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Please ensure that you have selected the correct specification.

Module 10 – Life Processes and Living Things

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Cell Activity		
10.1	**Plant and Animal Cells**	
KS3	All animals and plants are made up of cells. 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. 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.	8 12, 15 15, 16
FT & HT	Most 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. Plants also have: • A cell wall which strengthens the cell; and often have: • Chloroplasts which absorb light energy to make food; • A permanent vacuole filled with cell sap.	8 8 8 9 9 9
HT	The chemical reactions inside cells are controlled by enzymes. The cytoplasm contains structures called mitochondria, which is where most energy is released in respiration.	29-36 9
10.2	**Transport Across Boundaries**	
FT & HT	Diffusion is the spreading of the particles of a gas, or of any substance in solution, resulting in a net movement from a region where they are at a higher concentration to a region where they are at a lower concentration. The greater the difference in concentration, the faster the rate of diffusion. Oxygen required for respiration passed through cell membranes and through gas exchange surfaces, such as alveoli in the lungs, by diffusion. Carbon dioxide enters leaves and leaf cells by diffusion. Osmosis is the diffusion of water from a dilute to a more concentrated solution through a partially permeable membrane that allows the passage of water molecules but not solute molecules. Other substances such as sugar and ions can also pass through cell membranes. Many organ systems are specialised for exchanging materials: • In humans the surface area of the lungs is increased by the alveoli, and that of the small intestine by villi; • In plants the surface area of the roots is increased by root hairs, and the surface area of leaves by the flattened shape and internal air spaces.	20 21 26 77, 61 12, 226, 214
HT	Substances are sometimes absorbed against a concentration gradient. This requires the use of energy from respiration. The process is called active transport. It enables plants to absorb ions from very dilute solutions. Similarly sugar may be absorbed from low concentrations in the intestine and from low concentrations in the kidney tubules.	26, 61, 112

10.3	Cell Division	
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. Many genes have different forms called alleles, which may produce different characteristics. In body cells the chromosomes are normally found in pairs. Body cells divide to produce additional cells during growth or to produce replacement cells.	272-273 279-280 272, 276
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. Cells in reproductive organs – testes and ovaries in humans – divide to form sex cells (gametes). When a cell divides to form gametes: • 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. 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.	276 155-158, 277 277 277 277 277, 276

Humans as Organisms		
10.4	**Nutrition**	
KS3	The human diet includes carbohydrates, proteins and fats.	44, 45-47
	The digestive system breaks down food and absorbs it in 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.	57-61
	The breakdown of large molecules into smaller molecules is speeded up (catalysed) by enzymes.	29-33
	The enzyme amylase is produced in the salivary glands, the pancreas and the small intestine. This enzyme catalyses the breakdown of starch into sugars.	32, 57
	Protease enzymes are produced by the stomach, the pancreas and the small intestine. These enzymes catalyse the breakdown of protein into amino acids.	34, 57, 59
	Lipase enzymes are produced by the pancreas and small intestine. These enzymes catalyse the breakdown of lipids (fats and oils) 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 produced bile which is stored in the gall bladder being released into the small intestine. Bile neutralises the acid that was added to food in the stomach This provides 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.	61

10.5	Circulation	
FT & HT	The circulation system transports substances around the body. The heart pumps blood around the body. Much of the wall of the heart is made from muscle fibres.	88, 92
	Blood enters an atrium of the heart. The atrium contracts are forces blood into a ventricle. The ventricle contracts and forces blood out of the heart. Valves in the heart ensure that blood flows in the correct direction.	92-93
	Blood flows from the heart to the organs through arteries and returns through veins. There are two separate circulation systems, one to the lungs and one to all other organs of the body.	90-91
	Arteries have thick walls containing muscle and elastic fibres. Veins have thinner wall and often have valves to prevent the back-flow of blood.	91
	In the organs, blood flows through very narrow, thin-walled, blood vessels called capillaries. Substances needed by the cells in body tissues pass out of the blood, and substances produced by the cells pass into the blood through the walls of the capillaries.	89, 101
	Blood consists of a fluid called plasma in which are suspended white blood cells, platelets and red blood cells.	97-99
	Plasma transports:	
	• Carbon dioxide from the organs to the lungs;	101
	• Soluble products of digestion from the small intestine to the organs;	101
	• Urea from the liver to the kidneys.	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 to clot at the site of a wound.	100
	Red blood cells transport oxygen from the lungs to the organs.	98
HT	Red blood cells have no nucleus. They are packed with a red pigment called haemoglobin. In the lungs haemoglobin combines with oxygen o form oxyhaemoglobin. In other organs oxyhaemoglobin splits up into haemoglobin and oxygen.	98
10.6	**Breathing**	
KS3	The breathing systems includes ribs, rib muscles, diaphragm, lungs, trachea, bronchi, bronchioles and alveoli.	74-75
	The windpipe (trachea) splits into two branches called bronchi, one going to each lung. The bronchi divide repeatedly into smaller braces called bronchioles which end in a very large number of alveoli.	77
FT & HT	The breathing system takes air into and out of the body so that oxygen from the air can diffuse into the bloodstream and carbon dioxide can diffuse out of the bloodstream into the air. The lungs are in the upper part of the body (thorax), protected by the ribcage ad separated from the lower part of the body (abdomen) by the diaphragm.	76-77
	To make air move into the lungs the ribcage moves out and the diaphragm becomes flatter. These changes are then reversed to make air move out of the lungs. The movement of air into and out of the lungs is called ventilation.	76

HT	To inhale: • Muscles between the ribs contract, pulling the ribcage upwards; • At the same time the diaphragm muscles contract causing the diaphragm to flatten; • These two movements cause an increase in the volume of the thorax; • The consequent decrease in pressure results in atmospheric air entering the lungs. The alveoli provide a very large, moist surface, richly supplied with blood capillaries so that gases can readily diffuse into and out of the blood.	 76 76 76 76 77
10.7	**Respiration**	
KS3	All living cells in the body respire. During aerobic respiration (respiration which uses oxygen) chemical reactions occur which: • Use glucose (a sugar) and oxygen; • Release energy; • Produce carbon dioxide.	69 69-72 69-72 69-72
FT & HT	Aerobic respiration is summarised by the equation: Glucose + oxygen → carbon dioxide + water [+ energy] During vigorous exercise, muscle cells may be short of oxygen. They can then obtain energy from glucose by anaerobic respiration (respiration which does not use oxygen). The waste produce from this process is lactic acid. The body then needs oxygen to break down this lactic acid. The oxygen that is needed is called an oxygen debt. The energy that is released during respiration is used: • To build up larger molecules using smaller ones; • To enable muscles to contract; • To maintain a steady body temperature in colder surroundings;	69 82 82 70 70 70
HT	• In the active transport of materials across boundaries. Aerobic respiration inside cells occurs in mitochondria. If muscles are subjected to long periods of vigorous activity, they become fatigued, i.e. they stop contracting efficiently. If insufficient oxygen is reaching the muscles, they use anaerobic respiration to obtain energy. This is the incomplete breakdown of glucose and produces lactic acid. Because the breakdown of glucose is incomplete, much less energy is released than during aerobic respiration. Anaerobic respiration results in an oxygen debt that has to be repaid in order to oxidise lactic acid to carbon dioxide and water.	70, 26 82

10.8	Nervous System	
FT & HT	The nervous system enables humans to react to their surroundings and coordinate their behaviour. Cells called receptors detect stimuli (changes in the environment). These include:	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 to smell;	127
	• Receptors in the skins that are sensitive to touch and pressure and to temperature changes.	126
	Information from receptors passes along cells (neurones) in nerves to the brain. The brain coordinates 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;	130
	• The muscular iris controls the size of the pupil and hence the amount of light reaching the retina;	130
	• The lens is held in position by suspensory ligaments and ciliary muscles;	130-131
	• The retina contains the receptor cells which are sensitive to light.	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.	131
	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:	123
	• Impulses from a receptor pass along a sensory neurone to the central nervous system;	123
	• 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;	122
	• 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;	122
	• The effector is either a muscle or a gland;	123
	• A muscle responds by contracting, a gland by releasing (secreting) chemical substances.	123

HT	**Candidates should be able**, when provided with appropriate information, to analyse a reflex action in terms of: Stimulus → receptor → coordinator → effector → response.	118, 123
10.9	**Hormones**	
FT & HT	Many processes within the body are coordinated by chemical substances called hormones. Hormones are secreted by glands and are transported to their target organs by the bloodstream. The blood glucose concentration is controlled by the hormones insulin and glucagon which are released (secreted) by the pancreas. Diabetes is a disease in which a person's blood glucose may rise to a fatally high level because the pancreas does not secrete enough of the hormone insulin. Diabetes may be treated by careful attention to diet and by injecting insulin into the blood. 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: • Hormones that stimulate the release of eggs from the ovaries (fertility drugs); • Hormones that prevent the release of eggs from the ovaries (oral contraception).	132-133 108 114 162-163 163, 167-168 163, 164
HT	The blood glucose concentration of the body is monitored and controlled by the pancreas. If the blood glucose concentration is too high, the pancreas secretes insulin into the blood. This causes the liver to convert glucose into insoluble glycogen and store it. If the blood glucose concentration is too low, the pancreas secretes glucagon which causes the liver to convert glycogen into glucose and release it into the blood. Several hormones are involved in the menstrual cycle of a woman. Those hormones involved in promoting the release of an egg include: • 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; • 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; • LH which is secreted by the pituitary gland and stimulates the release of the egg about the middle of the menstrual cycle. 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; • Giving oral contraceptives which contain oestrogen, to inhibit FSH production so that no eggs mature.	108 108 108 162 163 163 163 167-168 164

