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Additional Science

First certification Summer 2008

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Name : ______________________________________

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.	pages 6, 358
	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.	7, 359
	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.	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).	6
	• 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).	360
	• 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).	361
	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.	7, 359

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

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. Candidates should know and understand:	360
	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. A fair test is one in which only the independent variable affects the dependent variable, as all other variables are kept the same.	360
	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). 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).	361
	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.	362
	Random error can result from inconsistent application of a technique. Systematic error can result from consistent misapplication of a technique.	
	Any anomalous values should be examined to try and identify the cause and, if a product of a poor measurement, ignored.	362

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.	363
	Candidates should know and understand:	
	The range of the data refers to the maximum and minimum values.	361
	The mean (or average) of the data refers to the sum of all the measurements divided by the number of measurements taken.	361
	Tables are an effective means of displaying data but are limited in how they portray the design of an investigation.	363
	Bar charts can be used to display data in which the independent variable is categoric and the dependent variable continuous.	363
	Line graphs can be used to display data in which both the independent and dependent variables are continuous.	363
	Scattergrams can be used to show an association between two variables (eg water content of soil and height of plants).	

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:	364
	Patterns in tables and graphs can be used to identify anomalous data that require further consideration.	364
	A line of best fit can be used to illustrate the underlying relationship between variables.	364
	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).	364
	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.	364
	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

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

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: $\text{Acceleration} = \frac{\text{change in velocity (metre/second, m/s)}}{\text{time taken for change (second, s)}}$ (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

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.	137-8 136, 138
	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	136
	Momentum has both magnitude and direction.	136
	When a force acts on a body that is moving, or able to move, a change in momentum occurs.	136
	Momentum is conserved in any collision/explosion provided no external forces act on the colliding/exploding bodies.	137-8
HT only	Force, change in momentum and time taken for the change are related by the equation: $\text{force (newton, N)} = \dfrac{\text{change in momentum (kilogram metre/second)}}{\text{time taken for the change (second, s)}}$	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.	245, 246 246, 315
	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.	241-2
	The material that gains electrons becomes negatively charged. The material that loses electrons is left with an equal positive charge.	242
	When two electrically charged bodies are brought together they exert a force on each other.	241
	Two bodies that carry the same type of charge repel. Two bodies that carry different types of charge attract.	241
	Electrical charges can move easily through some substances, eg metals.	243, 245
	The rate of flow of electrical charge is called the current.	245, 248
	A charged body can be discharged by connecting it to earth with a conductor. Charge then flows through the conductor.	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.	245
	Electrostatic charges can be useful, for example in photocopiers and smoke precipitators and the basic operation of these devices.	246, 315

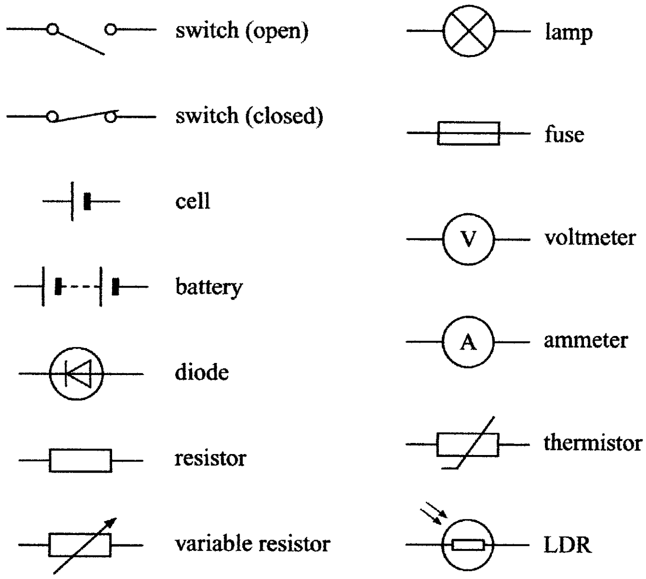
12.6 What does the current through an electrical circuit depend on?

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



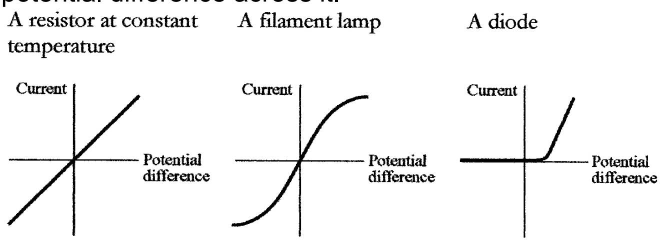
- to apply the principles of basic electrical circuits to practical situations.

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



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:

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

253

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

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. $\text{power (watt, W)} = \dfrac{\text{energy transformed (joule, J)}}{\text{time (second, s)}}$	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

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

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