AQA : GCSE specification 3469

Science : Single Award Specification A (Modular)

Please ensure that you have selected the correct specification.

Summary of Subject Content (in Biology for You)

10.	**Module 13 – Life and living processes**	
10.1	What are human bodies built for?	
10.2	What is the job of the digestive system and how does it do that job?	
10.3	How are substances transported by the blood?	
10.4	What causes disease and how do our bodies defend themselves against it?	
10.5	How do humans respond to their surroundings?	
10.6	How do our bodies maintain the conditions inside them that they need to work properly?	
10.7	How do drugs affect our bodies?	
11.	**Module 14 – Environment, inheritance and selection**	
11.1	What determines where particular species live and how many of them there are?	
11.2	How do humans affect the environment?	
11.3	Why are individuals of the same species different from each other?	
11.4	How can we breed plants and animals with the characteristics we prefer?	
11.5	Why have some species of plants and animals died out? How do new species of plants and animals develop?	
11.6	Which human characteristics show a simple pattern of inheritance?	
11.7	How can women control their fertility?	

(In Chemistry for You)

12	**Module 15 – Material and Reactions**	
12.1	Where do metals fit into a table of the elements?	
12.2	What chemical reactions are used to extract metals?	
12.3	How can metal compounds be made?	
12.4	Why is limestone such a useful material?	
12.5	How can so many useful products be made from crude oil?	
13.	**Module 16 – Patterns and Reactions**	
13.1	How can we speed up or slow down chemical reactions?	
13.2	How can we use living things to do our chemistry for us?	
13.3	What happens when elements react?	
13.4	How can chemical elements be grouped into families?	
13.5	How can the similarities between elements in the same group be explained?	

(In Physics for You)

14.	**Module 17 – Energy and Electricity**	
14.1	How is heat (thermal energy) transferred and how can we reduce heat transfer?	
14.2	Why are electrical appliances so useful and what does it cost to use them?	
14.3	How efficient are the appliances we use?	
14.4	How should we generate the electricity we need?	
14.5	What does the current through an electrical circuit depend on?	
14.6	What is mains electricity and how can it be used safely?	
14.7	How do generators work?	
15.	**Module 18 – Forces, Waves and Radiation**	
15.1	How do planets and artificial satellites stay in orbit?	
15.2	What do we know about the origins of the Universe and the life histories of stars?	
15.3	Why do scientists talk about light and sound as waves?	
15.4	Is there radiation we cannot see beyond the ends of the spectrum?	
15.5	What do we know about the radiation from radioactive substances?	
15.6	What happens to radioactive substances when they decay or are used in nuclear reactors?	
15.7	What is ultrasound and how can it be used?	

On the following pages, the left-hand column shows:

KS3	Content which is particularly relevant from key stage 3.
FT and HT	Content included in both Foundation and Higher tiers.
HT	Content included only in Higher tier.

10	Module 13 – Life and Living Processes	
	This module includes the following: *Exploring the digestive system which enables nutrients from food to enter the bloodstream;* *Examining how blood transports materials around the body.* *Examining the ways in which the body defends itself against infection.* *Exploring how humans:* • *co-ordinate their behaviour in response to stimuli from their environment;* • *maintain a stable internal environment.* *Examining the effects of drugs on the human body.*	
10.1	**What are human bodies built for?** *All living things are made up of cells. Different types of cells do different jobs.*	
KS3	Cells may be specialised to carry out a particular function. A group of cells with similar structure and a particular function is called a tissue.	pages 12, 15
	Organs are made of tissues. Different organs are combined to form organ systems. Each system in the body carries out a particular function or range of functions.	p. 15, 16
FT & HT	Most human cells like most other animal cells have the following parts: • A nucleus which controls the activities of the cell; • Cytoplasm in which most of the chemical reactions take place; • A cell membrane which controls the passage of substances in and out of the cell.	p. 8
	Candidates should be able, when provided with appropriate information, to relate the structure of different types of human cells to their function in a tissue, an organ or the whole organism.	8-16
HT	The chemical reactions in cells are controlled by enzymes	29-36
	The cytoplasm contains structures called mitochondria which is where most energy is released in respiration.	9
10.2	**What is the job of the digestive system and how does it do that job?** *When the food we eat is in our stomach and intestines it is still not really inside our bodies. The job of the digestive system is to convert food into soluble substances and then to absorb it into the bloodstream.*	
KS3	The human diet includes carbohydrates, proteins and fats.	44, 45-47
	The digestive system breaks down food and absorbs it into the bloodstream.	57-61
	The digestive system includes the gullet, stomach, liver, pancreas, small intestine and large intestine.	58-61

FT & HT	Starch (a carbohydrate), proteins and fats are insoluble. They are broken down into soluble substances so that they can be absorbed into the bloodstream in the wall of the small intestine. In the large intestine much of the water is absorbed into the bloodstream. The indigestible food which remains makes up the bulk of the faeces. Faeces leave the body via the anus.	p. 57-61
	The breakdown of large molecules into smaller molecules is speeded up (catalysed) by enzymes.	29-33
	The enzyme amylase is produces in the salivary glands, the pancreas and the small intestine. This enzyme catalyses the breakdown of starch into sugars.	32, 57
	Protease enzymes are produces by the stomach, the pancreas and the small intestine. These enzymes catalyse the breakdown of protein into amino acids.	24, 57, 59
	Lipase enzymes are produced by the pancreas and small intestine. These enzymes catalyse the breakdown of fat into fatty acids and glycerol.	60
	The stomach also produces hydrochloric acid. The acid kills most of the bacteria taken in with food. The enzymes in the stomach work most effectively in these acid conditions.	59
	The liver produces bile which is stored in the gall bladder before being released into the small intestine. Bile neutralises the acid that was added to food in the stomach. This provides alkaline conditions in which enzymes in the small intestine work most effectively. Bile also emulsifies fats (breaks large drops of fats into smaller droplets). This increases the surface area of fats for lipase enzymes to act upon.	60
10.3	**How are substances transported by the blood?** *Substances are transported around the body, for example by the blood.*	
FT & HT	Blood consists of a fluid called plasma in which are suspended white blood cells, red blood cells and platelets.	97-99
	Plasma transports: • Carbon dioxide from the organs to the lungs; • Soluble products of digestion from the small intestine to other organs; • Urea from the liver to the kidneys.	 101 101 101
	White blood cells have a nucleus. They form part of the body's defence system against microorganisms.	99
	Platelets are small fragments of cells. They have no nucleus. Platelets help blood clot at the site of a wound.	100
	Red blood cells transport oxygen from the lungs to the organs.	99
HT	Red blood cells have no nucleus. They are packed with a red pigment called haemoglobin. In the lungs haemoglobin combines with oxygen to form oxyhaemoglobin. In other organs oxyhaemoglobin splits up into haemoglobin and oxygen.	98

10.4	**What causes disease and how do our bodies defend themselves against it?** *Our bodies provide an excellent environment for many microbes which can make us ill once they are inside. Our bodies need to stop microbes from getting in and deal with any microbes which do get in.*	
KS3	Bacteria and viruses may reproduce rapidly inside the body and may produce poisons (toxins) which make us feel ill. Viruses damage the cells in which they reproduce.	p. 171-173
	Vaccination is used to protect us against bacteria and viruses.	181
FT & HT	Diseases can be caused when microorganisms such as certain bacteria and viruses enter the body: • A bacterial cell consists of cytoplasm and a membrane surrounded by a white cell wall; the genes are not in a distinct nucleus; • Viruses are smaller than bacteria; they consist of only a protein coat surrounding a few genes; they can only reproduce inside living cells.	171-181
	Diseases are more likely to occur if large numbers of microorganisms enter the body as a result of unhygienic conditions or contact with infected people.	175-176
	The body has several methods of defending itself against the entry of microorganisms: • The skin acts as a barrier • The breathing organs produce a sticky liquid mucus which covers the lining of these organs and traps microorganisms; • The blood produces clots that seal cuts.	178 74, 178 100, 178
	White blood cells help to defend against infective microorganisms: • By ingesting microorganisms; • By producing antibodies which destroy particular bacteria or viruses; • By producing antitoxins which counteract the toxins (poisons) released by microorganisms.	p. 99 p. 99 p. 99
	When people are vaccinated they are immunised against disease by introducing a mild, or dead, form of the infecting organism into their bodies. The white blood cells respond by producing antibodies. If the infective organism enters the body, antibodies are rapidly produced to destroy it.	179, 181
	Once they have produced antibodies against a particular bacterium or virus, white blood cells can quickly produce them again so that the person is immune to that disease.	179, 181
	Candidates should be able, when provided with appropriate information, to evaluate evidence relating living conditions and lifestyle to the spread of disease.	175-176

10.5	**How do humans respond to their surroundings?** *We detect features of the world around us using our senses. Processing this information and co-ordinating the actions which we make in response to it, is the job of our nervous system.*	
FT & HT	The nervous system enables humans to react to their surroundings and co-ordinate their behaviour. Cells called receptors detect stimuli (changes in the environment). These include:	p. 118-131
	• Receptors in the eyes which are sensitive to light;	130-131
	• Receptors in the ears which are sensitive to sound;	128
	• Receptors in the ears which are sensitive to changes in position and enable us to keep our balance;	129
	• Receptors on the tongue and in the nose which are sensitive to chemicals and enable us to taste and smell;	127
	• Receptors in the skin that are sensitive to touch and pressure and temperature changes.	126
	Information from receptors passes along cells (neurones) in nerves to the brain. The brain co-ordinates the response.	118-120
	Some responses to stimuli are automatic, rapid and are called reflex actions.	124
	In a simple reflex action, electrical impulses pass from a receptor along a sensory neurone to the spinal cord or brain, then along a motor neurone to a muscle or gland. The muscle or gland brings about the response.	121
	The eye includes sclera, cornea, iris, pupil, lens, ciliary muscle, suspensory ligament, retina and optic nerve.	130
	In the eye: • The tough outer sclera has a transparent region at the front called the cornea; • The muscular iris controls the size of the pupil and hence the amount of light reaching the retina; • The lens is held in position by suspensory ligaments and ciliary muscles; • The retina contains the receptor cells which are sensitive to light.	p. 130 130 130-131, Also in Physics for You, p. 208 130-131
	Light from an object enters the eye through the cornea. The curved cornea and the lens produce an image on the retina. The receptor cells in the retina send impulses to the brain along sensory neurones in the optic nerve.	131

