SUBJECT CRITERIA
FOR
GCSE IN APPLIED SCIENCE

1. INTRODUCTION

1.1 GCSE in Applied Science subject criteria set out the knowledge, understanding, skills and schemes of assessment common to all GCSE in Applied Science specifications in a given subject/sector. They provide the framework within which the awarding body creates the detail of the specification. Subject criteria are intended to help ensure consistent and comparable standards in the same subject area across awarding bodies and to help further and higher education institutions and employers know what has been studied and assessed.

2. AIMS

2.1 GCSE in Applied Science specifications should enable students to develop a broad knowledge and understanding of the science sector. They should prepare students for further study on an applied course in science or in a science-related subject, or prepare for employment or further training in the industry. They should encourage students to develop:

- an understanding of science and how it is used to the benefit of society
- an awareness of how institutions and companies use science in a wide range of essential functions
- the ability to apply knowledge and skills to solving scientific problems in a variety of vocational contexts
- the experimental and laboratory techniques used by scientists in a range of vocational contexts, taking appropriate consideration of health and safety issues
- the skills to use scientific instruments and equipment in a competent fashion and with confidence
- an interest in science through studying science in a vocational context.

3. SPECIFICATION CONTENT

3.1 The specification must consist of three units, titled as follows:

- Unit 1: Developing scientific skills
- Unit 2: Science for the needs of society
- Unit 3: Science at work.

3.2 The GCSE in Applied Science is about the science used by people in a wide variety of jobs. It is also about management of time and resources, working alongside others, and effective and unambiguous communication between scientists and with other people who are not experts. Key skills are central to the effectiveness of the scientist.

The vocational nature of the GCSE in Applied Science should be reflected in specifications.

3.3 The skills, knowledge and understanding required for each unit are specified in *Annex A*.

4. ASSESSMENT OBJECTIVES (AOs)

4.1 The specification must require the candidates to demonstrate the following objectives in a range of vocationally-related contexts:

AO1: show knowledge and understanding of facts, principles, procedures and practical techniques, and the use made of science by individuals and organisations in modern society

AO2: apply the knowledge, skills and understanding by explaining and interpreting data in terms of scientific principles and concepts, interpreting data, carrying out calculations, and applying principles and concepts to unfamiliar situations

AO3: carry out practical tasks, and plan and carry out investigations, in which they choose safe and appropriate strategies; use appropriate equipment and procedures to gather, record and analyse relevant data; evaluate the data and methods and present their conclusions.

5. SCHEME OF ASSESSMENT

5.1 The weightings for the assessment objectives over the whole qualification are:

AO	Weighting
AO1:	25-35%
AO2:	25-35%
AO3:	30-40%

5.2 The weightings for the assessment objectives per unit are:

AO	Unit 1	Unit 2	Unit 3
AO1	10-20%	55-65%	10-20%
AO2	25-35%	25-35%	25-35%
AO3	45-55%	0-10%	45-55%

5.3 There must be three equally weighted units, with one method of assessment per unit, and a weighting of 33.3% external assessment and 66.6% internal assessment.

5.4 All specifications must include an **external assessment** weighting of 33.3%. The external written assessment should:

- assess candidates' knowledge and understanding across the unit content within appropriate vocational contexts
- be taken under timed, controlled conditions of not less than 1½ hours.

5.5 External assessments must be targeted at two tiers of GCSE in Applied Science grades: A* to D[1] and C to G. In each tier, the overall level of demand of the external assessment in the GCSE in Applied Science must be broadly comparable to that in existing GCSE Double and Single Award Science specifications, and that in existing Intermediate and Foundation GNVQ in Science specifications. (Please note that GNVQs will be withdrawn in three stages from 2005 to 2007, starting with titles with extremely low numbers of candidate entries. For science, AQA and Edexcel will be last assessed in Summer 2006, and OCR in Summer 2007.) In particular, procedures and expectations in the setting and marking of externally assessed items should be consistent, wherever appropriate, with current practice adopted by examiners in the external assessments in, and across, other GCSE Double and Single Award Science specifications, and Intermediate and Foundation GNVQ in Science specifications.

[1] A safety net for candidates entering for the higher tier in these specifications is provided. In these specifications, an allowed grade E is awarded on the higher tier. Candidates failing to achieve grade E are reported as Unclassified.

5.6 All specifications must include an **internal assessment** weighting of 66.6%. Teachers must be guided to produce/use internal assessments set within appropriate vocational contexts, which enable students to meet the assessment evidence requirements for units 1 and 3, as specified in *Annex A*.

5.7 All specifications must include guidance for teachers on how to derive grades G, E, D, B, and A* for internally assessed units. This guidance may take a similar form to the assessment evidence requirements for grades F, C and A, as presented to students as part of the unit content (see *Annex A*), or may be presented in some other comparable format.