10.10	Homeostasis	
FT & HT	Humans need to remove waste products from their bodies and to keep their internal environment relatively constant.	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 breathe out;	69-72, 111
	• Urea produced in 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.	111
	Internal conditions which are controlled include:	
	• The water content of the body – water leaves the body via the lungs when we breathe out and via the skin when we sweat, and excess is lost in the kidneys in the urine;	69, 72, 109-113
	• The ion content of the body – ions are lost via the skins when we sweat and excess are lost via the kidneys in the urine;	107, 111-113
	• Temperature – to maintain the temperature at which enzymes work best.	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
HT	The kidneys help to maintain the internal environment by:	112
	• First filtering the blood;	112
	• Re-absorbing all the sugar;	112
	• Re-absorbing the dissolved ions needed by the body;	112-113
	• Re-absorbing as much water as the body needs;	112
	• Releasing urea, excess ions and excess water as urine.	
	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 re-absorb 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 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;	110
	• Sweat glands release more sweat which cools the body as it evaporates.	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;	110
	• Muscles may 'shiver' – their contraction needs respiration which releases some energy as heat.	110

10.11	Disease	
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.	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:	171-181
	• A bacterial cell consists of cytoplasm and a membrane surrounded by a cell wall; the genes are not in a distinct nucleus;	171
	• Viruses are smaller than bacteria; they consist of only a protein coat surrounding a few genes; they can only reproduce inside living cells.	173
	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:	178
	• The skin acts as a barrier;	178
	• The breathing organs produce a sticky liquid mucus which covers the lining of these organs and traps microorganisms;	74, 178
	• The blood produces clots that seal cuts.	100, 178
	White blood cells help to defend against infective microorganisms:	
	• By ingesting microorganisms;	99
	• By producing antibodies which destroy particular bacteria or viruses;	99
	• By producing antitoxins which counteract the toxins (poisons) released by microorganisms.	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

10.12	Drugs	
KS3	Solvents, alcohol, tobacco and other drugs may harm the body.	185-189
FT & HT	Solvents:	187
	• Affect behaviour;	
	• May cause damage to the lungs; liver and brain.	187
	Alcohol:	
	• Affects the nervous system by slowing down reactions and may lead to lack of self-control, unconsciousness or even coma;	188
	• May cause damage to the liver and brain.	189
	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;	83-84
	• Other lung diseases such as bronchitis and emphysema;	83-84
	• Disease of the heart and blood vessels.	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
HT	Carbon monoxide combines irreversibly with the haemoglobin in red blood cells.	83

Green Plants as Organisms		
10.13	**Plant Nutrition**	
KS3	Green plants photosynthesise when it is light.	205
FT & HT	Photosynthesis is summarised by the equation: Carbon dioxide + water [+ light energy] → glucose + oxygen. During photosynthesis: • Light energy is absorbed by a green substance called chlorophyll which is found in chloroplasts in some plant cells; • This energy is used by converting carbon dioxide and water into a sugar (glucose); • Oxygen is released as a by-product. The rate of photosynthesis may be limited by: • Low temperature; • Shortage of carbon dioxide; • Shortage of light. The glucose produced in photosynthesis may be converted into insoluble starch for storage. Plant cells use some of the glucose produced during photosynthesis for respiration. Plant roots absorb mineral salts including nitrate needed for healthy growth. Light, temperature and availability of carbon dioxide interact and in practice any one of them may be the factor that limits photosynthesis.	205 207, 208, 217 207, 208 207, 209 212, 221 213, 221 211, 221 206 209 226, 230 211-213
HT	The energy released by plants during respiration is used to build up smaller molecules into larger molecules: • Sugars into starch; • Sugars into cellulose for cell walls; • Sugars, nitrates and other nutrients into amino acids which are then built up into proteins; • Sugars into lipids (fats or oils) for storage in seeds. For healthy growth plants also need mineral ions including: • Nitrate – for the synthesis of proteins; • Phosphate – which has an important role in the reactions involved in photosynthesis and respiration. • Potassium – which helps enzymes involved in photosynthesis and respiration to work; The symptoms shown by plants growing in conditions where mineral ions are deficient include: • Stunted growth and yellow older leaves if nitrate ions are deficient; • Poor root growth and purple younger leaves if phosphate ions are deficient; • Yellow leaves with dead spots if potassium ions are deficient.	71, 216 209 209 209 209 218-219 218-219 218-219 218 218 218 218

10.14	Plant Hormones	
FT & HT	Plants are sensitive to light, moisture and gravity:	
	• Their shoots grow towards light and against the force of gravity;	243
	• Their roots grow towards moisture and in the direction of the force of gravity.	244
	Plants produce hormones to co-ordinate and control growth.	
	The responses of plant roots and shoots to light, gravity and moisture are the result of unequal distribution of hormones, causing unequal growth rates.	243-244
	The hormones which control the processes of growth and reproduction in plants and be used by humans to:	
	• Produce large numbers of plants quickly by stimulating the growth of roots from cuttings;	234, 245
	• Regulate the ripening of fruits on the plant and during transport to consumers;	245
	• Kill weeds by disrupting their normal growth patterns.	245

10.15	Transport and Water Relations	
KS3	Most of the water and minerals which enter a plant root are absorbed by root hair cells.	224, 226
FT & HT	Plants lose water vapour from the surface of their leaves. This loss of water vapour is called transpiration. Transpiration is more rapid in hot, dry and windy conditions. Most plants have a waxy layer (cuticle) on their leaves which stops tem losing too much water. Plants living in dry conditions have a thicker cuticle.	227-229
	Most of the transpiration is through tiny holes called stomata. Plants need stomata to obtain carbon dioxide from the atmosphere.	215, 227
	The size of the stomata is controlled by guard cells which surround them. If plants lost water faster than it is replaced by the roots, the stomata can close to prevent wilting.	215, 228
	The water inside plant cells gives support for young plants. This is the main method of support and the plant wilts if the cells are short of water.	228
	Flowering plants have separate transport systems for water and nutrients:	
	• Xylem tissue transports water and minerals from the roots to the stem and leaves;	224, 225-227
	• Phloem tissue carries nutrients such as sugars from the leaves to the rest of the plant including the growing regions and the storage organs.	224, 225, 230
HT	When water moves into plant cells by osmosis it increases the pressure inside the cell. The cell walls are sufficiently strong to withstand the pressure. It is the pressure which keeps the cells rigid (maintains their turgor) and hence provides support.	22-24 226-228

Variation, Inheritance and Evolution

10.16 Variation

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.	251-256
	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);	255
	• the conditions in which they have developed (environmental causes);	255
	or a combination of both.	
	New forms of genes result from changes (mutations) in existing genes. Mutations occur naturally. The chance of mutations occurring is increased by:	285
	• exposure to ionising radiations, including ultra-violet light, X-rays and radiation from radioactive substances; the greater the dose of radiation, the greater the chance of mutation;	285
	• certain chemicals.	285
	There are two forms of reproduction:	
	• sexual reproduction – which involves the joining (fusion) of male and female gametes;	155, 277
	• asexual reproduction – where there is no fusion of cells and only one individual is needed as the single parent.	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	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. Sexual reproduction gives rise to variation because: • the gametes are produced from the parental cells by meiosis; • when gametes fuse, one of each pair of alleles comes from each parent; • the alleles in a pair may vary and therefore produce different characteristics. Most mutations are harmful: • if mutations occur in reproductive cells, young may develop abnormally or die at an early stage of their development; • if mutations occur in body cells, these may start to multiply in an uncontrolled way and invade other parts of the body; this is cancer. Some mutations are neutral in their effects and, in rare cases, a mutation may increase the chances of survival of an organism and any offspring which inherit the mutant gene.	276 277 277 277, 279 285 285 285
10.17	**Genetics and DNA**	
FT & HT	In human body cells, one of the 23 pairs of chromosomes carries the genes which determine sex. In females the sex chromosomes are the same (XX); in males the sex chromosomes are different (XY). Chromosomes have long molecules of a substance called DNA. A gene is a section of a DNA molecule. For certain characteristics, the characteristic is controlled by one gene. Some genes have two different forms called alleles. An allele which controls the development of a characteristic when it is present on only one of the chromosomes is a dominant allele. An allele which controls the development of characteristics only if the dominant allele is not present is a recessive allele. Some disorders are inherited: *[Attention is drawn to the potential sensitivity needed in teaching about inherited disorders.]* • Huntington's disease – a 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.	272, 278 273 279-280 280-281 281 287 286 288

HT	If both chromosomes in a pair contain the same allele of a gene, the individual is homozygous for that gene. If the chromosomes in a pair contain different alleles of a gene, the individual is heterozygous for that gene. **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. DNA contains coded information that determines inherited characteristics. DNA is made of very long strands which have four different compounds called bases. A sequence of three bases is the code for a particular amino acid. The order of bases controls the order in which amino acids are assembled to produce a particular protein. *[Candidates are <u>not</u> expected to know the names of the four bases or how complementary pairs of bases enable DNA replication to take place.]*	281 281 282-284 282-284 273-275 275
10.18	**Controlling Inheritance**	
KS3	Selective breeding 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. 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. 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. 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. 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 bacteria 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. 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.	234 234 290 290 234 291 289 289, 291, 293