HT	The shape of the lens can be altered, by contraction or relaxation of the ciliary muscles, to focus near or distant objects respectively.	p. 131 Also in Physics for You, p. 154
	Electrical impulses transmit information from receptor cells along sensory neurones to the central nervous system that includes the brain and the spinal cord.	123
	Reflex actions often involve three neurones called sensory, relay and motor neurones. In such a reflex action: • Impulses from a receptor pass along an sensory neurone to the central nervous system; • At a junction (synapse) between a sensory neurone and a relay neurone in the central nervous system, a chemical is released which causes an impulse to be sent along a relay neurone. • A chemical is then released at the synapse between a relay neurone and a motor neurone in the central nervous system, causing impulses to be sent along a motor neurone to the organ (the effector) which brings about the response. • The effector is either a muscle or a gland; • A muscle responds by contracting, a gland by releasing (secreting) chemical substances.	123 123 122 122 123 123
	Candidates should be able, when provided with appropriate information, to analyse a reflex action in terms of : Stimulus → receptor → co-ordinator → effector → response	118, 123
10.6	**How do bodies maintain the conditions inside them that they need to work properly?** *To survive our bodies must keep themselves at just the right temperature, have just the right amount of water and sugar in the bloodstream etc. The body has automatic systems which constantly monitor and control these things.*	
FT & HT	Humans need to remove waste products from their bodies and to keep their internal environment relatively constant.	p. 106-107
	Waste products which have to be removed from the body include: • Carbon dioxide produced by respiration – most of this leaves the body via the lungs when we breath out; • Urea produced by the liver by the breakdown of excess amino acids – this is removed by the kidneys in the urine, which is temporarily stored in the bladder.	69-72, 111 111
	Internal conditions which are controlled include: • The water content of the body – water leaves the body via the lungs when we breath out and via the skin when we sweat, and excess is lost via the kidneys in the urine; • The ion content of the body – ions are lost via the skin when we sweat and excess are lost via the kidneys in the urine; • Temperature – to maintain the temperature at which enzymes work best	69, 72, 109-113 107, 111-113 109-110
	Sweating helps to cool the body. More water is lost when it is hot, and more water has to be taken as drink or in food to balance this loss.	109-110

FT & HT	Many processes within the body are co-ordinated by chemical substances called hormones. Hormones are produced by glands and are transported to their target organs by the bloodstream.	p. 132-133
HT	The kidneys help maintain the internal environment by: • First altering the blood; • Re-absorbing all the sugar: • Re-absorbing the dissolved ions needed by the body; • Re-absorbing as much water as the body needs; • Releasing urea, excess ions and excess water as urine.	 112 112 112 112-113
	The kidneys produce dilute urine if there is too much water in the blood or concentrated urine if there is too little water in the blood. If the water content of the blood is too low, the pituitary gland releases a hormone called ADH into the blood. This causes the kidneys to reabsorb more water and results in a more concentrated urine. If the water content of the blood is too high, less ADH is released into the blood. Less water is re-absorbed in the kidneys resulting in a more dilute urine.	111-113
	Body temperature is monitored and controlled by the thermoregulatory centre in the brain. This centre has receptors sensitive to the temperature of blood flowing through the brain. Also temperature receptors in the skin send impulses to the centre giving information about skin temperature.	110
	If the core body temperature is too high: • Blood vessels supplying the skin capillaries dilate so that more blood flows through the capillaries and more heat is lost; • Sweat glands release more sweat which cools the body as it evaporates;	 p. 110 110
	If the core body temperature is too low: • Blood vessels supplying the skin capillaries constrict to reduce the flow of blood through the capillaries; • Muscles may ‘shiver’ – their contraction needs respiration which releases some energy as heat.	 110 110

10.7	**How do drugs affect our bodies?** *Even very common drugs such as alcohol and tobacco which may be used legally by people over a certain age harm our bodies. People cannot make sensible decisions about drugs unless they know the dangers involved.*	
KS3	Solvents, alcohol, tobacco and other drugs may harm the body.	p. 185-189
FT & HT	Solvents: • Affect behaviour; • May cause damage to the lungs, liver and brain.	 187 187
	Alcohol: • Affects the nervous system by slowing down reactions and may lead to lack of self-control, unconsciousness or even coma: • May cause damage to the liver and brain.	 188 188
	Drugs change the chemical processes in people's bodies so that they may become dependent or addicted to them and suffer withdrawal symptoms without them. Nicotine is the addictive substance in tobacco.	185-189
	Tobacco smoke contains substances which can help to cause: • Lung cancer; • Other lung diseases such as bronchitis and emphysema; • Disease of the heart and blood vessels	 83-84 83-84 83-84
	Tobacco smoke also contains carbon monoxide which reduces the oxygen-carrying capacity of the blood. In pregnant women this can deprive a fetus of oxygen and lead to a low birth mass.	83-84
	Candidates should be able, when provided with appropriate information, to explain how the link between smoking tobacco and lung cancer gradually became accepted.	83-84
HT	Carbon monoxide combines irreversibly with the haemoglobin in red blood cells.	83

11	**Module 14 – Environment, inheritance & selection**	
	This module includes the following: Examining how various organisms are adapted to survive in their normal environment and the factors which govern the population of a species in a particular location Considering the ways in which human activities can disrupt ecosystems which would otherwise be sustained in a relatively stable condition by the biological and geochemical cycling of materials. *Investigating the variation between individuals of the same species and interpreting this in terms of both heredity and environmental factors.* *Explaining inheritance in terms of information carried on chromosomes and, at the higher tier only, developing this explanation further in terms of cell division by mitosis and meiosis.* *Exploring the use of selective breeding, cloning and, at the higher tier only, genetic engineering, to produce plants and animals with preferred characteristics.* *Considering how natural selection has resulted in the evolution of some species and the extinction of others, and examining the role of mutation in this process.* *Studying a selection of simple patterns of inheritance in humans:* • *The determination of sex:* • *The inheritance both of diseases caused by dominant alleles and diseases caused by recessive alleles* *Examining and evaluating the hormonal control of fertility in human females.*	
11.1	**What determines where particular species live and how many of them there are?** *Animals and plants are normally well adapted to survive in their normal environment. Their population depends on many factors including competition for the things they need, being eaten for food and being infected by disease.*	
KS3	Physical factors which may affect organisms include:	
	• Temperature;	p. 329
	• Amount of light;	329
	• Availability of water;	329
	• The availability of oxygen and carbon dioxide.	329
	These factors may vary according to the time of day and the time of year.	333
	Organisms live, grown and reproduce in places where, and at times when, conditions are suitable.	328, 333
	This helps to explain why the types of organisms vary from place to place and from time to time.	333

FT & HT	Organisms have features (adaptations) which enable them to survive in the conditions in which they normally live.	p. 336-338
	Candidates should be able, when provided with appropriate information to:	
	• Explain how animals are adapted for survival in arctic and desert environments in terms of :	338
	- Body size and surface area	338
	- Thickness of insulating coat	338
	- Amount of body fat	338
	- Camouflage;	338
	• Explain how plants are adapted to survive in arid conditions	336
	• Suggest how other organisms are adapted to the conditions in which they live	p. 336-337
	Plants often compete with each other for space, and for water and nutrients from soil.	339-340
	Animals often compete with each other for space, food and water.	339-340
	Candidates should be able, when provided with appropriate information, to suggest the factors for which organisms are competing in a given habitat.	339-340
	Animals which kill and eat other animals are called predators; the animals they eat are called prey.	339-340
	In a community: • The number of animals of a particular species (its population) is usually limited by the amount of food available; • If the population of prey increases, more food is available for its predators and their population may also increase; • If the population of predators increases, more food is needed and the population of prey will decrease.	 333, 341-343 341-343 341-343
	The size of a population may be affected by: • The total amount of food or nutrients available; • Competition for food or nutrients; • Competition for light; • Predation or grazing; • Disease	 332-333 333, 339-340 333, 339-340 333, 339-340 333, 339-340

11.2	**How do humans affect the environment?** *Humans often upset the balance of different populations in natural ecosystems, or change the environment so that some species find it difficult to survive. With so many people in the world, there is a serious danger of causing permanent damage not just to local environments but also to the global environment.*	
FT & HT	Humans reduce the amount of land available for other animals and plants by: • Building; • Quarrying: • Farming: • Dumping waste.	 p. 330, 346 330 330, 346 330
	Human activities may pollute: • Water – with sewage, fertiliser or toxic chemicals; • Air – with smoke and gases such as sulphur dioxide; • Land – with toxic chemicals, such as pesticides and herbicides, with may be washed from land into water.	 348-349 347 348-349, 364-365
	When fossil fuels are burned carbon dioxide is released into the atmosphere.	347
	Sulphur dioxide and nitrogen oxides may also be released. These gases dissolve in rain and make it more acidic. Acid rain may damage trees directly. If the water in rivers and lakes becomes too acidic, plants and animals cannot survive.	347
	When the Earth's human population was much smaller, the effects of human activity were usually small and local.	344-345
	Rapid growth in the human population and an increase in the standard of living means that:	
	• Raw materials, including non-renewable energy resources, are rapidly being used up;	346
	• Increasingly more waste is produced;	344-345
	• Unless waste is properly handled more pollution will be caused.	344-345
	Large scale deforestation in tropical areas, for timber and to provide land for agriculture, has:	346
	• Increased the release of carbon dioxide into the atmosphere (because of burning of and the activities of micro-organisms);	346, 371
	• Reduced the rate at which carbon dioxide is removed from the atmosphere and 'locked-up' for many years as wood.	346, 371
	Increases in the numbers of cattle and rice fields have increased the amount of methane released into the atmosphere.	372
	The levels of carbon dioxide and methane in the atmosphere are slowly rising.	372
	Increasing levels of these gases may be causing the 'greenhouse effect'	372
	An increase in the Earth's temperature of only a few degrees Celsius: • May cause quite big changes in the Earth's climate; • May cause a rise in sea level.	372 372 372

FT & HT	**Candidates should be able,** when supplied with appropriate information, to use their scientific knowledge, weigh evidence and form balanced judgements about some of the major environmental issues facing society, including the importance of sustainable development.	p. 344-352, 364-365, 372-374
HT	Farmers add fertiliser to soil to replace the nutrients which crops remove. Excess fertilisers may be washed into lakes and rivers.	p. 219, 348, 374
	Pollution of water by fertilisers may cause eutrophication. The stages in this process are:	
	• The rapid growth of water plants;	374
	• Death of some of these due to competition, e.g. for light;	374
	• An increase in the number of micro-organisms which feed on dead organisms;	374
	• The increased use of oxygen from the water by these micro-organisms for their respiration;	374
	• The resultant death due to oxygen shortage of fish and other aquatic animals.	374
	Untreated sewage provides food for micro-organisms. This has the same effect (eutrophication) in water as dead vegetation.	349, 374
	Carbon dioxide and methane in the atmosphere absorb most of the energy radiated by the Earth. Some of this energy is re-radiated back to the Earth and so keeps the Earth warmer than it would otherwise be.	372
11.3	**Why are individuals of the same species different from each other?** *There are not only differences between different species of plants and animals, but also between individuals of the same species. These differences are due partly to the information in the cells they have inherited from their parents and partly to the different environment in which the individuals live and grow.*	
FT & HT	Young plants and animals resemble their parents (have similar characteristics) because of information passed on to them in the sex cells (gametes) from which they developed.	p. 254-256
	This information is carried by genes. Different genes control the development of different characteristics.	254-256
	Candidates should be able, when provided with appropriate information, to explain:	
	• Why Mendel proposed the idea of separately inherited factors that we now call genes;	279
	• Why the importance of Mendel's discovery was not recognised until after his death.	279
	Differences in the characteristics of different individuals of the same kind (species) may be due to differences in: • The genes they have inherited (genetic causes) • The conditions in which they have developed (environmental causes); • Or a combination of both	255

