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Name : _____

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How Science Works		Page numbers in New Physics for You
10.1 The thinking behind the doing		
Foundation Tier (FT) and Higher Tier (HT)	Science attempts to explain the world in which we live. It provides technologies that have had a great impact on our society and the environment. Scientists try to explain phenomena and solve problems using evidence. The data to be used as evidence must be reliable and valid, as only then can appropriate conclusions be made. A scientifically literate citizen should, amongst other things, be equipped to question, and engage in debate on, the evidence used in decision-making. The reliability of evidence refers to how much we trust the data. The validity of evidence depends on the reliability of the data, as well as whether the research answers the question. If the data is not reliable the research cannot be valid. To ensure reliability and validity in evidence, scientists consider a range of ideas which relate to: • how we observe the world • designing investigations so that patterns and relationships between variables may be identified • making measurements by selecting and using instruments effectively • presenting and representing data • identifying patterns, relationships and making suitable conclusions. These ideas inform decisions and are central to science education. They constitute the 'thinking behind the doing' that is a necessary complement to the subject content of biology, chemistry and physics. The sections below introduce the key ideas relating to evidence that underpin scientific practice.	pages 6, 358 7, 359 7

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10.2 Fundamental ideas		
FT & HT	Evidence must be approached with a critical eye. It is necessary to look closely at how measurements have been made and what links have been established. Scientific evidence provides a powerful means of forming opinions. These ideas pervade all of 'How Science Works'. Candidates should know and understand: • It is necessary to distinguish between opinion based on valid and reliable evidence and opinion based on non-scientific ideas (prejudices, whim or hearsay). • Continuous variables (any numerical values, eg weight, length or force) give more information than ordered variables (eg small, medium or large lumps) which are more informative than categoric variables (eg names of metals). A variable may also be discrete, that is, restricted to whole numbers (eg the number of layers of insulation). • Scientific investigations often seek to identify links between two or more variables. These links may be: - causal, in that a change in one variable causes a change in another - due to association, in that changes in one variable and a second variable are linked by a third variable (eg an association noted between soil acidity and crop growth may be the effect of a third variable, fertiliser type and quantity, on both) - due to chance occurrence (eg increase in the early 20th century in radio use was accompanied by an increase in mental illness). Evidence must be looked at carefully to make sure that it is: - reliable, ie it can be reproduced by others - valid, ie it is reliable *and* answers the original question.	6 360 361 7, 359

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10.3 Observation as a stimulus to investigation		
FT & HT	*Observation is the link between the real world and scientific ideas. When we observe objects, organisms or events we do so using existing knowledge. Observations may suggest hypotheses and lead to predictions that can be tested.* Candidates should know and understand: Observing phenomena can lead to the start of an investigation, experiment or survey. Existing theories and models can be used creatively to suggest explanations for phenomena (hypotheses). Careful observation is necessary before deciding which are the most important variables. Hypotheses can then be used to make predictions that can be tested. An example is the observation that shrimp only occur in parts of a stream. Knowledge about shrimp and water flow leads to a hypothesis relating the distribution to the stream flow rate. A prediction leads to a survey that looks at both variables. Data from testing a prediction can support or refute the hypothesis or lead to a new hypothesis. For example, the data from the shrimp survey could suggest that, at slow flow rates, oxygen availability might determine abundance. If the theories and models we have available to us do not completely match our data or observations, we need to check the validity of our observations or data, or amend the theories or models.	6, 360-1

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10.4 Designing an investigation		
FT & HT	An investigation is an attempt to determine whether or not there is a relationship between variables. Therefore it is necessary to identify and understand the variables in an investigation. The design of an investigation should be scrutinised when evaluating the validity of the evidence it has produced.	360
	Candidates should know and understand:	
	An independent variable is one that is changed or selected by the investigator. The dependent variable is measured for each change in the independent variable.	360
	Any measurement must be valid in that it measures only the appropriate variable, for instance colour change in a pH indicator to measure respiration in woodlice could be affected by their excretion.	359
	Fair Test It is important to isolate the effects of the independent variable on the dependent variable. This may be achieved more easily in a laboratory environment than in the field, where it is harder to control all variables.	360
	A fair test is one in which only the independent variable affects the dependent variable, as all other variables are kept the same.	
	In field investigations it is necessary to ensure that variables that change their value do so in the same way for all measurements of the dependent variable (eg in a tomato growth trial, all plants are subject to the same weather conditions).	361
	When using large-scale survey results, it is necessary to select data from conditions that are similar (eg if a study is to survey the effect of age on blood pressure, a group of people with approximately the same diet or weight could be used).	
	Control groups are often used in biological and medical research to ensure that observed effects are due to changes in the independent variable alone (eg in drug experiments, a placebo drug is used as a control).	
	Choosing values of a variable Care is needed in selecting values of variables to be recorded in an investigation. A trial run will help identify appropriate values to be recorded, such as the number of repeated readings needed and their range and interval. For example, in an investigation of the effect of temperature on enzyme activity it is necessary to: • use a sufficient amount of enzyme so that its activity can be detected • use a sensible range of temperatures • have readings .closer together. (at smaller intervals) where a change in pattern is detected.	361

continued…

	Accuracy and precision. Readings should be repeated to improve the reliability of the data. An accurate measurement is one which is close to the true value. The design of an investigation must provide data with sufficient accuracy. For example, measures of blood alcohol levels must be accurate enough to be able to determine whether the person is legally fit to drive. The design of an investigation must provide data with sufficient precision to form a valid conclusion. For example, in an investigation into the bounce of different balls, less precision is needed to tell if a tennis ball bounces higher than a squash ball than if you wanted to distinguish between the bounce of two very similar tennis balls.	361 362