10.19	Evolution	
FT & HT	Fossils are the 'remains' of plants or animals from many years ago which are found in rocks. Fossils may be formed in various ways including:	302-303
	• 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 of 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
	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.	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 and 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 evolution of resistant bacteria.	300
	Candidates should be able, when provided with additional information, to interpret evidence relating to evolutionary theory.	
	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 adapted to survive these changes they may become extinct.	296-301, 305
	Candidates should be able, when provided with appropriate information, to:	
	• Suggest reasons why Darwin's theory of natural selection was only gradually accepted;	298-299
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

Living Things in their Environment		
10.20	**Adaptation and Competition**	
KS3	Physical factors which may affect organisms include:	
	• Temperature;	329
	• Amount of light;	329
	• Availability of water;	329
	• Availability of oxygen and carbon dioxide.	329
	These factors vary according to the time of day and the time of year.	333
	Organisms live, grow 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.	336-338
	Candidates should be able, when provided with appropriate information, to:	338
	• Explain how animals are adapted for survival in arctic and desert environments in terms of:	
	- body size and surface area	
	- thickness of insulating coat	
	- amount of body fat	
	- camouflage;	336
	• Explain how plants are adapted to survive in arid conditions;	
	• Suggest how other organisms are adapted to the conditions in which they live.	336-337
	Plants often compete with each other for space, and for water and nutrients from the 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.	341-342
	In a community:	
	• The number of animals of a particular species (its population) is usually limited by the amount of food available;	333, 341-343
	• If the population of prey increases, more food is available for its predators and their population may also increase;	341-343
	• If the population of predators increases, more food is needed and the population of prey will decrease.	341-343
	The size of a population may be affected by:	332-333
	• The total amount of food or nutrients available;	333, 339-340
	• Competition for food or nutrients;	333, 339-340
	• Competition for light;	333, 339-340
	• Predation or grazing;	333, 339-340
	• Disease.	333, 339-340

10.21	**Human Impact on The Environment**	
FT & HT	Humans reduce the amount of land available for other animals and plants by:	
	• Building;	330, 346
	• Quarrying;	330
	• Farming;	330, 346
	• Dumping waste.	330
	Human activities may pollute:	
	• Water – with sewage, fertiliser or toxic chemicals;	348-349
	• Air – with smoke and gases such as sulphur dioxide;	347
	• Land – with toxic chemicals, such as pesticides and herbicides, which may be washed from land into water.	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, plans and animals cannot survive.	347
	When the Earth's human population was much smaller, the effects of human activity were usually small and local. Rapid growth in the human population and an increase in the standard of living means that:	344-345
	• 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 and the activities of microorganisms);	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 methane in the atmosphere are slowly rising. Increasing levels of these gases many be causing the 'greenhouse effect'.	372
	An increase in the Earth's temperature of only a few degrees Celsius:	372
	• may cause quite big changes in the Earth's climate;	372
	• may cause a rise in sea level.	372
HT	Farmers add fertiliser to soil to replace the nutrients which crops remove. Excess fertilisers may be washed into lakes and rivers.	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 microorganisms which feed on dead organisms;	374
	• the increased use of oxygen from the water by these microorganisms for their respiration;	374
	• the resultant death due to oxygen shortage of fish and other aquatic animals.	374

HT	Untreated sewage provides food for microorganisms. This has the same effect (eutrophication) in water as dead vegetation. Carbon dioxide and methane in the atmosphere absorb much 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.	349, 374 372
10.22	**Energy and Nutrient Transfer**	
KS3	Food chains show which organisms eat other organisms. In a food chain, A → B→ C means that B eats A and C eats B. Food chains always begin with green plants (producers) which provide food for other organisms (consumers). Food chains are often interconnected to form food webs. Food chains and food webs show the transfer of energy and materials from one type of organism to another. The number of organisms at each stage of a food chain can be shown as a pyramid of numbers.	356 356 356 357 356-357 358
FT & HT	Radiation from the Sun is the source of energy for all communities of living organisms. Green plants capture a small part of the solar energy which reaches them. This energy is stored in the substances which make up the cells of the plants. The mass of living material (biomass) at each stage in a food chain is less than it was at the previous stage. The biomass at each stage can be drawn to scale and shown as a pyramid of biomass. **Candidates should be able** to interpret pyramids of **biomass** and construct them from appropriate information. At each stage in a food chain, less material and less energy are contained in the biomass of the organisms. This means that the efficiency of food production can be improved by reducing the number of stages in food chains.	362 359 359 360-363
HT	The amounts of material and energy contained in the biomass of organisms is reduced at each successive stage in a food chain because: • some materials and energy are always lost in the organisms' waste materials; • respiration supplies all the energy needs for living processes, including movement; much of this energy is eventually lost as heat to the surroundings; these losses are especially large in mammals and birds whose bodies must be kept at a constant temperature which is usually higher than that of their surroundings. The efficiency of food production can also be improved by: • restricting energy loss from food animals by limiting their movement and by controlling the temperature of their surroundings; • using hormones to regulate the ripening of fruits on the plant and during transport to consumers.	360-363 360-363 360-363 366 345

10.23	Nutrient Cycles	
FT & HT	Living things remove materials from the environment for growth and other processes. These materials are returned to the environment either in waste materials or when living things die and decay.	369
	Materials decay because they are broken down (digested) by microorganisms.	369-370
	Microorganisms digest materials faster in warm, moist conditions.	370
	Many microorganisms are also more active when there is plenty of oxygen.	370
	Microorganisms are used:	
	• at sewage works to break down waste from humans;	316
	• in compost heaps to break down waste plant materials.	380
	The decay process releases substances which plants need to grow.	370
	In a stable community, the processes which remove materials are balanced by processes which return materials. The materials are constantly cycled.	369-370
	The constant cycling of carbon is called the carbon cycle.	
	In the carbon cycle:	
	• carbon dioxide is removed from the environment by green plants for photosynthesis; the carbon from the carbon dioxide is used to make carbohydrates, fats and proteins which make up the body of plants;	371
	• some carbon dioxide is returned to the atmosphere when green plants respire;	371
	• when green plants are eaten by animals and these animals are eaten by other animals, some of the carbon becomes part of the fats and proteins which make up their bodies;	371
	• when animals respire some of this carbon becomes carbon dioxide and is released into the atmosphere;	371
	• when plants and animals die, some animals and microorganisms feed on their bodies; carbon is released into the atmosphere as carbon dioxide when these organisms respire.	370-371
HT	The constant cycling of nitrogen is called the nitrogen cycle.	
	In the nitrogen cycle:	
	• green plants absorb nitrates from the soil;	373
	• they use the nitrogen in these nitrates to make proteins;	373
	• when green plans are eaten by animals and these animals are eaten by other animals, some of the nitrogen then becomes part of the proteins in their bodies;	373
	• when putrefying (decay) bacteria and fungi break down the waste products of animals and the protein from dead animals and plants, ammonium compounds are produced;	373
	• nitrifying bacteria convert ammonium compounds to nitrates.	373
	[diagram]	
	By the time microorganisms and detritus feeders have broken down the waste products and dead bodies of organisms in ecosystems and cycled the material as plant nutrients, all the energy originally captured by green plants has been transferred.	369-370

Module 11 – Materials and Their Properties

• Classifying Materials – Atomic Structure, Bonding	Chap 3,21,22,23
• Changing Materials – Useful Products from Oil, Useful Products from Metal Ores, Useful Products from Rocks, Useful Products from Air, Representing Reactions, Quantitative Chemistry, Changes to the Earth and Atmosphere, The Rock Record	Chapters 13,8,9,10,11,20,25, 26,27
• Patterns of Behaviour – The Periodic Table, Chemical Reactions, Rates of Reactions, Reactions involving Enzymes, Reversible Reactions, Energy Transfer in Reactions.	Chapters 4,5,6,12,15,16,17 19

Materials and their Properties		
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. **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. As a result of their study of sections 11.1 – 11.15: **Candidates should be able** to use information on the Data Sheet where appropriate, in answering examination questions; **Candidates should be able** to describe simple laboratory tests for alkenes (HT only), carbon dioxide, chlorine, hydrogen, and water as described in the syllabus and for oxygen (re-lights a glowing splint); **Candidates should be able** to describe and give examples of the following types of chemical reaction: • thermal decomposition (including cracking) • neutralisation • displacement • electrolysis • oxidation (as addition of oxygen) • reduction (as removal of oxygen) • exothermic • endothermic • reversible	
HT	• oxidation (as the loss of electrons) • reduction (as the gain of electrons) • redox	

Classifying Materials		
11.1	**Atomic Structure**	
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.	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
	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	29
	In an atom, the number of electrons is equal to the number of protons in the nucleus. Atoms have no overall electrical charge.	31
	All atoms of a particular element have the same number of protons. Atoms of different elements have different numbers of protons. The number of protons in an atom is called its atomic number (proton number). The total number of protons and neutrons (nucleons) in an atom is called its mass number.	31
	Atoms of the same element can have different numbers of neutrons, these atoms are called isotopes of that element. **Candidates should be able** to represent and interpret atoms as shown: mass number 23 **Na** atomic number 11	32
	Electrons occupy particular energy levels. 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 specification, candidates may answer in terms of shells if they are prefer.]*	30
	Candidates should be able to represent the electronic structure of the first twenty elements of the periodic table in the following forms: for sodium [diagram] and 2, 8, 1	31, 70