FT & HT	The nucleus of a cell contains chromosomes. Chromosomes carry genes that control the characteristics of the body. Each chromosome carries a large number of genes.	p. 272-273
	Many genes have different forms called alleles, which may produce different characteristics.	p. 279-280
	In body cells the chromosomes are normally found in pairs. Body cells divide to produce additional cells during growth or to produce replacement cells.	272, 276
	There are two forms of reproduction: • Sexual reproduction – which involves the joining (fusion) of male and female gametes; • Asexual reproduction – where there is no fusion of cells and only one individual is needed as the single parent.	 155, 277 154, 233, 276
	Asexual reproduction gives rise to individuals whose genetic information is identical with that of the parent. These genetically identical individuals are known as a clone.	154, 233-234, 276
	Sexual reproduction results in individuals that have a mixture of the genetic information from two parents. These individuals show more variation than offspring from asexual reproduction.	155, 277
HT	Before each cell division, a copy of each chromosome is made so that each body cell has exactly the same genetic information. This type of cell division is called mitosis.	276
	Cells in reproductive organs – testes and ovaries (in humans) – divide to form sex cells (gametes). When a cell divides to form gametes:	155-158, 277
	• Copies of the chromosomes are made; • Then the cell divides twice to form four gametes, each with a single set of chromosomes. This type of cell division is called meiosis.	277
	When gametes join at fertilisation, a single body cell with new pairs of chromosomes is formed. A new individual then develops by this cell repeatedly dividing by mitosis.	277, 276
	The cells of the offspring produced by asexual reproduction are produced by mitosis from the parental cells. They contain the same genes as the parents.	276
	Sexual reproduction gives rise to variation because:	
	• The gametes are produced from the parental cells by meiosis;	277
	• When gametes fuse, one of each pair of alleles come from each parent;	277
	• The alleles in a pair may vary and therefore produce different characteristics.	277, 279
11.4	**How can we breed plants and animals with the characteristics we prefer?** *By selecting only preferred plants and animals for sexual reproduction we can gradually breed animals and plants with desired characteristics. Non-sexual reproduction can be used to produce individuals exactly like their parents. [Scientists can now add, remove or change genes to produce the plants and animals they want].*	
KS3	Selective breeding in agriculture has resulted in varieties of plants and breeds of animals that have increased yields.	290

FT & HT	New plants can be produced quickly and cheaply by taking cuttings from older plants. These new plants are genetically identical to the parent plant. Cuttings are most likely to grow successfully if they are grown in a damp atmosphere until roots develop.	p. 234
	We can use artificial selection to produce new varieties of organisms. We do this by choosing individuals which have characteristics useful to us and breeding from them.	290
	Selective breeding greatly reduces the number of alleles in a population. Widespread use of clones in agriculture also reduces the number of alleles available for further selective breeding. Selective breeding to produce new varieties for changed conditions may not then be possible.	290
	Modern cloning techniques include: • Tissue culture – using small groups of cells from part of a plant; • Embryo transplants – splitting apart cells from a developing animal embryo before they become specialised, then transplanting the identical embryos into host mothers.	 234 291
	Genes from the chromosomes of humans and other organisms can be 'cut out' using enzymes and transferred to bacterial cells. The transferred gene continues to make the same protein in a bacterial cell. By culturing the genetically engineered bacterial on a large scale, commercial quantities of the protein can be produced. This process is used in the manufacture of drugs and hormones, including human insulin.	289
	Genes can also be transferred to the cells of animals or plants at an early stage in their development so that they develop with desired characteristics.	289, 291, 293
	Candidates should be able to make informed judgements about the economic, social, and ethical issues concerning cloning and genetic engineering that they have studied or from information that is presented to them.	290-291, 234, 289-293
11.5	**Why have some species of plants and animals died out? How do new species of plants and animals develop?** *Changes in the environments of plants and animals may cause them to die out. Particular genes, or accidental changes in genes of plants or animals may give them characteristics which enable them to survive better. Over a period this may result in entirely new species.*	
FT & HT	Fossils are the 'remains' of plants or animals from many years ago which are found in rocks.	302-303
	Fossils may be formed in various ways including:	
	• From the hard parts of animals which do not decay easily;	302
	• From parts of animals or plants which have not decayed because one or more of the conditions needed for decay are absent;	302
	• When parts of the plant or animal are replaced by other materials as they decay;	302
	• As preserved traces or animals or plants, e.g. footprints, burrows or rootlet traces.	302
	We can learn from fossils how much (or how little) different organisms have changed since life developed on Earth.	303-304

FT & HT	The theory of evolution states that all species of living things which exist today – and many more which are now extinct – have evolved from simple life-forms which first developed more than three billion years ago.	p. 296-305
	Evolution occurs via natural selection:	
	• Individual organisms within a particular species may show a wide range of variation because of differences in their genes;	296-301
	• Predation, disease and competition cause large numbers of individuals to die;	296-301
	• Individuals with characteristics most suited to the environment are more likely to survive to breed successfully;	296-301
	• The genes which have enabled these individuals to survive are then passed on to the next generation.	296-301
	Candidates should be able to:	
	• Explain how fossils provide evidence for the theory of evolution;	302-303
	• Explain how over-use of antibiotics can lead to the evolution of resistant bacteria.	300
	Candidates should be able, when provided with additional information, to interpret evidence relating to evolutionary theory.	296-306
	The environment that species need to be able to survive may change or successful new predators, new diseases or new competitors may arise. Unless evolution occurs and species become better adapted to survive these changes they may become extinct.	296-301, 305
	New forms of genes result from changes (mutations) in existing genes.	285
	Mutations occur naturally. The chance of mutations occurring is increased by: • Exposure to ionising radiations, including ultra-violet light, X-rays and radiation from radioactive substances; the greater the does of radiation, the greater the chance of mutation; • Certain chemicals.	285 285
	Candidates should be able, when provided with appropriate information, to: • Suggest reasons why Darwin's theory of natural selection was only gradually accepted.	
HT	• Identify the differences between Darwin's theory of evolution and conflicting theories, e.g. Lamarck's;	298-299
	• Suggest reasons for the different theories.	298-299
	Most mutations are harmful: • If mutations occur in reproductive cells, young may develop abnormally or die at an early state of their development; • If mutations occur in the body cells, these may start to multiply in an uncontrolled way and invade other parts of the body; this is cancer.	285 285
	Some mutations are neutral in their effects and, in rare cases, a mutation may increase the chances of survival or an organism and any offspring which inherit the mutant gene.	285

11.6	**Which human characteristics show a simple pattern of inheritance?** *What sex human beings are, and whether or not they inherit certain disease, show a very simple pattern of inheritance.*	
FT & HT	In human body cells, one of the 23 pairs of chromosomes carries the genes which determines sex. In females the sex chromosomes are the same (XX); in males the sex chromosomes are different (XY).	p. 272, 278
	For certain characteristics, the characteristic is controlled by one gene. Some genes have two different forms called alleles.	279-280
	An allele which controls the development of a characteristic when it is present on only one of the chromosomes is a dominant allele.	280-281
	An allele which controls the development of characteristics only if the dominant allele is not present is a recessive allele.	281
	Some disorders are inherited: [Attention is drawn to the potential sensitivity needed in teaching about inherited disorders.] • Huntington's disease – disorder of the nervous system – is caused by a dominant allele of a gene and can therefore be passed on by only one parent who has the disorder; • Cystic fibrosis – a disorder of cell membranes – must be inherited from both parents. The parents may be carriers of the disorder without actually having the disorder themselves. It is caused by a recessive allele of a gene and can therefore be passed on by parents, neither of whom has the disorder; • Sickle-cell anaemia – a disorder of the red blood cells which reduces the oxygen-carrying capacity of the blood. Being a carrier of the allele can be advantageous in countries where malaria is prevalent.	287 286 288
HT	If both chromosomes in a pair contain the same allele of a gene, the individual is homozygous for that gene.	281
	If the chromosomes in a pair contain different alleles of a gene, the individual is heterozygous for that gene.	281
	Candidates should be able, when provided with appropriate information: • To predict and/or explain the outcomes of crosses between individuals for each possible combination of dominant and recessive alleles of the same gene; • To construct and/or interpret genetic diagrams.	282-284 282-284
11.7	**How can women control their fertility?** *The monthly cycle which controls the release of eggs by woman's ovaries is controlled by hormones. These hormones can be deliberately used to increase or reduce fertility.*	
FT & HT	The monthly release of an egg from a woman's ovaries and the changes in the thickness of the lining of her womb are controlled by hormones secreted by the pituitary gland and by the ovaries. Fertility in women can be controlled by giving:	162-163
	• Hormones that stimulate the release of eggs from the ovaries (fertility drugs);	163, 167-168
	• Hormones that prevent the release of eggs from the ovaries (oral contraception).	163, 164

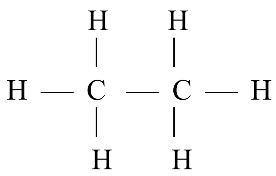
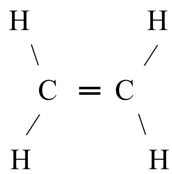
FT & HT	**Candidates should be able** to evaluate the benefits of, and the problems that may arise from, the use of hormones to control fertility.	
HT	Several hormones are involved in the menstrual cycle of a woman. Those hormones involved in promoting the release of an egg include:	p. 162
	• FSH which is secreted by the pituitary gland and causes an egg to mature in one of the ovaries, and also stimulates the ovaries to produce hormones including oestrogen;	163
	• Oestrogen which is secreted by the ovaries and inhibits the further production of FSH as well as stimulating the pituitary gland to produce a hormone called LH;	163
	• LH which is secreted by the pituitary gland and stimulates the release of the egg about the middle of the menstrual cycle;	163
	The uses of hormones in controlling fertility include:	
	• Giving FSH as a 'fertility drug' to a woman whose own level of FSH is too low to stimulate eggs to mature;	167-168
	• Giving an oral contraceptive which contains oestrogen, to inhibit FSH production so that no eggs mature;	164