10.5 Making measurements		
FT & HT	When making measurements we must consider such issues as inherent variation due to variables that have not been controlled, human error and the characteristics of the instruments used. Evidence should be evaluated with the reliability and validity of the measurements that have been made in mind.	362
	A single measurement There will always be some variation in the actual value of a variable no matter how hard we try to repeat an event. For instance, if a ball is dropped and doesn't land on exactly the same point on its surface there will be a slight difference in the rebound height.	362
	When selecting an instrument, it is necessary to consider the accuracy inherent in the instrument and the way it has to be used. For example, expensive thermometers are likely to give a reading nearer to the true reading and to be more accurately calibrated.	362
	The sensitivity of an instrument refers to the smallest change in a value that can be detected. For example, bathroom scales are not sensitive enough to detect the weekly changes in the mass of a baby, whereas scales used by a midwife are sensitive enough to permit a growth chart to be plotted.	362
	Even when an instrument is used correctly, human error may occur which could produce random differences in repeated readings or a systematic shift from the true value which could, for instance, occur due to incorrect use or poor calibration. Random error can result from inconsistent application of a technique. Systematic error can result from consistent misapplication of a technique.	362
	Any anomalous values should be examined to try and identify the cause and, if a product of a poor measurement, ignored.	362

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10.6 Presenting data		
FT & HT	To explain the relationship between two or more variables, data may be presented in such a way as to make the patterns more evident. There is a link between the type of graph used and the type of variable represented. The choice of graphical representation depends upon the type of variable they represent. Candidates should know and understand: The range of the data refers to the maximum and minimum values. The mean (or average) of the data refers to the sum of all the measurements divided by the number of measurements taken. Tables are an effective means of displaying data but are limited in how they portray the design of an investigation. Bar charts can be used to display data in which the independent variable is categoric and the dependent variable continuous. Line graphs can be used to display data in which both the independent and dependent variables are continuous. Scattergrams can be used to show an association between two variables (eg water content of soil and height of plants).	363 361 361 363 363 363

10.7 Using data to draw conclusions		
FT & HT	The patterns and relationships observed in data represent the behaviour of the variables in an investigation. However, it is necessary to look at patterns and relationships between variables with the limitations of the data in mind in order to draw conclusions. Candidates should know and understand: Patterns in tables and graphs can be used to identify anomalous data that require further consideration. A line of best fit can be used to illustrate the underlying relationship between variables. The relationships that exist between variables can be linear (positive or negative, eg height of wax remaining in a candle and time it has been burning) or directly proportional (eg extension of a spring and applied force). On a graph, the relationship could show as a curve (eg velocity against time for a falling object). Conclusions must be limited by the data available and not go beyond them. For example, the beneficial effects of a new drug may be limited to the sample used in the tests (younger men perhaps) and not the entire population. **Evaluation** In evaluating a whole investigation the reliability and validity of the data obtained must be considered. The reliability of an investigation can be increased by looking at data obtained from secondary sources, through using an alternative method as a check and by requiring that the results are reproducible by others.	364 364 364 364 364 364

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10.8 Societal aspects of scientific evidence		
FT & HT	A judgement or decision relating to social-scientific issues may not be based on evidence alone, as other societal factors may be relevant. Candidates should know and understand:	
	The credibility of the evidence is increased if a balanced account of the data is used rather than a selection from it which supports a particular pre-determined stance.	358-9
	Evidence must be scrutinised for any potential bias of the experimenter, such as funding sources or allegiances.	359
	Evidence can be accorded undue weight, or dismissed too lightly, simply because of its political significance. If the consequences of the evidence might provoke public or political disquiet, the evidence may be downplayed.	359
	The status of the experimenter may influence the weight placed on evidence; for instance, academic or professional status, experience and authority. It is more likely that the advice of an eminent scientist will be sought to help provide a solution to a problem than that of a scientist with less experience.	359
	Scientific knowledge gained through investigations can be the basis for technological developments.	
	Scientific and technological developments offer different opportunities for exploitation to different groups of people.	
	The uses of science and technology developments can raise ethical, social, economic and environmental issues.	6, 107, 216-7, 359
	Decisions are made by individuals and by society on issues relating to science and technology.	6, 358-9