11.2	**Bonding**	
KS3	When the particles of a substance gain or lose energy, the substance may change its state. If energy is supplied to a solid, its particles vibrate more violently; they may separate from each other and become free to move. This is melting. The temperature at which a solid melts is called the melting point. Heating a liquid makes its particles move around more quickly. Particles which have enough energy may overcome attractive forces and escape from the liquid and become a gas. This is evaporation. When the temperature is higher, more particles have enough energy to escape so evaporation is faster. If the temperature is high enough, a liquid will boil. The temperature at which a liquid boils is called its boiling point.	Chp 1
FT & HT	Compounds are substances in which atoms of two, or more, elements are not just mixed together but chemically combined.	16
	Chemical reactions between elements involve either the giving and taking, or sharing, of electrons in the highest occupied energy levels of atoms.	70, 262, 270
	When atoms form chemical bonds by gaining and losing electrons they form electrically charged atoms called ions. Atoms can also form bonds by sharing electrons.	263, 270
	The atoms which lose electrons become positively charged ions and the atoms which gain electrons become negatively charged ions. These ions now have the electronic structure of a noble gas.	71, 262-4
	Candidates should be able to represent the electronic structure of the ions in sodium chloride, magnesium oxide and calcium chloride in the following forms: [diagram] $[Na]^{+}$	263-4
	An ionic compound is a giant structure of ions. Substances with giant structures have high melting points and boiling points.	266
	Ionic compounds are held together by strong forces of attraction between oppositely charged ions. This is the ionic bond.	263, 267
	Atoms which share electrons often form molecules. The atoms in molecules are held together because they share pair of electrons. The strong bonds between the atoms are called covalent bonds.	270-7
	Candidates should be able to represent the covalent bonds in water, ammonia, hydrogen, hydrogen chloride, methane and oxygen in the following forms: [diagram]	271
	Substances which are made of molecules have low melting points and boiling points.	276

HT	Simple molecular compounds are gases, liquids or solids which have relatively low melting points and boiling points and do not conduct electricity. This is because: • the forces between the molecules (intermolecular forces) are weak; • the molecules do not carry an overall electric charge.	276
	Atoms which share electrons can also form giant structures. Diamond and graphite (forms of carbon) and silicon dioxide (silica) are giant covalent structures (lattices) of atoms. Because of the large number of covalent bonds in their structures, they have very high melting points.	272-6
	In diamond each carbon atom forms four covalent bonds in a rigid, giant covalent structure.	272
	In graphite each carbon atom forms three covalent bonds and the carbon atoms form layers which are free to slide over each other. In graphite there are free electrons which allow graphite to conduct electricity.	273
	Ionic compounds form regular structures (giant ionic lattices) in which the strong forces between oppositely charged ions result in these compounds having high melting points and high boiling points. When they are melted or dissolved in water, ionic compounds conduct electricity because the ions are free to move.	266-7
	Metals consist of giant structures in which the electrons from the highest occupied (outer) energy levels of metal atoms are free to move through the whole structure. These free electrons: • hold the atoms together in a regular structure; • allow the atoms to slide over each other; • allow the metal to conduct heat and electricity.	280

Changing Materials		
11.3	**Useful Products from Oil**	
KS3	Crude oil is obtained from the Earth's crust. It was formed from the remains of organisms which lived millions of years ago. It is a fossil fuel. 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 or 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. 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 catalyst. A thermal decomposition reaction then occurs.	165
	Some of the products of cracking are useful as fuels. 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
	Other products of cracking can be used to make plastics (polymers) such as poly(ethene) and poly(propylene). Poly(ethene) is used for making plastic bags and bottles. Poly(propylene) is used for crates and ropes.	166, 171
	Most plastics, including poly(ethene) and poly(propylene), are not broken down by microorganisms. They are not bio-degradable. This can lead to problems with waste disposal.	172-3

<table>
<tr><td>HT</td><td>Carbon atoms form the spine of hydrocarbon molecules.

When the carbon atoms are joined by single covalent carbon carbon bonds (when the hydrocarbons are saturated) they are know as alkanes.</td><td>172-3</td></tr>
<tr><td></td><td>Candidates should be able to represent and to interpret saturated hydrocarbon molecules in the following form:
H H
| |
H — C — C — H
| |
H H</td><td>159</td></tr>
<tr><td></td><td>Other hydrocarbons have carbon carbon double covalent bonds (they are unsaturated) and are know as alkenes. A simple laboratory test for an unsaturated hydrocarbon is to use bromine water. The yellow-brown bromine water becomes colourless as the bromine reacts with the hydrocarbon.</td><td>167</td></tr>
<tr><td></td><td>Candidates should be able to represent and to interpret unsaturated hydrocarbon molecules in the following form:
H H
\ /
C = C
/ \
H H

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.</td><td>166-7</td></tr>
<tr><td></td><td>When unsaturated monomers join together to form a polymer with no other substance being produced in the reaction, the process is called addition polymerisation.

Plastics are polymers and are made by polymerisation.

For example, poly(ethene) (often called polythene) is made by polymerising the simplest alkene, ethene.</td><td>168</td></tr>
<tr><td></td><td>Candidates should be able:
• To interpret diagrammatic representations of addition polymerisation;
• To represent the formation of a simple addition polymer in the following form:

[diagram]</td><td>168-9</td></tr>
</table>

11.4	Useful Products from Metal Ores	
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.	Chp 7
FT & HT	The Earth's crust contains metals and metal compounds. These are always found mixed with other substances In ores, the metal or metal compound is concentrated enough to make it economic to extract the metal. Gold, an unreactive metal, is found in the Earth as the metal itself. Chemical separation is not needed.	88
	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.	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), code 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 the 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
	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. 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 a reactivity series to predict how a metal could be extracted from a compound. *[See Data Sheet for a reactivity series of metals which also includes carbon and hydrogen.]*	98
	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.	92-3, 95

FT & HT	Reactive metals such as aluminium are extracted by electrolysis.	98, 107
	When substances which are made of ions are dissolved in water, or melted, they can be broken down (decomposed) into simpler substances by passing an electric current through them. This process is called electrolysis. When an ionic substance is melted or dissolved in water the ions are free to move about.	100-1
	During electrolysis, positively charged ions – for example, metal ions – move to the negative electrode, and negatively charged ions move to the positive electrode. During electrolysis, gases may be given off, or metals deposited at the electrodes.	102-4
	The raw material for producing aluminium is aluminium oxide purified from aluminium ore (bauxite). Because aluminium oxide has a very high melting point it is dissolved in a molten aluminium compound called cryolite at a much lower temperature. The electrodes are made of carbon. The aluminium forms at the negative electrode and oxygen forms at the positive electrodes. This makes the positive electrodes burn away quickly so that they frequently have to be replaced. Aluminium does not oxidise (corrode) as quickly as its reactivity would suggest. Once a thin oxide layer has formed on the surface, it forms a barrier to water and oxygen and so prevents any further corrosion. Aluminium is a useful structural metal. It can be made harder, stronger and stiffer by mixing in small amounts of other metals to make alloys. Copper can be purified by electrolysis using a positive electrode made of the impure copper and a negative electrode of pure copper in a solution containing copper ions.	107
HT	At the negative electrode positively charged ions gain electrons (reduction). At the positive electrode negatively charged ions lose electrons (oxidation). In a chemical reaction if oxidation occurs reduction also occurs. These reaction are called redox reactions.	105, 115
11.5	**Useful Products from Rocks**	
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.	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 a 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.	129-30
	Glass is made by heating a mixture of limestone, sand and soda (sodium carbonate).	132

11.6	**Useful Products from Air**	
FT & HT	Air is almost 80% nitrogen.	314
	The nitrogen can be used to manufacture several important chemicals, including nitrogen-based fertilisers. Nitrogen-based fertilisers are important in agriculture for increasing the yields of crops. Nitrates can however, create problems if they find their way into streams, rivers or groundwater and so contaminate our drinking water.	242-50
	Candidates should be able, when provided with appropriate information, to reach balanced judgements concerning the benefits of using nitrate fertilisers and the contamination of drinking water they can cause.	250
	Ammonia is manufactured in the Haber process. The raw materials are nitrogen from the air and hydrogen obtained from natural gas. The purified gases are passed over a catalyst of iron at a high temperature (about 450^0C) and a high pressure (about 200 atmospheres). Some of the hydrogen and nitrogen reacts for form ammonia. The reaction is reversible. This means that ammonia also breaks back down again into nitrogen and hydrogen: nitrogen + hydrogen $\rightleftharpoons$ ammonia The reaction conditions are chosen to produce a reasonable yield of ammonia quickly. On cooling the ammonia liquefies and is removed. The remaining hydrogen and nitrogen is re-cycled.	240-1 243
	Ammonia can be oxidised to produce nitric acid. Ammonia gas reacts with oxygen in air in the presence of a hot platinum catalyst. This oxidation reaction forms nitrogen monoxide which is then cooled and reacted with water and more oxygen to form nitric acid.	245
	Ammonium nitrate fertiliser is made by the neutralisation reaction between ammonia and nitric acid.	247
	Candidates should be able to outline and evaluate the economic factors associated with the conditions under which the Haber process is normally carried out. **Candidates should be able** to explain the details of these processes in terms of chemical principles from this syllabus including: • Energy transfers during the reaction; • The rates of the reactions; Equilibrium conditions in reversible reactions.	241

