest or of uniform motion is called inertia. 4.5.6.2.2 Newton's Second Law Newton's Second Law: The acceleration of an object is proportional to the resultant force acting on the object, and inversely proportional to the mass of the object. As an equation: resultant force = mass × acceleration $F = m a$ force, F, in newtons, N mass, m, in kilograms, kg acceleration, a, in metres per second squared, m/s^2 (HT only) Students should be able to explain that: • inertial mass is a measure of how difficult it is to change the velocity of an object		

			• inertial mass is defined as the ratio of force over acceleration. Students should be able to estimate the speed, accelerations and forces involved in large accelerations for everyday road transport. Students should recognise and be able to use the symbol that indicates an approximate value or approximate answer, ~ 4.5.6.2.3 Newton's Third Law Newton's Third Law: Whenever two objects interact, the forces they exert on each other are equal and opposite. Students should be able to apply Newton's Third Law to examples of equilibrium situations. 4.5.6.3 Forces and braking The stopping distance of a vehicle is the sum of the distance the vehicle travels during the driver's reaction time (thinking distance) and the distance it travels under the braking force (braking distance). For a given braking force the greater the speed of the vehicle, the greater the stopping distance. (Physics only) Students should be able to estimate how the distance for a vehicle to make an emergency stop varies over a range of speeds typical for that vehicle. (Physics only) Students will be required to interpret graphs relating speed to stopping distance for a range of vehicles. Reaction times vary from person to person. Typical values range from 0.2 s to 0.9 s. A driver's reaction time can be affected by tiredness, drugs and		

			alcohol. Distractions may also affect a driver's ability to react. Students should be able to: • explain methods used to measure human reaction times and recall typical results • interpret and evaluate measurements from simple methods to measure the different reaction times of students • evaluate the effect of various factors on thinking distance based on given data. The braking distance of a vehicle can be affected by adverse road and weather conditions and poor condition of the vehicle. Adverse road conditions include wet or icy conditions. Poor condition of the vehicle is limited to the vehicle's brakes or tyres. Students should be able to: • explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies, and the implications for safety • estimate how the distance required for road vehicles to stop in an emergency varies over a range of typical speeds. When a force is applied to the brakes of a vehicle, work done by the friction force between the brakes and the wheel reduces the kinetic energy of the vehicle and the temperature of the brakes increases. The greater the speed of a vehicle the greater the braking force needed to stop the vehicle in a certain distance. The greater the braking force the greater the deceleration of the vehicle. Large decelerations may lead to brakes		

			overheating and/or loss of control. Students should be able to: • explain the dangers caused by large decelerations • (HT only) estimate the forces involved in the deceleration of road vehicles in typical situations on a public road. 4.5.1.3 Gravity Weight is the force acting on an object due to gravity. The force of gravity close to the Earth is due to the gravitational field around the Earth. The weight of an object depends on the gravitational field strength at the point where the object is. The weight of an object can be calculated using the equation: weight = mass × gravitational field strength $W = m\ g$ weight, W, in newtons, N mass, m, in kilograms, kg gravitational field strength, g, in newtons per kilogram, N/kg (In any calculation the value of the gravitational field strength (g) will be given.) The weight of an object and the mass of an object are directly proportional. Weight is measured using a calibrated spring-balance (a newtonmeter). 4.5.6.1.5 Acceleration An object falling through a fluid initially accelerates due to the force of gravity. Eventually		

			the resultant force will be zero and the object will move at its terminal velocity. (Physics only) Students should be able to: • draw and interpret velocity–time graphs for objects that reach terminal velocity • interpret the changing motion in terms of the forces acting. 4.5.2 Work done and energy transfer When a force causes an object to move through a distance work is done on the object. So a force does work on an object when the force causes a displacement of the object. The work done by a force on an object can be calculated using the equation: work done = force × distance moved along the line of action of the force $W = F s$ work done, W, in joules, J force, F, in newtons, N distance, s, in metres One joule of work is done when a force of one newton causes a displacement of one metre. 1 joule = 1 newton-metre Students should be able to describe the energy transfer involved when work is done Students should be able to convert between newton-metres and joules. Work done against the frictional forces acting on an object causes a rise in the temperature of the object. 4.5.6.1.5 Acceleration		

			The following equation applies to uniform acceleration: final velocity ^{2} − initial velocity ^{2} = 2 × acceleration × distance $v^2 - u^2 = 2as$ final velocity, v, in metres per second, m/s initial velocity, u, in metres per second, m/s acceleration, a, in metres per second squared, m/s^2 distance, s, in metres, m Near the Earth's surface any object falling freely under gravity has an acceleration of about 9.8 m/s^2		