10.9 Limitations of scientific evidence		
FT & HT	Science can help us in many ways but it cannot supply all the answers. We are still finding out about things and developing our scientific knowledge. There are some questions that we cannot answer, maybe because we do not have enough reliable and valid evidence. For example, it is generally accepted that the extra carbon dioxide in the air (from burning fossil fuels) is linked to global warming, but some scientists think there is not sufficient evidence and that there are other factors involved.	6, 107, 359
	And there are some questions that science cannot answer at all. These tend to be questions where beliefs and opinions are important or where we cannot collect reliable and valid scientific evidence. For example, science may be able to answer questions that start 'How can we'... such as 'How can we clone babies?' but questions starting 'Should we..' such as 'Should we clone babies?' are for society to answer.	6, 359

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Unit Physics 1		Page numbers in New Physics for You
11.1 How is heat (thermal energy) transferred and what factors affect the rate at which heat is transferred?		
Foundation Tier (FT) and Higher Tier (HT)	Candidates should use their skills, knowledge and understanding of how science works: • to evaluate ways in which heat is transferred in and out of bodies • and ways in which the rates of these transfers can be reduced. Their skills, knowledge and understanding of how science works should be set in these substantive contexts: Thermal (infra red) radiation is the transfer of energy by electromagnetic waves. All bodies emit and absorb thermal radiation. The hotter a body is the more energy it radiates. Dark, matt surfaces are good absorbers and good emitters of radiation. Light, shiny surfaces are poor absorbers and poor emitters of radiation. The transfer of energy by conduction and convection involves particles and how this transfer takes place. Under similar conditions different materials transfer heat at different rates. The shape and dimensions of a body affect the rate at which it transfers heat. The bigger the temperature difference between a body and its surroundings, the faster the rate at which heat is transferred.	pages 43, 51 43, 49, 51 40, 46-51 46 41 46-7 46-7 40-45 41, 43 41, 43 43, 46

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11.2 What is meant by the efficient use of energy?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to describe the intended energy transfers/transformations and the main energy wastages that occur with a range of devices	100-103, 116
	• to calculate the efficiency of a device using: efficiency = <u>useful energy transferred by the device</u> total energy supplied to the device	102-3, 116
	• to evaluate the effectiveness and cost effectiveness of methods used to reduce energy consumption.	43, 102
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	Energy cannot be created or destroyed. It can only be transformed from one form to another form.	10-11, 98-9
	When energy is transferred and/or transformed only part of it may be usefully transferred/transformed.	100-1
	Energy which is not transferred/transformed in a useful way is 'wasted'.	102
	Both wasted energy and the energy which is usefully transferred/transformed are eventually transferred to their surroundings which become warmer.	102-3
	Energy becomes increasingly spread out and becomes increasingly more difficult to use for further energy transformations.	102
	The greater the percentage of the energy that is usefully transformed in a device, the more efficient the device is.	102-3

11.3 Why are electrical devices so useful?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to compare and contrast the particular advantages and disadvantages of using different electrical devices for a particular application	264-5
	• to calculate the amount of energy transferred from the mains using: energy transferred = power × time (kilowatt-hour, kWh) (kilowatt, kW) (hour, h)	267
	• to calculate the cost of energy transferred from the mains using: total cost = number of kilowatt-hours × cost per kilowatt-hour	267
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	Examples of energy transformations that everyday electrical devices are designed to bring about.	264-7, 11, 100
	Examples of everyday electrical devices designed to bring about particular energy transformations.	264-7, 11, 100
	The amount of electrical energy a device transforms depends on how long the appliance is switched on and the rate at which the device transforms energy.	267
	The power of an appliance is measured in watts (W) or kilowatts (kW).	266
	Energy is normally measured in joules (J).	35, 97
	Electricity is transferred from power station to consumers along the National Grid.	303
	The uses of step-up and step-down transformers in the National Grid.	303
	Increasing voltage (potential difference) reduces current, and hence reduces energy losses in the cables.	303

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11.4 How should we generate the electricity we need?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to compare and contrast the particular advantages and disadvantages of using different energy sources to generate electricity.	13-15, 104-6
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	In most power stations an energy source is used to heat water. The steam produced drives a turbine which is coupled to an electrical generator.	104
	Common energy sources include coal, oil and gas, which are burned to produce heat and uranium/plutonium, in which nuclear fission produces heat.	104, 348-9
	Energy from renewable energy sources can be used to drive turbines directly.	14-15, 106
	Renewable energy sources used in this way include wind, the rise and fall of water due to waves and tides, and the falling of water in hydroelectric schemes.	14-15, 105-6
	Electricity can be produced directly from the Sun's radiation using solar cells.	14, 103-4, 115
	In some volcanic areas hot water and steam rise to the surface. The steam can be tapped and used to drive turbines. This is known as geothermal energy.	15
	Using different energy resources has different effects on the environment. These effects include the release of substances into the atmosphere, noise and visual pollution, and the destruction of wildlife habitats.	104-6
	The advantages and disadvantages of using fossil fuels, nuclear fuels and renewable energy sources to generate electricity. These include the cost of building power stations, the start-up time of power stations, the reliability of the energy source, the relative cost of energy generated and the location in which the energy is needed.	105-6