11.7	Representing Reactions	
KS3	Each element is represented by a different symbol. The chemical formula for a compound shows which elements are in the compound. A chemical reaction can be described using a word equation: Reactants → products	14-17
FT & HT	**Candidates should be able** to write word equations for all reactions referred to in the tier of the specification for which they are entered.	17
	The symbols for elements are used to write chemical formulae for compounds which show the ratios of atoms from different elements which are combined to form the compounds.	15
	Candidates should be able to write down the correct formulae for simple ionic compounds. *[See Data Sheet for the formulae of, and charges on common ions.]*	265
	Candidates should be able to recall the formulae of all simple covalent compounds referred to in the relevant tier of the specification. **Candidates should be able** to interpret chemical formulae or symbolic representations of molecules in terms of the elements present and the ratios of their atoms. Chemical reactions can be represented using the chemical formulae for the reactants and the products.	throughout
	Candidates should be able to interpret supplied symbol equations, which may include the state symbols (s), (l), (g) and (aq).	26
	The total mass of the product(s) of a chemical reaction is always equal to the total mass of the reactant(s). This is because the products of a chemical reaction are made up from exactly the same atoms as the reactants. Symbol chemical equations must, therefore, always be balanced. The total number of atoms of each element on the reactants side of the equation must be equal to the total number of atoms of the same element on the products side of the equation. **Candidates should be able** to: • Balance supplied symbol equations; • Write a balanced symbol equation from a supplied word equation.	24-5
	During electrolysis, ions gain or lose electrons at the electrodes. Electrically neutral atoms or molecules are released. **Candidates should be able** to complete and balance supplied half equations for the reactions occurring at the electrodes during electrolysis. *The supplied equations will include information about the charge of the ion and the atomic or molecular nature of the product.* *For example, when supplied with* $Cl^- - e^- \rightarrow Cl_2$ ***Candidates should be able** to produce* $2Cl^- - 2e^- \rightarrow Cl_2$	105-7

11.8	Quantitative Chemistry	
FT & HT	Atoms of different elements have different masses. To be able to work out exactly what is happening in chemical reactions we need to know how the masses of atoms compare with each other, i.e. their relative atomic masses (A_r).	34
	Candidates should be able to: • Calculate the relative formula mass (M_r) of compounds whose formulae are supplied;	35
	• Calculate the percentage of an element in a compound whose formula is supplied. *[See Data Sheet for A_r of elements.]*	360-1
HT	**Candidates should be able** to use supplied balanced symbol equations and supplied data about the masses / volumes of some reactants / products: • To calculate the masses / volumes of other reactants / products; *[Candidates may use moles in their calculations but are not required to do so. The volume of the M_r in grams, of a gas, will be given.]*	362-5
	• To determine the ratios of atoms in compounds from supplied masses or percentage composition (empirical formulae)	358-61
	Candidates should be able to use given half equations for reactions occurring at the electrodes and given data about the mass / volume of one of the products to calculate the mass / volume of the other product.	366-7
11.9	**Changes to the Earth and Atmosphere**	
FT & HT	For 200 million years the proportions of different gases in the atmosphere have been much the same as they are today: • About four-fifths (80%) nitrogen; • About one-fifth (20%) oxygen; • Small proportions of various other gases, including carbon dioxide, water vapour and noble gases.	314
	During the first billion years of the Earth's existence there was intense volcanic activity. This activity released the gases which then formed the early atmosphere and water vapour which condensed to form the oceans. During this period the Earth's atmosphere was probably mainly carbon dioxide and there would have been little or no oxygen gas (like the atmospheres of Mars and Venus today). There would also have been water vapour, and small proportions of methane and ammonia. When plants evolved and successfully colonised most of the Earth's surface: • The atmosphere gradually became more and more "polluted" with oxygen. This meant that, gradually, there were fewer habitats suitable for microorganisms which could not tolerate oxygen; • Most of the carbon from the carbon dioxide in the air gradually became locked up in sedimentary rocks as carbonates and fossil fuels; • The methane and ammonia in the atmosphere reacted with the oxygen;	320-1

HT	• Nitrogen gas was released into the air, partly from the reaction between oxygen and ammonia, but mainly from living organisms, including denitrifying bacteria; • The oxygen in the atmosphere resulted in the development of an ozone layer. This filters out harmful ultraviolet radiation from the Sun allowing the evolution of new living organisms.	320-1
	Carbonate rocks are sometimes moved deep into the Earth by geological activity. They may then release carbon dioxide back into the atmosphere via volcanoes.	318
	The release of carbon dioxide by burning the carbon locked up over hundreds of millions of years in fossil fuels increases the level of carbon dioxide in the atmosphere. Though the reaction between carbon dioxide and sea-water also increases, producing insoluble (mainly calcium) carbonates which are deposited as sediment and soluble hydrogencarbonates (mainly calcium and magnesium), this does not wholly absorb the additional carbon dioxide released into the atmosphere.	297
11.10	**The Rock Record**	
KS3	[diagram of rock cycle]	Chp 26
FT & HT	Metamorphic rocks are associated with the Earth movements (tectonic activity) which created present-day and ancient mountain belts. They are evidence of the high temperatures and pressure created by these mountain-building processes.	331
	Sediments contain evidence for how they were deposited (e.g. layers formed by discontinuous deposition, ripple marks formed by currents or waves). At the surface of the Earth younger sedimentary rocks usually lie on top of older rocks.	330
	Sedimentary rock layers are often found tilted, folded, fractured (faulted) and sometimes even turned upside down. This shows that the Earth's crust is unstable and has been subjected to very large forces. Large scale movements of the Earth's crust can cause mountain ranges to form very slowly over millions of years. These replace older mountain ranges worn down by weathering and erosion.	342

Patterns of Behaviour		
11.11	**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. 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 potassium in the periodic table so that it is in Group 0 and potassium is in Group 1. 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. The similarities and differences between the properties of elements in the same group of the periodic table can be explained by electronic structure of their atoms.	70
	Candidates should be able, when provided with appropriate additional information, to explain: • 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; • 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
	More than three-quarters of the elements are metals. In the periodic table metals are mainly found: • In the two left hand columns (Group 1 and Group 2) • In the central block (transition elements).	48
	The elements in Group 1 of the periodic table (known as the alkali metals): • Are metals with a low density (the first three in the Group are less dense than, and therefore float on, water); • React with non-metals to form ionic compounds in which the metal ion carries a charge of +1. The compounds are white solids which dissolve in water to form colourless solutions; • React with water releasing hydrogen; • Form hydroxides which dissolve in water to give alkaline solutions.	50-1, 71
	Fewer than one quarter of the elements are non-metals. Non-metal elements are found inn 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);	62, 66-7
	• They are brittle and crumbly when solid; • They are poor conductors of heat and electricity even when solid or liquid.	45

FT & HT	The elements in Group 7 of the periodic table (known as the halogens): • Have coloured vapours; • Consist of molecules which are made up of pairs of atoms; • Form ionic salts with metals in which the chloride, bromide, or iodide ion (halide ions) carries a charge of –1; • Form molecular compounds with other non-metallic elements. The elements in Group 0 of the periodic table (known as the noble gases): • Are all chemically very unreactive gases; • Exist as individual atoms rather than as diatomic gases like most other gaseous elements; • Are used as inert gases in filament lamps and in electrical discharge tubes. The first element in the Group, helium, is much less dense than air and is used in balloons. In the centre of the periodic table is a block of metallic elements. These elements, which include iron and copper, are known as transition metals. Like all other metals, transition metals are good conductors of heat and electricity and can easily be bent or hammered into shape. Compared to alkali metals: • They have high melting points (except for mercury, which is a liquid at room temperature); • They are hard, tough and strong; • They are much less reactive and so do not react (corrode) so quickly with oxygen and / or water. These properties make transition metals very useful as structural materials (e.g. iron, usually in the form of steel) and for making things which must allow heat or electricity to pass through them easily (e.g. copper for electrical cables). Most transition metals form coloured compounds. These can be seen: • In pottery glazes of various colours; • In weathered copper (green). Many transition metals, including iron and platinum, are used as catalysts. 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 tub of hydrogen is held to a flame the hydrogen burns in 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. A more reactive halogen can displace a less reactive halogen from an aqueous solution of its salt.	

HT	Elements in the same group have similar properties because they have had the same number of electrons in the highest occupied (outer) energy level. The higher this energy level: • The more easily electrons are lost; • The less easily electrons are gained. These ideas explain the trends on 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 lose or to share electrons.	66
11.12	**Chemical Reactions**	
KS3	When a substance dissolves in water it forms an aqueous solution which may be acidic, alkaline or neutral. Water itself is neutral. Indicators can be used to show whether a solution is acidic, alkaline or neutral by the way their colours change. The pH scale is used to show how acidic or alkaline a solution is: 0 ←———————— 7 ————————→ 14 increasing acidity neutral increasing alkalinity	143

FT & HT	Sodium chloride (common salt) is a compound of an alkali metal and a halogen. It is found in large quantities in the sea and in underground deposits.	118
	The electrolysis of sodium chloride solution (brine) is an important industrial process. Chlorine gas is formed at the positive electrode and hydrogen gas at the negative electrode. A solution of sodium hydroxide is also formed. Each of these products can be used to make other useful materials: • Chlorine is used to kill bacteria in drinking water and in swimming pools, and to manufacture hydrochloric acid, disinfectants, bleach and the plastic (polymer) known as PVC; • Hydrogen is used in the manufacture of ammonia and margarine; • Sodium hydroxide is used in the manufacture of soap, paper and ceramics.	122-5
	A simple laboratory test for chlorine is that it bleaches damp litmus paper.	62
	Silver chloride, silver bromide and silver iodide (silver halides) are reduced to silver by the action of light, X-rays and the radiation from radioactive substances. They are used to make photographic film and photographic paper.	268
	Hydrogen halides are gases which dissolve in water to produce acidic solutions.	TSP, 148
	Compounds of alkali metals called salts can be made by reacting solutions of their hydroxides which are alkaline with acids. In these neutralisation reactions: acid + alkaline hydroxide solutions → 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. Neutralising hydrochloric acid produces chlorides. Neutralising nitric acid produces nitrates. 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
	An indicator can be used to show when acidic and alkaline solutions have completely reacted to produce a neutral salt solution.	143-4
	Salts of transition metals, as with some other metals, can be made by reacting their oxides or hydroxides with acids. Transition metal oxides and hydroxides do not dissolve in water and are called bases. To produce a solution of a soluble transition metal salt, the metal oxide (or hydroxide) is added to an acid until no more will react. The excess metal oxide (or hydroxide) can then be filtered off. Hydrogen ions H^+ (aq) make solutions acidic. Hydroxide ions OH^- (aq) make solutions alkaline.	146
HT	In neutralisation reactions: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$	148