12	Module 15 – Materials and Reactions	
	This module includes the following: *Examining how common metals are, and where they are, in a periodic table of the elements. (N.B. For the purposes of this module, the periodic table is regarded as comprising the elements in order of their relative atomic masses. The periodic table in order of their proton (atomic) numbers is considered in Module 16 in the context of atomic structure).* *Explaining how metals are extracted from their ores and relating this to their reactivities.* *Investigating how metal compounds (salts) can be prepared.* *Investigating the uses of limestone both as a building material and as a raw material for producing a range of other useful materials.* *Studying the fractionation and cracking of crude oil to produce a range of useful materials, including plastics via the process of polymerisation.* *N.B. It is anticipated that candidates' abilities to represent chemical substances by formulae will be progressively developed throughout the modules associated with Materials and Reactions.* *The assessment of these abilities will, however, be incorporated into the assessment, via the terminal examination, of those modules where they are explicitly specified, i.e. Patterns and Reactions.* ***Candidates should be able** to write word equations for all reactions referred to in the tier of this module for which they are entered.*	
12.1	**Where do metals fit into a table of the elements?** *Chemists have for more than 150 years arranged elements into a table so that they form Groups with similar properties. There are several groups of metals in such a periodic table.*	
FT & HT	The chemical elements can be arranged in order of the relative atomic masses of their elements. This list can then be arranged in rows so that elements with similar properties are in the same columns, known as Groups. The resulting table is known as the periodic table.	p. 42-3
	Although most elements are in appropriate Groups, a few are not. Argon atoms, for example, have a greater relative atomic mass than potassium atoms but argon is better placed before the potassium in the periodic table so that it is in Group 0 and potassium is in Group 1.	43
	More than three-quarters of the elements are metals.	48
	In the periodic table metals are mainly found: • In the left hand columns (Group 1 and Group 2); • In the central block (transition elements).	48

12.2	**What chemical reactions are used to extract metals?** *How a metal is extracted from its ore depends on how reactive the metal is.*	
KS3	Some metals are more reactive than others.	
	By observing whether or not various metals react: • With air, to produce metal oxides; • With water (cold, hot or as steam) to produce metal hydroxides (or oxides) and hydrogen; • With dilute acids, to produce metal salts and hydrogen; and by observing how vigorous any of these reactions are – a reactivity series can be determined.	Chapter 14
	The reactivity series of metals lists metals in order of their reactivity, the most reactive metal being placed at the top of the list and the least reactive at the bottom.	p. 82-4
	A more reactive metal can displace a less reactive metal from its compounds.	82-4
	The non-metal elements carbon and hydrogen will also displace less reactive metals from oxides of those metals.	85, 90, 96
	Candidates should be able to use the position of a metal in the reactivity series to predict how the metal could be extracted from a compound. *[See Data Sheet for a reactivity series of metals, which also includes carbon and hydrogen].*	98
FT & HT	Often an ore contains a metal oxide or a substance which can easily be changed into a metal oxide. To extract the metal, the oxygen must be removed from the metal oxide. This is called reduction. How a metal is extracted from its ore depends on how reactive the metal is.	p. 89
	A metal such as iron, which is less reactive than carbon, can be extracted from its ore using carbon.	90
	The solid raw materials used in the blast furnace are iron ore (haematite), coke and limestone. Hot air is blown into the furnace and this causes the coke to burn forming carbon dioxide and releasing energy. At the high temperatures in the furnace the carbon dioxide reacts with coke to form carbon monoxide. The carbon monoxide reduces to iron oxide in the iron ore into molten iron which flows to the bottom of the furnace. The carbon monoxide combines with the oxygen from the iron ore to produce carbon dioxide. This is called oxidation. Limestone is added to remove acidic impurities forming a molten slag that floats on the surface of the molten iron.	91
	Iron (or steel) corrodes more quickly than most other transition metals. This corrosion can be prevented by connecting iron to a more reactive metal (e.g. zinc or magnesium) (sacrificial protection) or by mixing in other metals (e.g. chromium) to make non-rusting alloys called stainless steel.	93, 95

12.3	**How can metal compounds be made?** *Metal compounds called salts can be prepared by reacting metal hydroxides or metal oxides with acids.*	
KS3	When a substance dissolves in water it forms an aqueous solution which may be acidic, alkaline or neutral.	p. 143
	Water itself is neutral.	143
	Indicators can be used to show whether a solution is acidic, alkaline or neutral by the way their colours change.	143
	The pH scale is used to show how acidic or alkaline a solution is:	143
	0 ⟵ 7 ⟶ 14 increasing acidity — neutral — increasing alkalinity	
FT & HT	Compounds of alkali metals called salts can be made by reacting solutions of their hydroxides which are alkaline with acids. In these neutralisation reactions	144
	Acid + alkaline hydroxide solution ⟶ a neutral salt solution + water	144
	The particular salt produced in any reaction between an acid and an alkali depends on: • The acid used; • The metal in the alkali.	145
	Neutralising hydrochloric acid produces chlorides.	145
	Neutralising nitric acid produces nitrates.	145
	Neutralising sulphuric acid produces sulphates.	145
	Ammonia also dissolves in water to produce an alkaline solution. This can be neutralised with acids to produce ammonium salts.	244-7
	Hydrogen ions H^+ (aq) make solutions acidic. Hydroxide ions OH^- (aq) make solutions alkaline.	148
HT	In neutralisation reactions: $H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$	148
12.4	**Why is limestone such a useful material?** *Limestone is a commonly occurring rock which can be used not only for building but also for making man other useful materials including lime, cement and glass.*	
FT & HT	Limestone, which is mainly calcium carbonate, can be quarried and used as a building material. Powdered limestone can be used to neutralise acidity in lakes and soils.	p. 127, 147, 156
	When limestone is heated in a kiln it breaks down into quicklime (calcium oxide) and carbon dioxide. This type of reaction is called thermal decomposition (other carbonates behave in similar way). Quicklime reacts with water to produce slaked lime (calcium hydroxide) which is used to reduce the acidity of soil.	128-9
	Cement is produced by roasting powdered limestone with powdered clay in a rotary kiln. When cement is mixed with water, sand and crushed rock, a slow chemical reaction produces a hard, stone-like building material called concrete.	129-130

12.5	**How can so many useful products be made from crude oil?** *Many useful products can be obtained from crude oil by separating the many different substances it contains and by using some of these in chemical reactions to make new substances, for example plastics.*	
KS3	Crude oil is obtained from the Earth's crust.	p. 160
	It was formed from the remains of organisms which lived millions of years ago.	160
	It is a fossil fuel.	160
	The fossil fuels coal, oil and natural gas have resulted from the action of heat and pressure over millions of years, in the absence of air, on material from animals and plants (organic material) which has been covered by layers of sedimentary rock.	160
FT & HT	Crude oil is a mixture of a very large number of compounds.	159
	A mixture consists of two of more elements or compounds not chemically combined together. The chemical properties of each substance in the mixture are unchanged. This makes it possible to separate the substances in a mixture by physical methods including distillation.	18-19, 162
	Most of the compounds in crude oil consist of molecules made up of hydrogen and carbon atoms only (hydrocarbons).	159
	The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by evaporating the oil and allowing it to condense at a number of different temperatures. This process is fractional distillation.	162-4
	The hydrocarbon molecules in crude oil vary in size.	163
	The larger the molecules (the greater the number of carbon atoms) in a hydrocarbon: • The higher its boiling point. • The less volatile it is; • The less easily it flows (the more viscous it is); • The less easily it ignites (the less flammable it is). This limits the usefulness of hydrocarbons with large molecules as fuels.	163
	Large hydrocarbon molecules can be broken down (cracked) to produce smaller, more useful molecules. This process involves heating the hydrocarbons to vaporise them and passing the vapours over a hot catalyst. A thermal decomposition reaction then occurs.	165
	Some of the products of cracking are useful as fuels.	187-8
	Most fuels contain carbon and / or hydrogen and may also contain some sulphur. The gases released into the atmosphere when a fuel burns may include: • Carbon dioxide • Water (vapour), which is an oxide of hydrogen; • Sulphur dioxide.	187-8

FT & HT	Other products of cracking can be used to make plastics (polymers) such as poly(ethene) and poly(propene). Poly(ethene) is used for making plastic bags and bottles. Poly(propene) is used for making crates and ropes.	p. 166, 171
	Most plastics, including poly(ethene) and poly(propene), are not broken down by microorganisms. They are not biodegradable. This can lead to problems with waste disposal.	172-3
	Candidates should be able, when provided with appropriate information, to evaluate the impact on the environment of burning hydrocarbon fuels and of plastic waste disposal.	p. 172-3
HT	Carbon atoms form the spine of hydrocarbon molecules.	159
	Candidates should be able to represent and to interpret saturated hydrocarbon molecules in the following form: 	159
	Candidates should be able to represent and to interpret unsaturated hydrocarbon molecules in the following form: 	166-7
	These unsaturated hydrocarbons are reactive and so are useful for making many other substances including polymers. Polymers have very large molecules, and are formed when many small molecules, of substances called monomers, join together. This process is called polymerisation.	166-7
	When unsaturated monomers join together to form a polymer with no other substance being produced in the reaction, the process is called addition polymerisation.	168
	Plastics are polymers and are made by polymerisation.	168
	For example, poly(ethene) (often called polythene) is made by polymerising the simplest alkene, ethene.	168
	Candidates should be able:	
	• To interpret diagrammatic representations of addition polymerisation;	168-9
	• To represent the formation of a simple addition polymer in the following form: [diagram]	168-9

13	Module 16 – Patterns and Reactions	
	This module includes the following: *Exploring the similarities between elements in the same group of the periodic table and the trends in those properties within groups.* *Explaining in terms of atomic structure:* • *The similarities between elements in the same group;* • *The differences between elements in different groups;* *and, for the higher tier only;* • *The trends within groups.* *Investigating some reactions and uses of the metal-halogen compounds sodium chloride and silver halides.* *Exploring the various factors affecting the rates of chemical reactions and explaining these in terms of collisions between particles.* *Examining the energy changes which occur in chemical reactions.* *N.B. It is anticipated that candidates' ability to represent chemical substances by formulae will be progressively developed throughout the modules associated with Materials and their Properties.* *The assessment of this ability will, however, be incorporated into the assessment of this module via the terminal examination.* ***Candidates should be able** to write word equations for all reactions referred to in the tier of this module for which they are entered.*	
FT & HT	Candidates should be able to recognise, and explain the significance of, the following hazard symbols. *[insert symbols]* Oxidising These substances provide oxygen which allows other materials to burn more fiercely. Harmful These substances are similar to toxic substances but less dangerous. Highly flammable These substances easily catch fire Corrosive These substances attack and destroy living tissues, including eyes and skin.	