11.5 What are the uses and hazards of the waves that form the electromagnetic spectrum?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to evaluate the possible hazards associated with the use of different types of electromagnetic radiation • to evaluate methods to reduce exposure to different types of electromagnetic radiation. Set in these substantive contexts: Electromagnetic radiation travels as waves and moves energy from one place to another. All types of electromagnetic waves travel at the same speed through a vacuum (space). The electromagnetic spectrum is continuous but the wavelengths within it can be grouped into types of increasing wavelength and decreasing frequency: − gamma rays, X-rays, ultraviolet rays, visible light, infra red rays, microwaves and radio waves. Different wavelengths of electromagnetic radiation are reflected, absorbed or transmitted differently by different substances and types of surface. When radiation is absorbed the energy it carries makes the substance which absorbs it hotter and may create an alternating current with the same frequency as the radiation itself. Different wavelengths of electromagnetic radiation have different effects on living cells. Some radiations mostly pass through soft tissue without being absorbed, some produce heat, some may cause cancerous changes and some may kill cells. These effects depend on the type of radiation and the size of the dose. The uses and the hazards associated with the use of each type of radiation in the electromagnetic spectrum. Radio waves, microwaves, infra red and visible light can be used for communication. Microwaves can pass through the Earth's atmosphere and are used to send information to and from satellites and within mobile phone networks. Infra red and visible light can be used to send signals along optical fibres and so travel in curved paths. Communication signals may be analogue (continuously varying) or digital (discrete values only, generally on and off). Digital signals are less prone to interference than analogue and can be easily processed by computers. Electromagnetic waves obey the wave formula: wave speed = frequency × wavelength (metre/second, m/s) (hertz, Hz) (metre, m)	208-214, 216-7 214, 216-7 208-9 208-9 208-9, 210-213 208-9, 210-213 47, 209, 211 208-9, 214 208-9 211, 213, 314 211, 314 189, 192 218-219 167, 209

11.6 What are the uses and dangers of emissions from radioactive substances?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to evaluate the possible hazards associated with the use of different types of nuclear radiation • to evaluate measures that can be taken to reduce exposure to nuclear radiations • to evaluate the appropriateness of radioactive sources for particular uses, including as tracers, in terms of the type(s) of radiation emitted and their half-lives. Their skills, knowledge and understanding of how science works should be set in these substantive contexts: The basic structure of an atom is a small central nucleus composed of protons and neutrons surrounded by electrons. The atoms of an element always have the same number of protons, but have a different number of neutrons for each isotope. Some substances give out radiation from the nuclei of their atoms all the time, whatever is done to them. These substances are said to be radioactive. Identification of an alpha particle as a helium nucleus, a beta particle as an electron from the nucleus and gamma radiation as electromagnetic radiation. Properties of the alpha, beta and gamma radiations limited to their relative ionising power, their penetration through materials and their range in air. Alpha and beta radiations are deflected by both electric and magnetic fields but gamma radiation is not. The uses of and the dangers associated with each type of nuclear radiation. The half-life of a radioactive isotope is defined as the time it takes for the number of nuclei of the isotope in a sample to halve or the time it takes for the count rate from a sample containing the isotope to fall to half its initial level.	340-1, 350 350 346-7 342-3 343 340 340, 345 340-1 340-1 346-7, 350 344

11.7 What do we know about the origins of the Universe and how it continues to change?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to compare and contrast the particular advantages and disadvantages of using different types of telescope on Earth and in space to make observations on and deductions about the universe.	215
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	If a wave source is moving relative to an observer there will be a change in the observed wavelength and frequency.	158
	There is a red-shift in light observed from most distant galaxies. The further away galaxies are the bigger the red-shift.	158
	How the observed red-shift provides evidence that the universe is expanding and supports the 'big bang' theory (that the universe began from a very small initial point).	158
	Observations of the solar system and the galaxies in the universe can be carried out on the Earth or from space.	155, 215
	Observations are made with telescopes that may detect visible light or other electromagnetic radiations such as radio waves or X-rays.	215

Unit Physics 2		Page numbers in New Physics for You
12.1 How can we describe the way things move?		
Foundation Tier (FT) and Higher Tier (HT)	Candidates should use their skills, knowledge and understanding of how science works: • to construct distance-time graphs for a body moving in a straight line when the body is stationary or moving with a constant speed	page 126
	• to construct velocity-time graphs for a body moving with a constant velocity or a constant acceleration	123, 124-5
HT only	• to calculate the speed of a body from the slope of a distance-time graph	126
HT only	• to calculate the acceleration of a body from the slope of a velocity-time graph	124-5
HT only	• to calculate the distance travelled by a body from a velocity-time graph.	124-5
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	The slope of a distance-time graph represents speed.	126
	The velocity of a body is its speed in a given direction.	122
	The acceleration of a body is given by: Acceleration = change in velocity (metre/second, m/s) / time taken for change (second, s) (Acceleration in metre/second^2 or m/s^2)	122
	The slope of a velocity-time graph represents acceleration.	124-5
	The area under a velocity-time graph represents distance travelled.	124-5