11.13	**Rates of Reactions**	
FT & HT	The speed (rate) of a chemical reaction increases: • If the temperature increases;	206
	• If the concentration of dissolved reactants or the pressure of gases increases;	204-5
	• If solid reactants are in smaller pieces (greater surface area);	203
	• If a catalyst is used. 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
	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.	203, 209
	Increasing the temperature increases the speed of the reaction 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

11.14	Reactions Involving Enzymes	
FT & HT	Living cells use chemical reactions to produce new materials.	212
	Yeast cells convert sugar into carbon dioxide and alcohol. 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. A simple laboratory test for carbon dioxide is that it turns lime-water milky.	214-5
	Bacteria are used to produce yoghurt from milk. The bacteria convert the sugar in milk (lactose) to lactic acid.	216
	The chemical reactions brought about by living cells are quite fast in conditions that are warm rather than hot. This is because the cells use catalysts called enzymes. Enzymes are protein molecules which are usually damaged by temperatures above about 45°C. Different enzymes work best at different pH values.	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); 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. In industry, enzymes are used to bring about reactions at normal temperatures and pressures that would otherwise require expensive, energy-demanding equipment. **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
11.15	**Reversible Reactions**	
FT & HT	In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented: $A + B \rightleftharpoons C + D$ For example: Ammonium chloride $\rightleftharpoons$ ammonia + hydrogen chloride (white solid) (colourless gases)	232-3

HT	When a reversible reaction occurs in a closed system, an equilibrium is reached when the reactions occur at exactly the same rate in each direction.	234-5
	The relative amounts of all the reacting substances at equilibrium depend on the conditions of the reaction. If the forward reaction is an endothermic reaction, and the temperature is increased, the yield of products is increased; if the temperature is decreased, the yield of products is decreased. If the forward reaction is an exothermic reaction, and the temperature is increased, the yield of products is increased. In gaseous reactions, an increase in pressure will favour the reaction which produces the least number of molecules as shown by the symbol equation for that reaction.	236
	These factors, together with reaction rates, are important when determining the optimum conditions in industrial processes, including the Haber process.	240-1
11.16	**Energy Transfer in Reactions**	
KS3	When fuels burn, energy is released as heat.	186
FT & HT	Whenever chemical reactions occur, energy is usually transferred to or from the surroundings. An exothermic reaction is one which transfers energy, often as heat, to the surroundings. An endothermic reaction is one which takes in energy, often as heat, from the surroundings.	190-1
	If a reversible reaction is exothermic in one direction it is endothermic in the opposite direction. The same amount of energy is transferred in each case. For example Hydrated Copper sulphate (blue) [+ heat energy] $\rightleftharpoons$ anhydrous copper sulphate (white) + water The reverse reaction can be used as a test for water.	232, 236
HT	During a chemical reaction: • Energy must be supplied to break bonds; • Energy is released when bonds are formed. In an exothermic reaction, the energy released from forming new bonds is greater than the energy needed to break existing bonds. In an endothermic reaction, the energy needed to break existing bonds is greater than the energy released from forming new bonds.	194-5
	Candidates should be able to: • Interpret simple energy level diagrams in terms of bond breaking and bond formation (including the idea of activation energy and the effect on this of catalysts);	192, 194-5 209
	• Calculate the nett energy transfer in reactions, using simple energy level diagrams or supplied bond energies.	194-5

Module 12 – Physical Processes

Electricity		page numbers in **Physics for You**
12.1	**Potential Difference in Circuits**	
KS3	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 different 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. The p.d. across a component in a circuit is measured in volts (V) using a voltmeter connected across the component. The current flowing through a component in a circuit is measured in amperes (A) using an ammeter connected in series with the component.	p. 254 - 261
FT & HT	Current-voltage graphs are used to show how the current through a component varies with the voltage across it. *[insert 3 current-voltage graphs, for: resistor, filament lamp and diode]*	p. 265, worksheets
	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.	p. 262, 267
	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 of the component, the smaller the current; • The total current through the whole circuit is the sum of the currents through the separate components.	p. 263, 267
	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).	p. 266
	Candidates should be able to interpret and/or draw circuit diagrams using standard symbols. The following standard symbols should be known. *[insert symbols of: switch, lamp, cell, battery, ammeter, voltmeter, resistor, variable resistor, fuse, diode, thermistor, L.D.R.]*	p. 254

FT & HT	Potential difference, current and resistance are related as shown: Potential difference = current × resistance (volt, V) (ampere, A) (ohm, Ω) The current through a resistor (at constant temperature) is proportional to the voltage across the resistor. The resistance of a filament lamp increased as the temperature of the filament increases. The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction. The resistance of a light dependent resistor decreases as the light intensity increases. The resistance of a thermistor decreases as the temperature increases. *[i.e. knowledge of negative temperature coefficient thermistors only is required.]*	p. 259, 265, 322 325, 265
12.2	**Energy in Circuits**	
KS3	As an electric current flows through a circuit, energy is transferred from the battery or power supply to the components in the electrical circuit.	112, 270
FT & HT	An electric current is a flow of charge. When electrical charge flows through a resistor, electrical energy is transferred as heat. The rate of energy transfer (power) is given by: power = potential difference × current (watt, W) (volt, V) (ampere, A) 1 watt is the transfer of 1J of energy in 1s.	255, 267 270 272 118, 272
HT	The higher the voltage of a supply, the greater the amount of energy transferred for a given amount of charge which flows. energy transferred = potential difference × charge (joule, J) (volt, V) (coulomb, C) The amount of electrical charge which flows is related to current and time as follows: charge = current × time (coulomb, C) (ampere, A) (second, s)	266-7

12.3	Mains Electricity	
FT & HT	The UK mains supply is about 230 volts. Mains electricity can kill if it is not used safely. 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. 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. 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. **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. 274-5
	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.	274, 305
	Cells and batteries supply a current which always flows in the same direction. This is called a direct current (d.c.).	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.	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.	275
	Candidates should be able to, when provided with appropriate information explain how a circuit breaker works.	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.	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
12.4	**The Cost of Using Electrical Appliances**	
FT & HT	Much of the energy translated in homes and industry is electrical energy. This is because electrical energy is readily transferred as: • Heat (thermal energy); • Light; • Sound; • Movement (kinetic energy). **Candidates should be able**: • To specify the energy transfers everyday electrical devices are designed to bring about; • To give examples of everyday electrical devices designed to bring about particular energy transfers.	9-10, 112, 270
	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). 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	272-3, 119
	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)	119, 273

12.5	Electrical Charge	
FT & HT	When certain different insulating materials are rubbed against each other they become electrically charged. Electrically charged objects attract small objects placed near to them.	p. 247-8
	When two electrically charged objects are brought close together, they exert a force on each other. Two charged objects may either pull towards each other (attract) or push each other away (repel).	
	These observations can be explained in terms of two types of charge called positive (+) and negative (–). Two objects which have the same type of charge repel. Two objects which have different types of charge attract.	
	When two different materials are rubbed against each other, electrons, which have a negative charge, are rubbed off one material on to the other. The material which gains electrons becomes negatively charged; the material which loses electrons is left with an equal positive charge.	
	Electrostatic charges can be useful in everyday life.	
	For example, in a photocopier: • A copying plate is electrically charged; • An image of the page you want to copy is projected on to the plate; • Where light falls on the plate, the electrical charge leaks away; • The parts of the plate that are still charged attract bits of black powder; • The black powder is transferred from the plate to a sheet of paper; • The paper is heated to make the black powder stick; • There is now a copy of the original page	252, 321, worksheet
	When printing with an inkjet printer: • Tiny droplets of ink are electrically charged as they are forced out of a very fine nozzle; • The droplets pass between metal plates across which a voltage can be applied so that one plate is negative and the other plate is positive; • The charged droplets of ink are attracted towards the plate with the opposite charge and away from the plate with the same charge. This means that they are deflected as they pass between the plates; • The size and direction of the voltage applied across the plates is controlled so that each droplet in turn is deflected to a particular place on the paper; • Each droplet of ink produces a tiny dot on the paper and many such dots, each in exactly the right place, produce the printed characters.	321, worksheet
	A charged conductor can be discharged by connecting it to earth with a conductor.	
	Candidates should be able, when provided with information about a situation in which static electricity is dangerous, to explain why it is dangerous and how precautions can be taken to ensure that the electrostatic charge is discharged safely.	249 – 252
	In solid conductors, an electric current is a flow of electrons.	255
	When some chemical compounds are melted or dissolved in water they conduct electricity. These compounds are made up of electrically charged particles called ions. The current is due to negatively charged ions moving to the positive terminal (electrode) and the positively charged ions moving to the negative electrode. Simpler substances are released at the terminals (electrodes). This process is called electrolysis.	277