FT & HT	Toxic These substances can cause death. They may have their effects when swallowed or breathed in or absorbed through the skin. Irritant These substances are not corrosive but can cause reddening or blistering of the skin.	
	Candidates should be able : • to use information on the Data Sheet where appropriate, in answering examination questions; • to describe simple laboratory tests for carbon dioxide, chlorine, hydrogen, and water as described in the syllabus and for ixygen (re-lights a glowing splint); • to describe and give examples of the following types of chemical reaction: thermal decomposition (including cracking) neutralisation displacement oxidation (as addition of oxygen) reduction (as removal of oxygen)	
HT	oxidation (as the loss of electrons) reduction (as the gain of electrons) redox	
13.1	**How can we speed up or slow down chemical reactions?** *Being able to control the speed of chemical reactions is important both in everyday life (for example in cooking) and when making new materials on an industrial scale.*	
FT & HT	The speed (rate) of chemical reactions increases: • If the temperature increases; • If the concentration of dissolved reactants or the pressure of gases increases; • If solid reactants are in smaller pieces (greater surface area); • If a catalyst is used.	 p. 206 204-5 203 208
	A catalyst increases the rate of a chemical reaction but it is not used up during the reaction. It is used over and over again to speed up the conversion of reactants to products. Different reactions need different catalysts.	208
	Increasing the rates of chemical reactions is important in industry because it helps to reduce costs.	199 (240-1)
	The rate of a chemical reaction can be followed by measuring the rate at which the products are formed or the rate at which the reactants are used up. This allows a comparison to be made of the changing rate of a chemical reaction under different conditions.	199-201
	Candidates should be able to interpret graphs showing the amount of product formed (or reactant used up) with time in terms of the above principles.	201, 207

FT & HT	Chemical reactions can only occur when reacting particles collide with each other and with sufficient energy. The minimum amount of energy particles must have to react is the activation energy.	p. 203, 209
	Increasing the temperature increases the speed of the reacting particles so that they collide more frequently and more energetically. This increases the rate of reaction.	207
	Increasing the concentration of reactants in solutions and increasing the pressure of reacting gases also increases the frequency of collisions and so increases the rate of reaction.	205
13.2	**How can we use living things to do our chemistry for us?** *Living things produce catalysts called enzymes which allow chemical reactions to occur quite quickly at ordinary temperatures and pressures. Enzymes are widely used in the food industry and are being used more and more to manufacture many other chemicals.*	
FT & HT	Living cells use chemical reactions to produce new materials.	p. 212
	Yeast cells convert sugar into carbon dioxide and alcohol.	214-5
	This process is called fermentation and is used: • To produce the alcohol in beer and wine; • To produce the bubbles of carbon dioxide which make bread dough rise.	214-5
	A simple laboratory test for carbon dioxide is that it turns lime-water milky.	216
	Bacteria are used to produce yoghurt from milk. The bacteria convert the sugar in milk (lactose) to lactic acid.	213, 219 (Q5)
	Enzymes are involved in the following processes:	
	In the home: • Biological detergents may contain protein-digesting and fat-digesting enzymes (proteases and lipases);	217
	In industry: • Proteases are used to 'pre-digest' the protein in some baby foods; • Carbohydrases are used to convert starch syrup into sugar syrup; • Isomerase is used to convert glucose syrup into fructose syrup, which is much sweeter and therefore can be used in smaller quantities in slimming foods.	217
	In industry, enzymes are used to bring about reactions at normal temperatures and pressures that would otherwise require expensive, energy demanding equipment.	217
	Candidates should be able, when provided with appropriate information, to evaluate the advantages and disadvantages of using microorganisms and enzymes to bring about chemical reactions.	217
HT	Successful industrial processes depending on enzymes usually: • Stabilise the organism to keep it functioning for a long period; • Immobilise the enzyme by trapping it in an inert solid support or carrier such as alginate beads; • Allow a continuous process rather than batch process.	217

13.3	**What happens when elements react?** *Scientists believe that when elements react, their atoms are joining together or bonding. To understand the ways in which this can happen we need to know how atoms themselves are constructed.*	
FT & HT	All substances are made of atoms. There are about 100 different sorts of atoms. A substance which contains only one sort of atom is called an element.	p. 16
	Candidates should be able, when provided with appropriate information, to explain why the idea of atoms only became generally accepted by scientists after Dalton re-introduced the idea about 200 years ago.	14, 28, TSP
	Atoms have a small central nucleus made up of protons and neutrons around which there are electrons.	28
	Electrons occupy particular energy levels.	30
	Each electron in an atom is at a particular energy level (in a particular shell). The electrons in an atom occupy the lowest available energy levels (innermost available shells). *[N.B. Though only energy levels are referred to throughout this syllabus, candidates may answer in terms of shells if they prefer].*	30
	Candidates should be able to represent the electronic structure of the first twenty elements of the periodic table in the following forms: [diagram]	p. 31, 70
13.4	**How can chemical elements be grouped into families?** It is easier to remember the properties of more than 90 naturally occurring elements if we can group them into families of elements with similar properties. Chemists arrange these family groups of elements in a special way which is known as the periodic table.	
FT & HT	The chemical elements can be arranged in order of the relative atomic masses of their elements. This list can then be arranged in rows so that elements with similar properties are in the same columns, known as Groups. The resulting table is known as the periodic table.	42-3
	In the modern periodic table elements are arranged in order of their atomic (proton) number. All elements are then in the appropriate Group.	42-3
	The periodic table can be seen as an arrangement of the elements in terms of their electronic structure. From left to right, across each horizontal row (period) of the periodic table, a particular energy level is gradually filled up with electrons; in the next period, the next energy level is filled with electrons.	70
	The similarities and differences between the properties of elements in the same group of the periodic table can be explained by the electronic structure of their atoms.	70

FT & HT	**Candidates should be able,** when provided with appropriate additional information, to explain:	p. 42, 70
	• How attempts to classify elements in a systematic way, including those of Newlands and Mendeleev, have led through the growth of chemical knowledge to the modern periodic table;	42, 70
	• Why scientists regarded a periodic table of the elements first as a curiosity, then as a useful tool and finally as an important summary of the structure of atoms.	42, 70
	Fewer than one quarter of the elements are non-metals. Non-metal elements are found in the Groups at the right hand side of the periodic table.	48
	The elements in Group 7 and Group 0 have the typical properties of non-metals: • They have low melting points and boiling points (at room temperature all the Group 0 elements are gases, the first two Group 7 elements are gases and the third, bromine, is a liquid); • They are brittle and crumbly when solid; • They are poor conductors of heat and electricity even when solid or liquid.	62, 66-7 45 45
	In Group 1, the further down the group an element is: • The more reactive the element; • The lower its melting point and boiling point.	
	When a piece of lithium, sodium or potassium is placed in cold water the metal floats, may melt and moves around the surface of the water. The metal reacts with the water to form a metal hydroxide solution and hydrogen gas. The more reactive the metal, the more vigorous is the reaction with water.	
	A simple laboratory test for hydrogen is that when a test tube of hydrogen is held to a flame the hydrogen burns in the air with a squeaky explosion.	
	In Group 7, the further down the group an element is: • The less reactive the element; • The higher its melting point and boiling point.	
13.5	**How can the similarities between elements in the same group be explained?** *Once again, these similarities and differences can be explained in terms of the atomic structure of the atoms concerned.*	
HT	Elements in the same group have similar properties because they have the same number of electrons in the highest occupied (outer) energy level.	
	The higher the energy level: • The more easily electrons are lost; • The less easily electrons are gained.	p. 71
	These ideas explain the trends in the reactivity of elements in Groups 1 and 7 of the periodic table.	71
	Group 0 elements (noble gases) are unreactive and monatomic because their highest occupied energy level is full so that atoms have no tendency to gain, to lost or to share electrons.	66

14	Module 17 – **Energy and Electricity**	Physics for You
	This module includes the following: *Investigations of thermal energy transfer by means of radiation – and of how all types of thermal energy transfer can be reduced when necessary.* *For the higher tier only, explaining how thermal energy transfers by means of conduction and convection occur.* *An exploration of the range of devices used to transfer electrical energy as other required energy forms.* *Calculating:* • *The energy transferred by appliances from their power and the length of time they are used;* • *The cost of using electrical appliances;* *An examination of the idea of efficiency in relation to energy transfer.* *A detailed study of the advantages and disadvantages, from various points of view, of a range of renewable and non-renewable energy resources.* *Exploring the relationship between the 3 key variables, potential difference, resistance and current, and applying it to a range of devices.* *Considering the nature of mains electricity and its safe use.* *Investigating electromagnetic induction and its use in generators.*	Chapters 8, 16, 30, 31, 32, 36
14.1	**How is heat (thermal energy) transferred and how can we reduce heat transfer?** *Sometimes we want to transfer heat effectively from one place to another. At other times we want to reduce heat losses as much as we can. To be able to do either of these things we need to know how heat is transferred and which methods of heat transfer are most important in particular cases.*	
KS3	When different parts of a substance are at different temperatures, energy is transferred by the substance from places where the temperature is higher to places where the temperature is lower.	pages 42-43
	Transfer of energy by a substance, without the substance itself moving, is called conduction. Metals are very good conductors. Non-metals are usually poor conductors (insulators). Gases are very poor conductors.	p. 43-44
	Liquids and gases can flow and so can energy from places where the temperature is higher to places where the temperature is lower. Transfer of energy by liquids or gases moving in this way is called convection.	p. 46-47
	Energy is continually being transferred to and from all objects by radiation, even through empty space (a vacuum).	p. 48-50

FT & HT	Hot bodies mainly emit mainly infra red radiation. The hotter an object is, the more energy it radiates. Dark, matt surfaces emit more radiation than light, shiny surfaces at the same temperature. Particles of matter are not involved. Dark, matt surfaces are good absorbers (poor reflectors) of radiation. Light, shiny surfaces are good reflectors (poor absorbers) of radiation.	p. 48-9, 219, 221
	Candidates should be able: • To describe various ways in which heat energy is transferred from buildings; • To describe and explain ways in which the rates of these energy transfers can be reduced. **Candidates should be able,** when given appropriate information, to evaluate the effectiveness and cost-effectiveness of methods used to reduce energy consumption in buildings.	p. 45, 50
HT	Conduction occurs in metals because the hotter the metal is, the more kinetic energy the ions in the metal structure have. This energy is transferred to cooler parts of a piece of metal by free electrons as they diffuse through the metal and collide with ions and with other electrons.	p. 43
	Convection currents occur in liquids and gases because their particles move faster when they are hot, causing the liquid or gas to expand. Warm regions are then less dense than cold regions. The warm regions rise up through the colder regions and colder regions replace the warmer regions. Thermal radiation transfer is the transfer of energy by waves.	p. 46, 48, 219
14.2	**Why are electrical appliances so useful and what does it cost to use them?** *We often use electrical appliances because they transfer electrical energy as whatever form of energy we need at the flick of a switch. What we pay for when we use an electrical appliance is the energy it transfers. Some appliances transfer energy faster than others and so cost more to use.*	
FT & HT	Much of the energy transferred in homes and industry is electrical energy. This is because electrical energy is readily transferred as: • Heat (thermal energy); • Light; • Sound; • Movement (kinetic energy).	p. 9-10, 112, 270

continued . . .