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12.2 How do we make things speed up or slow down?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to draw and interpret velocity-time graphs for bodies that reach terminal velocity, including a consideration of the forces acting on the body • to calculate the weight of a body using: weight (newton, N) = mass (kilogram, kg) × gravitational field strength (newton/kilogram, N/kg)	89 130-1
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	Whenever two bodies interact, the forces they exert on each other are equal and opposite.	84-5
	A number of forces acting on a body may be replaced by a single force which has the same effect on the body as the original forces all acting together. The force is called the resultant force.	86-7
	If the resultant force acting on a stationary body is zero the body will remain stationary.	69, 86
	If the resultant force acting on a stationary body is not zero the body will accelerate in the direction of the resultant force.	86-7, 130
	If the resultant force acting on a moving body is zero the body will continue to move at the same speed and in the same direction.	69, 86-7
	If the resultant force acting on a moving body is not zero the body will accelerate in the direction of the resultant force.	86-7
	Force, mass and acceleration are related by the equation: resultant force (newton, N) = mass (kilogram, kg) × acceleration (metre/second^2, m/s^2)	130-1
	When a vehicle travels at a steady speed the frictional forces balance the driving force.	87
	The greater the speed of a vehicle the greater the braking force needed to stop it in a certain distance.	83
	The stopping distance of a vehicle depends on the distance the vehicle travels during the driver's reaction time and the distance it travels under the braking force.	83
	A driver's reaction time can be affected by tiredness, drugs and alcohol.	83
	A vehicle's braking distance can be affected by adverse road and weather conditions and poor condition of the vehicle. (continued…)	83

	The faster a body moves through a fluid the greater the frictional force which acts on it. A body falling through a fluid will initially accelerate due to the force of gravity. Eventually the resultant force on the body will be zero and it will fall at its terminal velocity.	83, 89 89, 128

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12.3 What happens to the movement energy when things speed up or slow down?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to discuss the transformation of kinetic energy to other forms of energy in particular situations.	11, 83
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	When a force causes a body to move through a distance, energy is transferred and work is done.	97
	Work done = energy transferred.	99
	The amount of work done, force and distance are related by the equation: work done = force applied × distance moved in direction of force (joule, J) (newton, N) (metre, m)	97
	Work done against frictional forces is mainly transformed into heat.	102
	For an object that is able to recover its original shape, elastic potential is the energy stored in the object when work is done on the object to change its shape.	10-11, 108
	The kinetic energy of a body depends on its mass and its speed.	83, 109
HT only	Calculate the kinetic energy of a body using the equation: kinetic energy = ½ × mass × speed^2 (joule, J) (kilogram, kg) ((metre/second)^2, (m/s)^2)	109

12.4 What is momentum?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to use the conservation of momentum (in one dimension) to calculate the mass, velocity or momentum of a body involved in a collision or explosion • to use the ideas of momentum to explain safety features. Their skills, knowledge and understanding of how science works should be set in these substantive contexts: Momentum, mass and velocity are related by the equation: Momentum = mass × velocity (kilogram metre/second) (kilogram) (metre/second) kg m/s kg m/s Momentum has both magnitude and direction. When a force acts on a body that is moving, or able to move, a change in momentum occurs. Momentum is conserved in any collision/explosion provided no external forces act on the colliding/exploding bodies.	137-8 136, 138 136 136 136 137-8
HT only	Force, change in momentum and time taken for the change are related by the equation: force = change in momentum (kilogram metre/second) (newton, N) time taken for the change (second, s)	136

12.5 What is static electricity, how can it be used and what is the connection between static electricity and electric currents?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to explain why static electricity is dangerous in some situations and how precautions can be taken to ensure that the electrostatic charge is discharged safely • to explain how static electricity can be useful. Their skills, knowledge and understanding of how science works should be set in these substantive contexts: When certain insulating materials are rubbed against each other they become electrically charged. Negatively charged electrons are rubbed off one material onto 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 bodies are brought together they exert a force on each other. Two bodies that carry the same type of charge repel. Two bodies that carry different types of charge attract. Electrical charges can move easily through some substances, eg metals. The rate of flow of electrical charge is called the current. A charged body can be discharged by connecting it to earth with a conductor. Charge then flows through the conductor.	245, 246 246, 315 241-2 242 241 241 243, 245 245, 248 245
HT only	The greater the charge on an isolated body the greater the potential difference between the body and earth. If the potential difference becomes high enough a spark may jump across the gap between the body and any earthed conductor which is brought near it. Electrostatic charges can be useful, for example in photocopiers and smoke precipitators and the basic operation of these devices.	245 246, 315