HT	The greater the charge on an isolated object, the greater the voltage (potential difference) between the object and earth. If the voltage becomes high enough, a spark may jump across the gap between the object and any earthed conductor which is brought near it. Metals are good conductors of electricity because some of the electrons from their atoms can move freely throughout the metal structure. During electrolysis the mass and / or volume of the substance deposited or released at the electrode increases in proportion to: • The current; • The time for which the current flows.	p. 251 255 278

12.6	**Representing and Measuring Motion**	
KS3	For an object moving at a steady speed in a straight line, the distance it travels and the time it takes are related as shown: speed (metre/second, m/s) = $\frac{\text{distance travelled (metre, m)}}{\text{time taken (second, s)}}$	p. 130
FT & HT	If an object moves in a straight line, how far it is from a certain point can be represented by a **distance-time graph**. **Candidates should be able** to construct and recognise the shape of a distance-time graph when a body is: • Stationary; • Moving with a steady speed. The steeper the slope of the graph, the greater the speed it represents.	134
	The velocity of an object is its speed in a given direction. **Velocity-time graphs** can represent the motion of a body. **Candidates should be able** to recognise the shape of the velocity-time graph when a body is moving with: • Constant velocity; • Constant acceleration. The steeper the slope of the graph, the greater the acceleration it represents. The acceleration of an object is the rate at which its velocity changes. For objects moving in a straight line with a steady acceleration, the acceleration, the change in velocity and the time taken for the change are related as shown: acceleration (metre/second squared, m/s^2) = $\frac{\text{change in velocity (metre/second m/s)}}{\text{time taken for change (second, s)}}$	130-3
HT	**Candidates should be able** to calculate the gradient of a distance-time graph.	134, 380
	The gradient of a velocity-time graph represents acceleration. The area under a velocity-time graph represents the distance travelled. **Candidates should be able** to calculate: • The gradient of a velocity-time graph and interpret this as acceleration; • The area under a velocity-time graph; for an object moving with constant acceleration.	132-3

12.7	Forces and Acceleration	
KS3	The forces acting on an object may cancel each other out (balance). When an object rests on a surface: • The weight of the object exerts a downward force on the surface; • The surface exerts an upwards force on the object; • The sizes of the two forces are the same.	p. 95
FT & HT	Whenever two bodies interact, the forces they exert on each other are equal and opposite.	94-5
	Balanced forces will have no effect on the movement of an object: it will remain stationary or, if it is already moving it will continue to move at the same speed and in the same direction.	77
	If the forces acting on an object do not cancel each other out, an unbalanced force will act on the object. This unbalanced force will affect the movement of the object. How the movement is affected depends on the direction and the size of the unbalanced force: • A stationary object will start to move in the direction of the unbalanced force; • An object moving in the direction of the force will speed up; • An object moving in the opposite direction to the force will slow down; • The greater the size of the unbalanced force, the faster the object will speed up or slow down. When an unbalanced force acts on an object in a particular direction its speed changes (it accelerates) in that direction. The greater the force, the greater the acceleration. The bigger the mass of an object, the greater the force needed to give the object a particular acceleration.	96, 138
HT	One newton is the force needed to give a mass of one kilogram an acceleration of one metre per second squared. Force, mass and acceleration are related as shown: Force = mass × acceleration (newton, N) (kilogram, kg) (metre/second squared, m/s^2)	138-9

12.8	Frictional Forces and Non-uniform Motion	
KS3	A force of friction acts: • When an object moves through air or water; • When solid surfaces slide (or tend to slide) across each other. The direction of this force of friction is always opposite to the direction in which the object or surface is moving. Friction causes objects to heat up and to wear away at their surfaces. The friction between solid surfaces is used in brakes which slow down and stop moving vehicles.	p. 92-3
FT & HT	The greater the speed of a vehicle: • The greater the braking force needed to stop it in a certain distance; • The greater the distance needed to stop it with a certain braking force. If too great a braking force is applied, friction between a vehicle's tyres and the road surface may not be great enough to prevent skidding. The stopping distance of a vehicle depends on: • The distance the vehicle travels during the driver's reaction time; • The distance the vehicle travels under the braking force. The overall stopping distance is greater if: • The vehicle is initially travelling faster; • The driver's reactions are slower (due to tiredness, drugs, alcohol); • There are adverse weather conditions (wet/icy roads, poor visibility); • The vehicle is poorly maintained (e.g. worn brakes/tyres). The faster an object moves through as gas or a liquid (a fluid) the greater the force of friction which acts on it. When a body falls: • Initially it accelerates due to the force of gravity; • Frictional forces increase until they balance the gravitational forces; • The resultant force eventually reaches zero and the body falls at its terminal velocity. When a vehicle has a steady speed the frictional forces balance the driving force.	98 99, 136

Waves		page numbers in **Physics for You**
12.9	**Characteristics of Waves**	
KS3	Sounds bounce back (reflect) from hard surfaces. Echoes are sound reflections. 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. 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. 230 185 192-3, 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 measure in hertz (Hz). Wave speed, wavelength and frequency are related as follows: wave speed = frequency × wavelength (metre/second, m/s) (hertz, Hz) (metre, m) Waves transfer energy from a source to other places without any matter being transferred. 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 the cross the boundary between two different substances 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).	174-6, 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. 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. When light travels down an optical fibre, all the light may stay inside the fibre until it emerges from the other end. This is because light travels down optical fibres by repeated total internal reflection. **Candidates should be able** to describe, using a suitable diagram, one other use of 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. 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.	174
	Sound waves travel through solids, liquids and gases as longitudinal waves.	229
	Light waves are transverse waves and can travel through a vacuum, i.e. they do not need a medium.	179, 219
	When a wave moves through a gap, or past an obstacle, it spreads out from the edges. This is called diffraction. Electromagnetic radiation and sound are also diffracted which supports the idea that they travel as waves. Because of diffraction: • Sounds can sometimes be heard in the shadow of buildings; • Radio signals can sometimes be received in the shadow of hills. Waves having a longer wavelength are more strongly diffracted.	177, 240

12.10 The Electromagnetic Spectrum		
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	218-9
	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.	226-7, 335
	The uses and effects of different types of radiation depend on these and other properties.	218-9
	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.	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 home networks. Microwave radiation, with wavelengths strongly absorbed by water molecules is used for cooking.	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.	227, 320, 50, 270
	Light is not only used for seeing but can also be sent along optical fibres, for example in endoscopes used by doctors to see inside patients' bodies.	200, 333
	More information can be carried than by sending electrical signals through cables of the same diameter. There is also less weakening of the signal in optical fibres.	

FT & HT	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.	218, 220, 226, 318
	Gamma radiation is used to: • Kill harmful bacteria in food; • Sterilise surgical instruments; • Kill cancer cells.	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 does 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.	227, 220, 356, 360, worksheet
	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. Information can also be converted into light or infrared signals and sent along optical fibres.	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 has only two states, on or off. Signals of this type are called digital signals.	312, 332, worksheet
	The advantages of digital signals are: • Their higher quality – the signals do not change their information during the transmission process. • Their information carrying capacity – more information can be sent in a given time via a given cable, optical fibre or carrier wave than with analogue signals.	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
12.11	**Sound and Ultrasound**	
KS3	Sounds are produced when objects vibrate. The greater the size (amplitude) of vibrations the louder the sound. The number of complete vibrations each second is called the frequency (hertz, Hz). The higher the frequency of a sound the higher the pitch.	228, 234
FT & HT	**Candidates should be able** to compare the amplitudes and frequencies of sounds from diagrams of oscilloscope traces. 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 for quality control; • In medicine for pre-natal scanning.	234-5 230, 240-1
HT	Ultrasonic waves are partly reflected when the 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.	240-1

<table>
<tr><th>12.12</th><th>Seismic Waves</th><th></th></tr>
<tr><td>FT & HT</td><td>Our knowledge of the structure of the Earth comes mainly from studying how the shockwaves from earthquakes (seismic waves) travel through it. These waves are detected using seismographs.

The Earth is nearly spherical and has a layered structure comprising:
• A thin crust;
• A mantle extending almost halfway to the Earth's centre, which has all the properties of a solid except that it can flow very slowly;
• A core, with just over half of the Earth's radius, made of nickel and iron the outer part of which is liquid and the inner part of which is solid.

The overall density of the Earth is much greater than the mean densities of the rocks which form the crust. This indicates that the interior of the Earth is made of material different from, and denser than, than of the crust.</td><td>p. 154</td></tr>
<tr><td>HT</td><td>Earthquakes produce surface waves that can cause earthquake damage and two types of waves that can travel through the Earth:
• Faster travelling P waves, which are longitudinal and travel through liquids as well as solids;
• Slower travelling S waves, which are transverse and travel only through solids.

The speed of both types of wave increases with depth through the mantle. The waves travel in curved paths as their speed changes gradually through a material. When the state of the transmitting medium changes abruptly, e.g. when moving from solid to liquid, the wave direction also changes abruptly.