FT & HT	Candidates should be able: • To specify the energy transfers that everyday electrical devices are designed to bring about; • To give examples of everyday electrical devices designed to bring about particular energy transfers.	p. 9-10
	Electrical energy may also be transferred as gravitational potential energy. Gravitational potential energy is the energy stored in an object because of the height to which the object has been lifted against the force of gravity. change in gravitational potential energy = weight × change in vertical height (joule, J) (newton, N) (metre, m)	p. 116
	How much electrical energy an appliance transfers depends on: • how long the appliance is switched on; • how fast the appliance transfers energy (its power). The power of an appliance is measured in watts (W) or kilowatts (1kW = 1000W).	p. 272
	The amount of energy transferred from the mains is measured in kilowatt-hours, called Units: energy transferred = power × time (kilowatt hour, kWh) (kilowatt, kW) (hour, h) **Candidates should be able,** when provided with suitable diagrams of a digital domestic electricity meter, to calculate the number of Units used. The cost of this energy can be calculated using: total cost = number of Units × cost per Unit	p. 273
	Energy is normally measured in joules (J).	p. 37, 107
	The total amount of energy, in joules, transferred by an electrical device can be calculated as follows: Energy transferred = power × time (joule, J) (watt, W) (second, s)	p. 119, 273

continued . . .

14.3	**How efficient are the appliances we use?** *The electrical appliances and all the other energy transferring devices we use are never perfect; they never transfer all the energy we supply as the energy form we want to the place where we want it.* *We need to know how efficient different energy-transferring devices are, so that we can choose between them and try to improve them.*	
FT & HT	Whenever energy is transferred, only part of it is transferred to where it is wanted and in the form it is wanted (usefully transferred). The rest of the energy is transferred in some non-useful way and so wasted. **Candidates should be able** to describe the intended energy transfers and the main energy wastages which occur when using a range of everyday devices. The energy which is 'wasted' during energy transfers and the energy which is usefully transferred both end up being transferred to the surroundings which become warmer. The energy becomes increasingly spread out, and becomes increasingly more difficult to use for further useful energy transfers. The more of the energy supplied to a device that is usefully transferred, the more efficient we say the device is. **Candidates should be able,** when provided with appropriate information, to evaluate methods of reducing wasteful transfers of energy. The efficiency of a device can be calculated using: $\text{efficiency} = \dfrac{\text{useful energy transferred by device}}{\text{total energy supplied to device}}$	p. 112-3, 122, 9-10, worksheet
14.4	**How should we generate the electricity we need?** *Electricity is what is called a secondary energy source; some other energy resource is needed to generate it. Various energy sources can be used to generate the electricity we need.* *We must carefully consider the advantages and disadvantages of using each energy source before deciding which source(s) it would be best to use in any particular situation.*	
KS3	Coal, oil, gas and wood are all fuels. They release energy when they are burned. The Earth's supply of the fossil fuels (coal, oil and gas) and of nuclear fuels is limited. They are often called non-renewable energy resources. It will take millions of years to replace the fossil fuels we have used. Most of the energy used by humans comes from non-renewable fuels, mainly from fossil fuels. The more economical people are with these fuels, the longer they will last. More trees can be grown to replace trees that are cut down to provide wood for fuel. Wood is a renewable energy resource. Renewable energy resources include sunlight, the wind, the waves, running water and the tides. These energy resources will not run out. Electricity is a very convenient and widely used energy source. It is generated in power stations using some other energy resource.	p. 11-13

FT & HT	In most power stations, energy from fuel is used to heat water. In Britain, many power stations burn fossil fuels. Other power stations use nuclear fuel, mainly uranium and plutonium. The steam which is produced is used to drive turbines. The turbines then drive generators which produce electricity.	p. 113
	Electricity can also be generated from renewable energy resources. Energy from renewable resources can be used to drive turbines directly. The resources used in this way include: • The wind; • The rise and fall of water due to waves; • The flow of water from a higher level to a lower level from behind tidal barrages or the dams of hydroelectric schemes.	p. 113, 12-13, 111, worksheet
	In some volcanic area, hot water and steam rise to the surface. The steam can be tapped and used to drive turbines producing geothermal energy supplies. The energy released in volcanic areas originally came from the decay of radioactive elements, including uranium, within the Earth.	p. 13
	Electricity can be produced directly from the Sun's radiation using solar cells.	p. 12, 114
	Using different energy sources has different effects on the environment. • Burning fossil fuels releases carbon dioxide, a gas which increases the greenhouse effect and causes increased global warming. For the same amount of energy released, coal produces more carbon dioxide than oil, and oil produces more carbon dioxide than natural gas. There is no feasible way of preventing the very large amounts of carbon dioxide involved from entering the atmosphere. Burning most types of coal and oil also releases sulphur dioxide, a gas that helps to produce acid rain. The sulphur can be removed from these fuels before they are burnt or the sulphur dioxide removed from the waste gases before they enter the atmosphere, though this increases the cost of the electricity that is generated. • Nuclear fuels do not produce gases which increase the greenhouse effect or which help to produce acid rain. When they are running normally, very little radiation or radioactive material escapes into the surroundings. If there is an accident, however, large amounts of very dangerous radioactive material may be released over a wide area. Nuclear power stations also produce waste, some of which stays dangerously radioactive for thousands of years and which has to be stored safely. • Groups of large wind generators (wind farms) are usually sited on hills and/or coasts and are considered unsightly by some people. They can also be noisy for people living nearby. Wind farms cause visual pollution and noise pollution. • Using energy from tides involves building barrages across river estuaries. This destroys the habitat of many organisms, e.g. wading birds and the mud-living organisms on which they feed. • Hydroelectricity schemes involve damming upland river valleys. This means flooding land that may have previously been used for farming or forestry.	p. 115, 359, 12-13

FT & HT	Energy sources also differ in when they are available for generating electricity. • Power stations which use fuels can produce electricity at any time (of the day or of the year); they are reliable energy sources. The time it takes to start them up varies considerably: Nuclear longest time Coal Oil natural gas shortest time • The amount of electricity produced by wind generators depends on the strength of the wind which varies considerably. The amount of electricity produced by tidal barrages depends on the state of the tide, which varies during each day, and the height of the tide, which varies both on a monthly and yearly cycle. The amount of electricity produced by solar cells depends on the intensity of light that falls on them. Each of these energy sources can generate electricity only at certain times; they are all to some extent unreliable. • Hydroelectric schemes are generally very reliable. They can also be started up very quickly to meet sudden increases in the demand for electricity. They can also be operated in reverse using surplus electricity from other power stations to pump water from a lower reservoir to a higher one. This means that most of the energy from the surplus electricity is stored rather than being wasted.	p. 114-5, 13
	Solar cells have a very high cost per Unit of electricity produced over their lifetime compared to all other sources of electricity except non-rechargeable batteries. Despite their cost, they are often the best energy source for producing electricity in remote locations (e.g. on satellites) or where only small amounts of electricity are needed (e.g. for watches or calculators).	p. 113, 114
	Candidates should be able to compare and contrast the particular advantages and disadvantages of using different energy sources to generate electricity.	p. 115, 359
HT	**Candidates should be able** to identify and evaluate the financial and environmental costs of using various energy resources to generate electricity and to evaluate these costs against the benefits to society, taking into consideration: • the factors listed above; • that though there are no fuel costs with renewables, the energy is dilute so that the capital cost of the generating equipment is high; • that though the fuel costs for nuclear power stations are low, the cost of building the power stations, and of de-commissioning them at the end of their useful life, is high; • the need to match supply and demand; • any additional information, including quantitative information, with which they are provided.	p. 113-115

continued . . .

<table>
<tr><td>14.5</td><td>What does the current through an electrical circuit depend on?

How large a current flows depends on how hard the supply is trying to push a current through a circuit and how hard the circuit resists having a current pushed through it.</td><td></td></tr>
<tr><td>KS3</td><td>A current will flow through an electrical component (or device) only if there is a voltage or potential difference (p.d.) across its ends. The bigger the potential difference across a component, the bigger the current that flows through it.

Components resist a current flowing through them. The bigger their resistance, the smaller the current produced by a particular voltage, or the bigger the voltage needed to produce a particular current.</td><td>pages 254-261</td></tr>
<tr><td></td><td>The p.d. across a component in a circuit is measured in volts (V) using a voltmeter connected across (in parallel with) the component.</td><td>p. 258</td></tr>
<tr><td></td><td>The current flowing through a component in a circuit is measured in amperes (A) using an ammeter connected in series with the component.</td><td>p. 256</td></tr>
<tr><td></td><td>As an electric current flows through a circuit, energy is transferred from the battery or power supply to the components in the electrical circuit</td><td>p. 112, 270</td></tr>
<tr><td>FT & HT</td><td>Current-voltage graphs are used to show how the current through a component varies with the voltage across it.

[insert Current-Voltage diagrams]</td><td>p. 265, worksheets</td></tr>
<tr><td></td><td>When components are connected in series:
• their total resistance is the sum of their separate resistances;
• the same current flows through each component;
• the total potential difference of the supply is shared between them.</td><td>p. 262, 267</td></tr>
<tr><td></td><td>When components are connected in parallel:
• there is the same potential difference across each component;
• the current through each component depends on its resistance; the greater the resistance; the smaller the current;
• the total current through the whole circuit is the sum of the currents through the separate components.</td><td>p. 263, 267</td></tr>
<tr><td></td><td>The potential difference provided by cells connected in series is the sum of the potential difference of each cell separately (bearing in mind the direction in which they are connected).</td><td>p. 266</td></tr>
</table>

FT & HT	An electric current is a flow of charge.	p. 255, 267
	When electrical charge flows through a resistor, electrical energy is transferred as heat.	p. 270
	Candidates should be able to interpret and/or draw circuit diagrams using standard symbols. The following standard symbols should be known. *[switch, lamp, fuse, cell, battery, voltmeter, ammeter, diode, resistor, variable resistor, thermistor, LDR]*	p. 254
	Potential difference, current and resistance are related as shown: Potential difference = current × resistance (volt, V) (ampere, A) (ohm, Ω)	p. 259
	The current through a resistor (at a constant temperature) is proportional to the voltage across the resistor.	p. 265
	The resistance of a filament lamp increases as the temperature of the filament increases.	p. 265
	The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction.	p. 265, 322
	The resistance of a light dependent resistor decreases as the light intensity increases.	p. 325
	The resistance of a thermistor decreases as the temperature increases *[i.e. knowledge of negative temperature coefficient thermistor only is required].*	p. 265, 325
19.4	**What is mains electricity and how can it be used safely?** *Mains electricity is very useful but is also very dangerous. It is important for everyone to know how to use it safely.*	
FT & HT	The UK mains supply is about 230 volts. Mains electricity can kill if it is not used safely.	p. 274
	Most electrical appliances are connected to the mains using cable and a 3-pin plug. To make them safe to use: cable comprises: • two or three inner cores of copper, because copper is a good conductor; • outer layers of flexible plastic, because plastic is a good insulator. a plug has: • a plastic or rubber case, because plastic and rubber are good insulators; • pins made from brass, because brass is a good conductor; • a fuse; • an earth pin; • a cable grip.	p. 275