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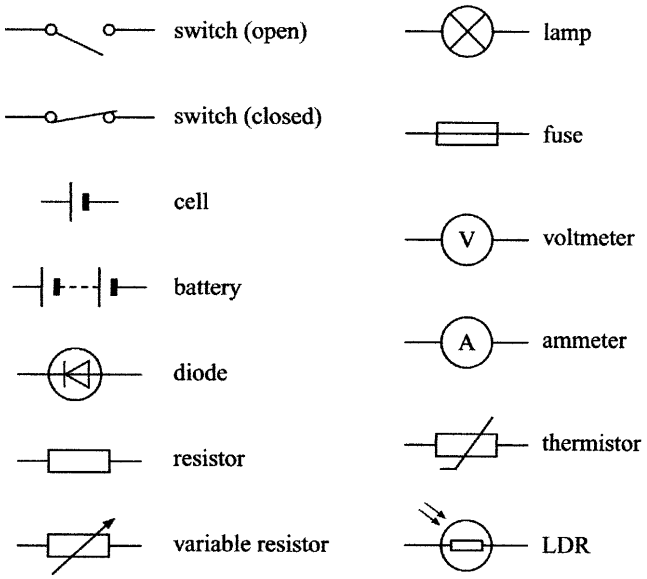
12.6 What does the current through an electrical circuit depend on?

FT & HT

Candidates should use their skills, knowledge and understanding of how science works:

- to interpret and draw circuit diagrams using standard symbols. The following standard symbols should be known:



248, 250, 252, 255, 269, 316, 319

- to apply the principles of basic electrical circuits to practical situations.

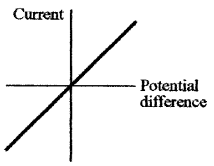
248-255

Their skills, knowledge and understanding of how science works should be set in these substantive contexts:

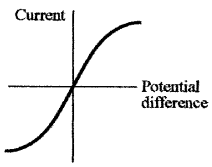
Current-potential difference graphs are used to show how the current through a component varies with the potential difference across it.

259, 316

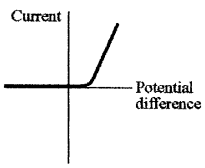
A resistor at constant temperature



A filament lamp



A diode



The current through a resistor (at a constant temperature) is directly proportional to the potential difference across the resistor.

253

Potential difference, current and resistance are related by the equation:

253

potential difference = current × resistance
(volt, V) (ampere, A) (ohm, Ω)

The resistance of a component can be found by measuring the current through, and potential difference across, the component.

255

continued…

	The resistance of a filament lamp increases as the temperature of the filament increases.	259
	The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction.	259, 316
	The resistance of a light-dependent resistor (LDR) decreases as light intensity increases.	319
	The resistance of a thermistor decreases as the temperature increases (ie. knowledge of negative temperature coefficient thermistor only is required).	319
	The current through a component depends on its resistance. The greater the resistance the smaller the current for a given potential difference across the component.	249, 253
	The potential difference provided by cells connected in series is the sum of the potential difference of each cell (depending on the direction in which they are connected).	260
	For components connected in series: − the total resistance is the sum of the resistance of each component − there is the same current through each component − the total potential difference of the supply is shared between the components.	256, 261 250, 256, 261 256, 261
	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.	257 251, 257

12.7 What is mains electricity and how can it be used safely?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works:	
	• to recognise errors in the wiring of a three-pin plug	270
	• to recognise dangerous practice in the use of mains electricity	268, 269, 270
	• to compare potential differences of d.c. supplies and the peak potential differences of a.c. supplies from diagrams of oscilloscope traces	299, 311
HT only	• to determine the period and hence the frequency of a supply from diagrams of oscilloscope traces.	299, 311
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	Cells and batteries supply current which always passes in the same direction. This is called direct current (d.c.).	248
	An alternating current (a.c.) is one which is constantly changing direction. Mains electricity is an a.c. supply. In the UK it has a frequency of 50 cycles per second (50 hertz).	268, 299
	UK mains supply is about 230 volts.	268
	Most electrical appliances are connected to the mains using cable and a three-pin plug.	270
	The structure of electrical cable.	270
	The structure of a three-pin plug.	270
	Correct wiring of a three-pin plug.	270
	If an electrical fault causes too great a current the circuit should be switched off by a fuse or a circuit breaker.	269
	When the current in a fuse wire exceeds the rating of the fuse it will melt, breaking the circuit.	269
	Appliances with metal cases are usually earthed.	269
	The earth wire and fuse together protect the appliance and the user.	269
HT only	The live terminal of the mains supply alternates between positive and negative potential with respect to the neutral terminal.	268
HT only	The neutral terminal stays at a potential close to zero with respect to earth.	268

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12.8 Why do we need to know the power of electrical appliances?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to calculate the current through an appliance from its power and the potential difference of the supply and from this determine the size of fuse needed.	270
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	Electric current is the rate of flow of charge.	260
	When an electrical charge flows through a resistor, electrical energy is transformed into heat energy.	264
	The rate at which energy is transformed in a device is called the power. power (watt, W) = energy transformed (joule, J) / time (second, s)	110, 266
	Power, potential difference and current are related by the equation: power (watt, W) = current (ampere, A) × potential difference (volt, V)	266
HT only	Energy transformed, potential difference and charge are related by the equation: energy transformed (joule, J) = potential difference (volt, V) × charge (coulomb, C)	261
HT only	The amount of electrical charge that flows is related to current and time by the equation: charge (coulomb, C) = current (ampere, A) × time (second, s)	260