It is by observing the path of these waves that scientists have been able to work out details of the Earth's layered structure:

Candidates should be able to interpret diagrams of the paths of seismic waves inside the Earth in terms of:
• The liquid nature of the Earth's outer core;
• Refraction at the boundaries between layers;
• Refraction due to change in speed within a particular layer.</td><td>154 - 155</td></tr>
</table>

12.13	Tectonics	
FT & HT	The edges of land masses (continents) which are separated by thousands of kilometres of ocean (e.g. the east coast of South America and the west coast of Africa): • Have shapes which fit quite closely; • Have similar patterns of rocks and fossils. This suggest that they were once part of a single land mass which has been split and been moved apart. The Earth's lithosphere (the crust and the upper part of the mantle) is cracked into a number of large pieces (tectonic plates) which are constantly moving at relative speeds of a few centimetres per year as a result of convection currents within the Earth's mantle driven by heat released by natural radioactive processes. Earthquakes and/or volcanic eruptions occur at the boundaries between tectonic plates. **Candidates should be able**, when provided with information about the complex probable causes of earthquakes and volcanic eruptions and the difficulty of making measurements of many of the factors involved, to explain why scientists cannot yet accurately predict when they will occur. At one time it was believed that the major features of the Earth's surface were the result of the shrinking of the crust as the Earth cooled down following its formation. **Candidates should be able**, when provided with appropriate additional information, to explain why Wegener's theory of crustal movement (continental drift) was not generally accepted until more than 50 years after it was proposed.	p. 156 – 157
HT	Tectonic plates: • May slide past each other. This is happening along the Californian coast giving rise to earthquakes; • May move towards each other. As this happens, a thinner, denser oceanic plate can be driven down (subducted) beneath a thicker granitic continental plate where it partially melts. The continental crust is compressed, causing folding, faulting and metamorphism. Earthquakes are produced and magma may rise through the continental crust to form volcanoes. This is happening along the western side of South America (the Andes); • May move away from each other. This causes fractures which are filled by magma producing new, basaltic, oceanic crust. This is known as sea floor spreading and is happening along oceanic ridges, including the mid-Atlantic ridge. The iron-rich minerals in the magma record the direction of the Earth's magnetic field at the time when the rising magma solidified. Magnetic reversal patterns in oceanic crust occur in stripes parallel to oceanic ridges, matching the period reversals of the Earth's magnetic field and so supporting the concept of sea floor spreading.	156 - 157

The Earth and Beyond	page numbers in **Physics for You**	
12.14	**The Solar System**	
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.	p. 158
	The Earth moves round (orbits) the Sun once every year (just over 365 days).	
	The stars in the night sky stay in fixed patterns (called constellations).	164
	The planets which are visible to the naked eye look just like stars. They move very slowly across the constellations.	161
	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.	
	Satellites can be put into orbit around the Earth. They can be used: • To send information between places which are a long way apart on the Earth; • To monitor conditions on Earth, including the weather; • To observe the Universe without the Earth's atmosphere getting in the way.	168-9, 162
FT & HT	The orbits of the planets are slightly squashed circles (ellipses) with the Sun quite close to the centre.	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.	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.	162, 158-9, 78
	A smaller body with stay in orbit around a larger one because of the combination of its high speed and the force of gravity between the bodies.	162, 168
	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.	
	Communications satellites, including those used for television programmes, are usually put into an 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 only about 400 geostationary satellites or they would interfere with each other's signals.	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.	168

12.15	The Universe	
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.	163
	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 received signals from other species with technologies that are at least as advanced as our own. The search for extra-terrestrial intelligence (SETI), using radio telescrops to try to find meaningful signals in a narrow band of wavelengths (i.e. not just "noise"), has gone on form 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.	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 extends 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.	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 light 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.	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 suggest that the solar system was formed from the material produced when earliers stars exploded.	165
	Theories of the origin of the Universe have had 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 suggest 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').	166, 369. worksheets

Energy Resources and Energy Transfer		page numbers in **Physics for You**
12.16	**Thermal Energy Transfer**	
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.	p. 42-3
	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.	43-44
	Liquids and gases can flow and so can carry 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.	46-7
	Energy is continually being transferred to and from all objects by radiation, even through empty space (a vacuum).	48-50
FT & HT	Hot bodies 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.	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 rate 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.	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.	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.	46
	Thermal radiation is the transfer of energy by waves.	48, 219

12.17	Efficiency	
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
12.18	**Energy Resources**	
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 with not run out. Electricity is a very convenient and widely used energy source. It is generated in power station using some other energy resource.	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. 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. In some volcanic areas, 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. Electricity can be produced directly from the Sun's radiation using solar cells.	111 – 113, 12 – 13 12, 114

FT & HT	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. 114 – 115, 359, 12 – 13
	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.	114
	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).	113, 114
	Candidates should be able to compare and contrast the particular advantages and disadvantages of using different energy sources to generate electricity.	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
12.19	**Work, Power and Energy**	
FT & HT	Energy is measured in joules (J).	37, 107
	When a force moves an object, energy is transferred and work is done: work done = energy transferred	109
	The amount of work done, force and distance are related as shown: work done = force applied × distance moved in direction of force (joule, J) (newton, N) (metre, m)	107
	Power is a measure of how fast energy is transferred. The greater the power, the more energy is transferred in a given time. $\text{power (watt, W)} = \frac{\text{work done (joule, J)}}{\text{time taken (second, s)}}$	118-9
	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. On Earth the gravitational field strength is about 10 N/kg. weight = mass × gravitational field strength (newton, N) (kilogram, kg) (newton/kilogram, N/kg) change in gravitational potential energy = weight × change in vertical height (joule, J) (newton, N) (metre, m)	116
	Elastic potential energy is the energy stored in an elastic object when work is done on the object to change its shape.	8, 108
	Kinetic energy is the energy an object has because of its movement. An object has more kinetic energy: • the greater its mass; • the greater its speed. Kinetic energy = ½ × mass × speed^2 (joule, J) (kilogram, kg) [$(\text{metre/second})^2$, $(\text{m/s})^2$]	117

12.20	Electromagnetic Forces	
KS3	A magnet exerts a force on any piece of magnetic material including iron and steel, or another magnet which is placed near it. (There is a magnetic field around the magnet). A coil of wire acts like a bar magnet when an electric current flows through it. One end becomes a north-seeking pole and the other end a south-seeking pole. This is called an electromagnet. Reversing the current in an electromagnet reverses the poles of the electromagnetic.	p. 284, 287 293
FT & HT	When a wire carrying an electric current is placed in a magnetic field, it may experience a force. The size of the force can be increased by: • Increasing the strength of the magnetic field; • Increasing the size of the current. The direction of the force is reversed if either the direction of the current or the direction of the magnetic field is reversed. **Candidates should be able** – when provided with diagrams and/or other appropriate information – to explain how electromagnetic effects are used in simple d.c. motors and circuit breakers. *[Details of the split ring, for reversing the current to a d.c. motor each half turn, will not be required.]*	296 – 299

continued . . .

12.21	Electromagnetic Induction	
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. 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 customers. 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. 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. 303 308-9 304-6
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. A changing magnetic field will also produce an induced voltage in a coil. This is how a transformer works. The higher the voltage, the smaller the current needed to transmit energy at the same rate. Less energy is wasted by heating up the power lines. A transformer consists of two separate coils wound around an iron core. When an alternating voltage is applied across one coil (the primary) an alternating voltage is produced across the other coil (secondary). The voltages across the primary and secondary coils of a transformer are related as shown: $\frac{\text{Voltage across primary (volt, V)}}{\text{Voltage across secondary (volt,V)}} = \frac{\text{number of turns on primary}}{\text{number of turns on secondary}}$	304 307-9

Radioactivity		page numbers in **Physics for You**
12.22	**Types, Properties And Uses of Radioactivity**	
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.	360
	When radiation from radioactive materials collides with neutral atoms or molecules these may become charged (ionised).	348
	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.	356-7
	Higher doses of ionising radiation can kill cells; they are used to kill cancer cells and harmful microorganisms.	
	As radiation passes through a material it can be absorbed. The greater the thickness of a material the greater the absorption. The absorption of radiation can be used to monitor/control the thickness of materials.	351, 357
	When sources of radiation are outside the body: • Beta and gamma radiation are the most dangerous because they can reach the cells of organs and may be absorbed by them; • Alpha radiation is least dangerous because it is unlikely to reach living cells.	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. The badge is a small packet containing photographic film. The more radiation a worker has been exposed to, the darker the film is when it has been developed.	
	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.	356
	The half-life of a radioactive substance: • Is the time it takes for the number of parent atoms in a sample to halve; • Is the time it takes for the count rate from the original substance to fall to half its initial level.	354
HT	**Candidates should be able** to evaluate the appropriateness of radioactive sources for particular uses, including as tracers, in terms of: • The type(s) of radiation emitted; • Their half-lives.	356-7, 362

12.23	Atomic Structure and Nuclear Fission	
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.	352, 368
	The relative masses of protons, neutrons and electrons and their relative electric charges are as shown:	352-3

	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.	
	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.	355
	The older a particular radioactive material, the less radiation it emits. This idea can be used to date materials, including rocks.	354, 357

HT	Alpha radiation consists of helium nuclei, particles made up of two protons and two neutrons. 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 a very short wavelength electromagnetic radiation.	218
	Nuclear reactors use a process called nuclear fission. When an atom with a very large nucleus is bombarded with neutrons: • The nucleus splits into two smaller nuclei; • Further neutrons are released which may cause further nuclear fission resulting in a chain reaction; • The new atoms which are formed are themselves radioactive. *[Details of nuclear reactors are not required.]* The energy released by an atom during radioactive disintegration or nuclear fission is very large compared to the energy released when a chemical bond is made between two atoms.	358
	During one half-life, half of the radioactive atoms initially present in a sample decay. This idea can be used to date materials. Uranium isotopes, which have a very long half-life, decay via a series of relatively short-lived radioisotopes to produce stable isotopes of lead. The relative proportions of uranium and lead isotopes in a sample of igneous rock can, therefore, be used to date the rock. The proportions of the radioisotope potassium-40 and its stable decay product argon can also be used to date igneous rocks from which the gaseous argon has been unable to escape. **Candidates should be able** to make such calculations when provided with appropriate data.	354, 362, worksheet

End of syllabus content