FT & HT	The fuse in a plug should always be the same as the one recommended by the manufacturer of the appliance. Appliances with metal cases are usually earthed.	p. 275
	When connecting an appliance to a 3-pin plug: • the blue wire is connected to the neutral terminal; • the brown wire is connected via a fuse to the live terminal; • the green/yellow wire (when fitted) is connected to the earth terminal; • the cable should be secured in the plug by the cable grip; • a fuse of the correct value (rating) should be in place.	p. 275
	Candidates should be able, when provided with appropriate diagrams: • to recognise errors in the wiring of a mains (3-pin) plug; • to recognise dangerous practice in the use of mains electricity.	p. 275
	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 or 50 hertz (Hz) which means that it changes direction and back again 50 times each second.	p. 274, 305
	Cells and batteries supply a current which always flows in the same direction. This is called a direct current (d.c.).	p. 254
	Candidates should be able to compare the voltages of d.c. supplies and the frequencies and peak voltages of a.c. supplies from diagrams of oscilloscope traces.	p. 305, 317 worksheet
	If a fault in an electrical circuit or an appliance causes too great a current to flow, the circuit is switched off by a fuse or a circuit breaker. The fuse should have a value higher than, but as close as possible to, the current through the appliance when it is working normally. When the current through a fuse wire exceeds the current rating of the fuse the wire becomes hot and will (eventually) melt breaking the circuit and switching off the current.	p. 275
	Candidates should be able, when provided with appropriate information, to explain how a circuit breaker works.	p. 270, 312, 345 worksheet
	Appliances with metal cases need to be earthed. The earth pin is connected to the case via the yellow/green wire. If a fault in the appliance connects the case to the live wire, and the supply is switched on, a very large current flows to earth and overloads the fuse.	p. 275
HT	The live terminal of the mains supply alternates between a positive and negative voltage with respect to the neutral terminal. The neutral terminal stays at a voltage close to zero with respect to earth.	p. 274

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14.7	**How do generators work?** *Just as electric currents can be used to produce magnetic fields, so magnetic fields can be used to produce electric currents.* *This idea is used in generators to produce.*	
FT & HT	If a magnet is moved into a coil of wire which is part of a complete circuit a current is produced (induced) in the wire. If the magnet is moved out of the coil, or the other pole of the magnet is moved into the coil, the direction of the induced current is reversed.	p. 303
	Transformers are used to change the voltage of an a.c. supply. At power stations, transformers are used to produce very high voltages before the electricity is transmitted to where it is needed through power lines (National Grid). Local transformers reduce the voltage to safer levels before the electricity is supplied to consumers.	p. 308-9
	Electricity can be generated by rotating a coil of wire in a magnetic field or by rotating a magnet inside a coil of wire. This is how a generator works.	p. 304
	If a wire, or coil of wire 'cuts through' a magnetic field, or vice-versa, a voltage (potential difference) is produced between the ends of the wire. This induced voltage causes a current to flow if the wire is part of a complete circuit. The size of the induced voltage increases when: • the speed of the movement increases; • the strength of the magnetic field is increased; • the number of turns on the coil is increased; • the area of the coil is greater.	p. 306
HT	Candidates should be able, when provided with a diagram, to explain how an a.c. generator works, including the purposes of the slip rings and brushes.	p. 304
	The higher the voltage, the smaller the current needed to transmit energy at the same time. Less energy is wasted by heating up the power lines.	p. 309

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15	Module 18 – **Forces, Waves and Radiation**	Physics for You
	This module includes the following: *Exploring the role of gravitational forces:* • *in keeping satellites in orbit;* • *in maintaining the stability of the solar system;* • *in the life histories of stars.* *Considering, at the Higher tier only, the implications of the estimated speeds of distant galaxies for the origins of the Universe.* *Comparing the behaviour of waves we can actually see (e.g. water waves) with the behaviour of light and sound.* *Investigating the different types of waves in the electromagnetic spectrum in terms of their wavelengths / frequencies, properties and uses.* *Examining the properties, uses and dangers of the radiation emitted by radioactive substances.*	Chapters 18, 20 21, 22, 39
15.1	**How do planets and artificial satellites stay in orbit?** *Astronomers believe that the planets, like Earth, orbit the Sun.* *Satellites which orbit Earth are used for communications and to monitor events on Earth.* *All these bodies can remain in orbit only because of gravitational forces.*	
KS3	The Earth spins on its own axis once every day (24 hours). The half of the Earth which faces the sun is in daylight; the other half of the Earth is in night. The Earth moves round (orbits) the Sun once each year (just over 365 days).	p. 158
	The stars in the night sky stay in fixed patterns (called constellations).	p. 164
	The planets which are visible to the naked eye look just like stars. They move very slowly across the constellations. The planets do not give out their own light. Like the Earth, they move in orbits around the Sun. We can see planets because they reflect light from the Sun. Where we see the planets against the background of the stars depends on exactly where they, and the Earth, are in their orbits round the Sun.	p. 161
	Satellites can be put into orbit around the Earth. They can be used: • to send information between places which are a long way apart from the Earth; • to monitor conditions on Earth, including the weather; • to observe the Universe without the Earth's atmosphere getting in the way.	p. 168-9, 162

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FT & HT	The orbits of the planets are slightly squashed circles (ellipses) with the Sun quite close to the centre.	p. 161
	Comets have orbits which are far from circular. They are very much closer to the Sun at some times than at others. This is when they can be seen.	p. 163
	The Earth, the Sun, the Moon and all other bodies attract each other with a force called gravity. As the distance between two bodies increases, the force of gravity between them decreases more than in proportion to the increase in distance.	p. 162, 158-9, 78
	A smaller body will stay in orbit around a larger one because of the combination of its high speed and the force of gravity between the bodies. To stay in orbit at a particular distance, smaller bodies, including planets and satellites, must move at a particular speed around larger bodies. The further away an orbiting body is the longer it takes to make a complete orbit.	p. 162, 168
	Communication satellites, including those used for television programmes, are usually put in to orbit high above the equator so that they move around the Earth at exactly the same rate as the Earth spins. This means that they are always in the same position when viewed from Earth (a geostationary orbit). There is space for about only 400 geostationary satellites or they would interfere with each other's signals.	p. 169, 162, worksheet
	Monitoring satellites are usually put into a low polar orbit so that the Earth spins beneath them and they can scan the whole Earth each day from much closer range than a geostationary satellite.	p. 168
15.2	**What do we know about the origins of the Universe and the life histories of stars?** *Astronomers also believe that gravitational forces are responsible for the formation of galaxies of stars and for stars like the Sun having a long stable period.* *The speed with which other galaxies appear to be moving away from us suggests how the Universe might have begun.*	
FT & HT	Our Sun is just one of many millions of stars in a group of stars called the Milky Way galaxy. The stars in a galaxy are often millions of times further away from each other than the planets in the solar system. The Universe as a whole is made up of at least a billion galaxies. Galaxies are often millions of times further apart than the stars within a galaxy.	p. 165-7
	Stars, including the Sun, 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.	p. 163

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FT & HT	If there is, or has been, life on other planets, in our own solar system or around other stars: • we may be able to observe living organisms (e.g. microbes), or their fossilised remains, directly, for example, by actually going to Mars or Europa (a satellite of Jupiter), by using robots to send back pictures or by using robots to collect samples to bring back to Earth; • we may be able to detect living organisms by the chemical changes they produce in a closed system (e.g. inside a closed container or in the atmosphere of their planet); Because of living organisms, the atmosphere of the Earth is very different from what it would be purely from chemical and geological processes; for example, there is much more oxygen; • we may be able to receive signals from other species with technologies that are at least as advanced as our own. The search for extra-terrestrial intelligence (SETI), using radio telescopes to try to find meaningful signals in a narrow band of wavelengths (i.e. not just "noise"), has gone on for more than forty years, so far without success. **Candidates should be able,** when provided with appropriate information to evaluate: • the methods scientists use to discover whether there is life elsewhere in the Universe; • evidence that such life exists.	p. 167
	Individual stars, including the Sun, do not stay the same forever. Stars are very massive so that the force of gravity which tends to draw together the matter from which they are made is very strong. The very high temperatures create forces which tend to make them expand. During the main stable period of a star, which may last for billions of years, these forces are balanced. The Sun is at this stage of its life. The star then expands to become a red giant. At a later point in its history it contracts under its own gravity to become a white dwarf. The matter from which the star is made may then be millions of times denser than any matter on Earth. If a red giant is massive enough, it may eventually rapidly contract and then explode (become a supernova) throwing dust and gas into space. The matter that is left behind may form a very dense neutron star.	p. 165
HT	If enough matter is left behind, this may be so dense, and its gravitational field so strong that nothing can escape from it, not even light or other forms of electromagnetic radiation. It is then called a black hole. We cannot see black holes but we can sometimes observe their effects on their surroundings, for example, the X-rays emitted when gases from a nearby star spiral into a black hole.	p. 165, 368
	During a star's lifetime, nuclei of lighter elements (mainly hydrogen and helium) gradually fuse to produce nuclei of heavier elements. These nuclear fusion reactions release the energy which is radiated by stars.	p. 164
	Nuclei of the heaviest elements are present in the Sun and atoms of these elements are present in the inner planets of the solar system. This suggests that the solar system was formed from the material produced when earlier stars exploded.	p. 165

HT	Theories of the origin of the Universe have to take into account: • that light from other galaxies is shifted to the red end of the spectrum; • that the further away galaxies are, the bigger this 'red-shift'. The current way of explaining this is: • that other galaxies are moving away from us very quickly; • that the further away from us a galaxy is, the faster it is moving away from us. This suggests that the whole Universe is expanding and that it might have started, billions of years ago, from one place with a huge explosion ('big bang').	p. 166, 369, worksheets
15.3	**Why do scientists talk about light and sound as waves?** *Water waves, and other waves that we can see, behave in the same way as light and sound. This suggests that light and sound might also travel as waves.*	
KS3	Sounds bounce back (reflect) from hard surfaces. Echoes are sound reflections.	page 230
	When a ray of light is reflected from a flat, shiny surface (plane mirror) the angle at which it leaves the surface is the same as the angle at which it meets the surface.	p. 185
	Rays of light change direction (are refracted) when they cross the boundary between one transparent substance and another, unless they meet the boundary at right angles (along a normal). Sounds are also refracted, i.e. their direction is changed when they cross the boundary between two different substances at an angle other than a right angle.	p. 192-3, 245
FT & HT	Waves can be produced in ropes and springs and on the surface of water. When waves travel along ropes or springs or across the surface of water they set up regular patterns of disturbances: • the maximum disturbance caused by a wave is called its amplitude; • the distance between a particular point on one disturbance and the same point on the next is called the wavelength; • the number of waves each second produced by a source (or passing a particular point) is called the frequency, and is measured in hertz (Hz).	p. 174-5
	Waves travelling along a rope or spring, or across the surface of water, can be reflected. Waves travelling across the surface of water can also be refracted. The change in the speed of water waves when they cross the boundary between two different depths causes a change in their direction (refraction), unless the direction of travel of the waves is along a normal. This behaviour of waves suggest that light and sound: • also travel as waves; • are refracted because they travel at different speeds in different substances (media).	p. 174, 176, 193