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12.9 What happens to radioactive substances when they decay?		
FT & HT **HT only**	Candidates should use their skills, knowledge and understanding of how science works: • to explain how the Rutherford and Marsden scattering experiment led to the 'plum pudding' model of the atom being replaced by the nuclear model.	342
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	The relative masses and relative electric charges of protons, neutrons and electrons.	341
	In an atom the number of electrons is equal to the number of protons in the nucleus. The atom has no net electrical charge.	342
	Atoms may lose or gain electrons to form charged particles called ions.	342, 244
	All atoms of a particular element have the same number of protons.	343
	Atoms of different elements have different numbers of protons.	343
	Atoms of the same element which have different numbers of neutrons are called isotopes.	343
	The total number of protons in an atom is called its atomic number.	343
	The total number of protons and neutrons in an atom is called its mass number.	343
	The effect of alpha and beta decay on radioactive nuclei.	345
	The origins of background radiation.	340, 350

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12.10 What are nuclear fission and nuclear fusion?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works:	
	• to sketch a labelled diagram to illustrate how a chain reaction may occur.	348
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	There are two fissionable substances in common use in nuclear reactors, uranium 235 and plutonium 239.	348
	Nuclear fission is the splitting of an atomic nucleus.	348
	For fission to occur the uranium 235 or plutonium 239 nucleus must first absorb a neutron.	348
	The nucleus undergoing fission splits into two smaller nuclei and 2 or 3 neutrons and energy is released.	348
	The neutrons may go on to start a chain reaction.	348
	Nuclear fusion is the joining of two atomic nuclei to form a larger one.	156
	Nuclear fusion is the process by which energy is released in stars.	156

Unit Physics 3		Page numbers in New Physics for You
13.1 How do forces have a turning effect?		
Foundation Tier (FT) and Higher Tier (HT)	Candidates should use their skills, knowledge and understanding of how science works: • to describe how to find the centre of mass of a thin sheet of a material	pages 92-3
HT only	• to calculate the size of a force, or its distance from an axis of rotation, acting on a body that is balanced	90
HT only	• to analyse the stability of bodies by considering their tendency to topple.	93-5
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	The turning effect of a force is called the moment.	90
	The size of the moment is given by the equation: Moment = force × perpendicular distance from the line of action of the force to the axis of rotation (newton metre, Nm) (newton, N) (metre, m)	90
	The centre of mass of a body is that point at which the mass of the body may be thought to be concentrated.	92
	If suspended, a body will come to rest with its centre of mass directly below the point of suspension.	92
	The centre of mass of a symmetrical body is along the axis of symmetry.	92-3
HT only	If a body is not turning, the total clockwise moment must be exactly balanced by the total anticlockwise moment about any axis.	91
HT only	Recognise the factors that affect the stability of a body.	93-5
HT only	If the line of action of the weight of a body lies outside the base of the body there will be a resultant moment and the body will tend to topple.	93

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13.2 What keeps bodies moving in a circle?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to identify which force(s) provide(s) the centripetal force in a given situation • to interpret data on bodies moving in circular paths. Their skills, knowledge and understanding of how science works should be set in these substantive contexts: When a body moves in a circle it continuously accelerates towards the centre of the circle. This acceleration changes the direction of motion of the body, not its speed. The resultant force causing this acceleration is called the centripetal force. The direction of the centripetal force is always towards the centre of the circle. The centripetal force needed to make a body perform circular motion increases as: − the mass of the body increases; − the speed of the body increases; − the radius of the circle decreases.	70-1 70-1 70 70-1 70-1 70

13.3 What provides the centripetal force for planets and satellites?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to interpret data on planets and satellites moving in orbits that approximate to circular paths.	150-1
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	The Earth, Sun, Moon and all other bodies attract each other with a force called gravity.	148, 149, 71
	The bigger the masses of the bodies the bigger the force of gravity between them.	153
	As the distance between two bodies increases the force of gravity between them decreases.	153
	The orbit of any planet is an ellipse (slightly squashed circle), with the Sun at one focus.	152
	Gravitational force provides the centripetal force that allows planets and satellites to maintain their circular orbits.	71, 153
	The further away an orbiting body is the longer it takes to make a complete orbit.	154
	To stay in orbit at a particular distance, smaller bodies, including planets and satellites, must move at a particular speed around larger bodies.	154
	Communications satellites are usually put into a geostationary orbit above the equator.	153, 154-5
	Monitoring satellites are usually put into a low polar orbit.	154-5

13.4 What do mirrors and lenses do to light?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works:	
	• to construct ray diagrams to show the formation of images by plane, convex and concave mirrors	181, worksheets
	• to construct ray diagrams to show the formation of images by diverging lenses and converging lenses	194, 196
	• to explain the use of a converging lens as a magnifying glass and in a camera	196, 198
	• to calculate the magnification produced by a lens or mirror using the formula: magnification = image height / object height	195
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	The normal is a construction-line perpendicular to the Reflecting/refracting surface at the point of incidence.	177
	The angle of incidence is equal to the angle of reflection.	176-7
	The nature of an image is defined by its size relative to the object, whether it is upright or inverted relative to the object and whether it is real or virtual.	174, 178, 182, 196
	The nature of the image produced by a plane mirror.	178-9
	The nature of the image produced by a convex mirror.	181-2
	The nature of the image produced by a concave mirror for an object placed at different distances from the mirror.	181-2
	Refraction at an interface.	184-5
	Refraction by a prism.	206-7
	The nature of the image produced by a diverging lens.	194, 196
	The nature of the image produced by a converging lens for an object placed at different distances from the lens.	194, 195, 196
	The use of a converging lens in a camera to produce an image of an object on a detecting device (eg film).	198, 196

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13.5 What is sound?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to compare the amplitudes and frequencies of sounds from diagrams of oscilloscope traces.	232-3, 311
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	Sound is caused by mechanical vibrations and travels as a wave.	224-5
	Sounds in the range 20-20 000 Hz can be detected by the human ear.	230
	Sound cannot travel through a vacuum.	225
	The pitch of a note increases as the frequency increases.	232
	The loudness of a note increases as the amplitude of the wave increases.	232
	The quality of a note depends upon the waveform.	233
	Sound waves can be reflected and refracted	226-9
13.6 What is ultrasound and how can it be used?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to compare the amplitudes and frequencies of ultrasounds from diagrams of oscilloscope traces	232-3
HT only	• to determine the distance between interfaces in various media from diagrams of oscilloscope traces.	228
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	Electronic systems can be used to produce ultrasound waves which have a frequency higher than the upper limit of hearing for humans.	226
	Ultrasound waves are partially reflected when they meet a boundary between two different media. The time taken for the reflections to reach a detector is a measure of how far away such a boundary is.	228-9
	Ultrasound waves can be used in industry for cleaning and quality control.	229
	Ultrasound waves can be used in medicine for pre-natal scanning.	229

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13.7 How can electricity be used to make things move?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to explain how the motor effect is used in simple devices.	291-3
	When a conductor carrying an electric current is placed in a magnetic field, it may experience a force.	290
	The size of the force can be increased by: − increasing the strength of the magnetic field − increasing the size of the current.	290
	The conductor will not experience a force if it is parallel to the magnetic field.	290
	The direction of the force is reversed if either the direction of the current or the direction of the magnetic field is reversed.	290

13.8 How do generators work?		
FT & HT **HT only**	Candidates should use their skills, knowledge and understanding of how science works: • to explain from a diagram how an a.c. generator works, including the purpose of the slip rings and brushes. Their skills, knowledge and understanding of how science works should be set in these substantive contexts: If an electrical conductor 'cuts' through magnetic field lines, an electrical potential difference is induced across the ends of the conductor. If a magnet is moved into a coil of wire, an electrical potential difference is induced across the ends of the coil. If the wire is part of a complete circuit, a current is induced in the wire. If the direction of motion, or the polarity of the magnet, is reversed, the direction of the induced potential difference and the induced current is reversed. The generator effect also occurs if the magnetic field is stationary and the coil is moved. The size of the induced potential difference increases when: − the speed of the movement increases − the strength of the magnetic field increases − the number of turns on the coil increases − the area of the coil is greater.	298-9 296 297 296-7 296-7 298 300

13.9 How do transformers work?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to determine which type of transformer should be used for a particular application.	302-3
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	The basic structure of the transformer.	301-2
	An alternating current in the primary coil produces a changing magnetic field in the iron core and hence in the secondary coil. This induces an alternating potential difference across the ends of the secondary coil.	302
HT only	The potential difference (p.d.) across the primary and secondary coils of a transformer are related by the equation: $\frac{\text{p.d. across primary}}{\text{p.d. across secondary}} = \frac{\text{number of turns on primary}}{\text{number of turns on secondary}}$	302-3
	In a step-up transformer the potential difference across the secondary coil is greater than the potential difference across the primary coil.	302
	In a step-down transformer the potential difference across the secondary coil is less than the potential difference across the primary coil.	302
	The uses of step-up and step-down transformers in the National Grid.	303

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13.10 What is the life history of stars?		
FT & HT	Candidates should use their skills, knowledge and understanding of how science works: • to explain how stars are able to maintain their energy output for millions of years	156
HT only	• to explain why the early Universe contained only hydrogen but now contains a large variety of different elements.	156-7
	Their skills, knowledge and understanding of how science works should be set in these substantive contexts:	
	Our Sun is one of the many billions of stars in the Milky Way galaxy.	157
	The Universe is made up of billions of galaxies.	158
	Stars form when enough dust and gas from space is pulled together by gravitational attraction. Smaller masses may also form and be attracted by a larger mass to become planets.	152
	Gravitational forces balance radiation pressure to make a star stable.	156
	A star goes through a life cycle (limited to the life cycle of stars of similar size to the Sun and stars much larger than the Sun).	157
HT only	Fusion processes in stars produce all naturally occurring elements. These elements may be distributed throughout the Universe by the explosion of a star (supernova) at the end of its life.	156-7

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