FT & HT	When a ray of light travels from glass, Perspex or water into air, some of the light is also reflected from the boundary.	p. 195
	If the angle between the ray and a normal is greater than a certain angle (called the critical angle), all of the light is reflected inside the glass, Perspex or water. This is called total internal reflection.	p. 195-7, 200
	The waves which travel along ropes and across the surface of water are transverse waves: the disturbances in the substance through which the waves travel is at right angles to the direction in which waves themselves travel.	p. 174
	The waves which travel through springs may also be longitudinal: the disturbances in the spring are along the same direction as that in which the waves themselves travel. Sound waves travel through solids, liquids and gases as longitudinal waves.	p. 174, 229
	Light waves are transverse waves and can travel through a vacuum, i.e. they do not need a medium.	p. 179, 219
15.4	**Is there radiation we cannot see beyond the ends of the spectrum?** *White light can be split up into a spectrum of different colours. There are many other types of radiation beyond the ends of the visible spectrum. Each type of radiation in this extended spectrum – known as the electromagnetic spectrum – has its own special properties and uses.*	
KS3	When rays of light pass through prisms their direction may be changed. When white light is used, a spectrum is produced. The spectrum is produced because white light is made up of many different colours. Different colours of light are refracted by different amounts; red light is refracted least and violet light most.	p. 216-7
FT & HT	Light is one type of electromagnetic radiation. All types of electromagnetic waves travel at the same speed through space. The various types of electromagnetic radiation form a continuous spectrum extending far beyond each end of the visible spectrum: highest frequency ↑ … shortest wavelength ↑ gamma rays X-rays ultraviolet rays light infra red rays microwaves radio waves lowest frequency ↓ … longest wavelength ↓	p. 218-219

FT & HT	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; • may create an alternating current with the same frequency as the radiation itself.	p. 226-7, 335
	The uses and effects of different types of radiation depend on these and other properties.	p. 218-219
	Radio waves are used to transmit radio and TV programmes between different points on the Earth's surface. Longer wavelength radio waves are reflected from an electrically charged layer in the Earth's upper atmosphere. This enables them to be sent between distant points despite the curvature of the Earth's surface.	p. 221
	Microwave radiation of wavelengths which can pass easily through the Earth's atmosphere is used to send information to and from satellites, and within mobile hone networks. Microwave radiation, with wavelengths strongly absorbed by water molecules is used for cooking.	p. 221, 320, 227
	Infra red radiation is used in grills, toasters and radiant heaters, in optical fibre communication and for the remote control of TV sets and VCRs.	p. 227, 320, 50, 270
	Ultraviolet radiation is used in sunbeds. Special coatings which absorb ultraviolet radiation and emit the energy as light, are used in fluorescent lamps and security coding.	p. 218, 220, 226
	X-radiation is used to produce shadow pictures of materials which X-rays do not easily pass through including bones and metals.	p. 218, 220, 226, 318
	Gamma radiation is used to: • kill harmful bacteria in food; • sterilise surgical instruments; • kill cancer cells.	p. 218, 220, 357
	Different types of radiation have different effects on living cells: • microwaves are absorbed by the water in cells, which may be damaged or killed by the heat released; • infra red radiation is absorbed by skin and is felt as heat; • ultra violet radiation can pass through skin to deeper tissues. The darker the skin, the more ultra violet it absorbs and the less reaches into deeper tissues; • X-radiation and gamma radiation mostly pass through soft tissues, but some is absorbed by the cells. High doses of ultra violet radiation, X-radiation and gamma radiation can kill normal cells. Lower doses of these types of ionising radiation can cause normal cells to become cancerous. **Candidates should be able,** when provided with appropriate information, to evaluate: • the dangers, or possible dangers, of exposure to different types of electromagnetic radiation and to radiation from radioactive substances; • measures that can be taken to reduce such exposure.	p. 227, 220, 356, 360, worksheet

FT & HT	Information such as speech or music can be converted into electrical signals so that they can be sent long distances through cables or using electromagnetic waves as carriers.	p. 295, 335, 200, 332
	Signals which vary continuously in amplitude and/or frequency, in the same way that the sound waves of speech or music do, are called analogue signals. Signals can also be coded as a series of pulses. The signal then only has two states, on or off. Signals of this type are called digital signals.	p. 312, 332, worksheet
	The advantages of digital signals are: • their higher quality – the signals do not change their information during the transmission process;	p. 333
HT	As signals travel they become weaker. Random additions to the signal (noise) may also be picked up. With analogue signals, different frequencies within the signal may weaken to different extents. Each time the signal is amplified, these differences, and any noise that has been picked up, are also amplified. This means that the signal becomes less and less like the original signal; its quality deteriorates. With digital signals, even though pulses weaken with distance, they are still recognisable as "on" states, whereas noise is generally of low amplitude and is ignored (i.e. interpreted as "off"). The quality of a digital signal is maintained, therefore, during the transmission process.	p. 333
15.5	**What do we know about the radiation from radioactive substances?** *Radioactive substances, which emit radiation all the time, are very useful but also very dangerous. It is important to understand the properties of the different types of radiation they emit.*	
FT & HT	Some substances give out radiation all the time, whatever is done to them. These substances are said to be radioactive. There are three types of radiation emitted by radioactive sources: • alpha (α) radiation – which is easily absorbed by a few centimetres of air or a thin sheet of paper; • beta (β) radiation – which easily passes through air or paper but is mostly absorbed by a few millimetres of metal; • gamma (γ) radiation – which is very penetrating and requires many centimetres of lead or metres of concrete to absorb most of it.	p. 350-1
	There are radioactive substances all around us, including in the ground, in the air, in building materials and in food. Radiation also reaches us from space. The radiation from all these sources is called background radiation.	p. 360
	When radiation from radioactive materials collides with neutral atoms or molecules these may become charged (ionised).	p. 348

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FT & HT	When radiation ionises molecules in living cells it can cause damage, including cancer. The larger the dose of radiation the greater the risk of cancer. Higher doses of radiation can kill cells; they are used to kill cancer cells and harmful microorganisms.	p. 356, 357
	When sources of radiation are outside the body: • beta and gamma radiation are the most dangerous because they can reach the cells or organs and may be absorbed by them; • alpha radiation is least dangerous because it is unlikely to reach living cells.	p. 356, 360
	Workers who are at risk from radiation often wear a radiation badge to monitor the amount of radiation they have been exposed to over a period of time. This is a small packet containing photographic film. The more radiation a worker has been exposed to, the darker the photographic film is when it has been developed.	p. 360
	When sources of radiation are inside the body: • alpha radiation is the most dangerous because it is so strongly absorbed by cells; • beta and gamma radiation are less dangerous because cells are less likely to absorb the radiation.	p. 356
15.6	**What happens to radioactive substances when they decay or are used in nuclear reactors?** *To understand what happens to radioactive substances when they decay, or when we use them in nuclear reactors, we need to understand the structure of the atoms from which they are made.*	
FT & HT	Radioactivity occurs as a result of changes in the nuclei of atoms (nuclear changes). Atoms have a small central nucleus made up of protons and neutrons around which there are electrons.	p. 352-3, 355
	Candidates should be able, when provided with appropriate information, to: • explain how the Rutherford and Marsden scattering experiment led to the current model of the atom replacing the earlier "plum pudding" model; • suggest why the new model very quickly became widely accepted.	p. 352, 368 worksheets
	The relative masses of protons, neutrons and electrons and their relative electric charges are as shown: Mass Charge Proton 1 +1 Neutron 1 0 Electron negligible -1 In an atom, the number of electrons is equal to the number of protons in the nucleus. The atom as a whole has no electrical charge. All atoms of a particular element have the same number of protons. Atoms of different elements have different numbers of protons. The total number of protons and neutrons (nucleons) in an atom is called its mass (nucleon) number. Atoms of the same element which have different numbers of neutrons are called isotopes.	p. 352-353

FT & HT	Radioactive isotopes (radioisotopes or radionuclides) are atoms with unstable nuclei. When an unstable nucleus splits up (disintegrates): • it emits radiation; • a different atom, with a different number of protons, is formed.	p. 355
	The older a particular radioactive material, the less radiation it emits.	p. 354
HT	Alpha radiation consists of helium nuclei, particles made up of two protons and two neutrons.	p. 350-1, 355
	Beta radiation consists of high-energy electrons emitted from the nuclei of atoms. For each electron emitted, a neutron in the nucleus becomes a proton.	p. 350-1, 355
	Gamma radiation is very short wavelength electromagnetic radiation.	p. 218
15.7	**What is ultrasound and how can it be used?** *Just as there is electromagnetic radiation with frequencies we cannot see, there are "sound" waves with frequencies we cannot hear. These ultrasounds have several important uses.*	
KS3	Sounds are produced when objects vibrate.	p. 228
	The greater the size (amplitude) of vibrations the louder the sound.	p. 234
	The number of complete vibrations each second is called the frequency (hertz, Hz). The higher the frequency of a sound the higher its pitch.	p. 234
FT & HT	**Candidates should be able** to compare the amplitudes and frequencies of sounds from diagrams of oscilloscope traces.	p. 234-5
	Electronic systems can be used to produce electrical oscillations with any frequency. These electrical oscillations can be used to produce ultrasonic waves which have a frequency higher than the upper limit of the hearing range for humans. Ultrasonic waves can be used: • in industry for cleaning and quality control; • in medicine for pre-natal scanning.	p. 230, 240-1
HT	Ultrasonic waves are partly reflected when they meet a boundary between two different media. The time taken for the reflections of ultrasonic pulses to reach a detector (usually placed near to the source) is a measure of how far away such a boundary is. This idea is used in industry to detect flaws in metal castings and in medicine for pre-natal scans. Information about the time taken for reflections to travel is usually processed to produce a visual display. Ultrasonic waves in liquids can also be used for cleaning delicate mechanisms without having to disassemble them.	p. 240-1

End of syllabus content