6. KEY SKILLS

6.1 The specifications should provide opportunities for developing and generating evidence for assessing the Key Skills listed below. Where appropriate, these opportunities should be directly cross-referenced, at specified level(s), to the criteria listed in Part B of the Key Skills specifications.

- Communication
- Information Technology
- Application of Number
- Improving Own Learning and Performance
- Working With Others
- Problem Solving.

7. GRADE DESCRIPTIONS

7.1 The following grade descriptions indicate the levels of attainment characteristic of the given grade for the GCSE in Applied Science. They provide a general indication of the required standard at each specified grade. The descriptions should be interpreted in relation to the content and assessment evidence requirements outlined in the specification; they are not designed to define that content. The grade awarded will depend, in practice, upon the extent to which the candidate has met the assessment evidence requirements overall. Shortcomings in some aspects of the assessment may be balanced by better performances in others.

7.2 **Grade F** candidates demonstrate knowledge and understanding of some aspects of science and how it is used. They use and apply this knowledge and understanding in some specific contexts. They carry out research uncritically and in a simple manner, using a limited range of sources, information and data. They follow instructions in a standard procedure one step at a time, with guidance. They show some awareness of safety issues and make simple decisions in assembling devices and carrying out investigations. They make straightforward observations and measurements and record them appropriately in tables and graphs. They demonstrate a basic understanding of the science linked to the contexts of their investigations when they report on their work. They offer simple explanations of their findings and simple evaluations of their investigations. They use basic communication skills, including a limited range of scientific and technical vocabulary.

7.3 **Grade C** candidates demonstrate knowledge and understanding of a range of aspects of science and how it is used. They use and apply knowledge and understanding in some general contexts. They carry out research using a range of sources, information and data to find out about issues or topics and indicate why these were chosen. They follow standard procedures, with some guidance for the more complex tasks. They select suitable components and equipment and use these correctly and safely. They make careful and accurate measurements and observations, and recognise when it is necessary to repeat them to improve reliability. They record their results accurately in tables and graphs, using lines of best fit where appropriate. They perform straightforward calculations accurately. They demonstrate a consistent understanding of the science linked to the contexts of their investigative work, and when they draw conclusions from the evidence obtained. They evaluate how strongly their evidence supports the conclusions. They communicate clearly, using appropriate scientific and technical vocabulary in a range of contexts.

7.4 **Grade A** candidates demonstrate a wide and detailed knowledge and understanding of science and how it is used. They use detailed scientific knowledge and understanding to solve problems in a range of contexts. They carry out research by identifying and using appropriate sources, information and data for a particular purpose. They follow standard procedures for all tasks with little guidance. They select and use a wide range of components and equipment effectively and with understanding of their functions. They are able to interpret information and data presented in a variety of forms and can critically evaluate its relevance in relation to the issues presented. They make careful and accurate measurements and observations consistently, repeating measurements and observations when necessary, and recording and presenting data in an appropriate form. They carry out a range of complex calculations accurately. They demonstrate a full and detailed understanding of the science linked to the contexts of their investigative work in their reports, and when giving their conclusions. They evaluate how strongly their evidence supports the conclusions and they identify any shortcomings in the evidence. They suggest improvements to the methods used that would enable more reliable evidence to be collected. They use scientific and technical vocabulary with fluency, clearly demonstrating communication skills appropriate to a range of vocational settings.

ANNEX A

COMMON UNITS FOR GCSE IN APPLIED SCIENCE

UNIT 1: DEVELOPING SCIENTIFIC SKILLS

About this unit

In this unit you will learn about the skills needed to carry out experiments and work in the laboratory. You will learn about:

- working safely in science
- carrying out practical tasks, involving the following skills:
  - following standard procedures
  - handling scientific equipment and materials
  - recording and analysing scientific data
- and in the areas of:
  - investigating living organisms
  - chemical analysis
  - investigating materials.

Scientists classify things (eg materials and organisms), obtain or make things (eg making chemical products, building electronic devices, obtaining products from organisms), and monitor and control changes (eg chemical reactions, the performance of machines, or the activities of organisms). In their work, they use a wide range of materials and scientific equipment. They need to be able to work with scientific equipment, apparatus and materials correctly.

Scientists carry out experiments, making measurements and observations, either in a laboratory or 'in the field'. They use a wide range of materials and equipment. Often they follow standard procedures. At other times, scientists have to devise procedures for themselves. Sometimes the unexpected happens, and they have to deal with this.

The unit also links with units from other GCSE in Applied Subjects, such as *Engineering, Manufacturing* and *Health and Social Care*, and with some NVQs, such as, *Laboratory & Associated Technical Activities* and *Laboratory Technicians: Working in Education*. Level 2 NVQs are required as part of a Foundation Modern Apprenticeship.

This unit is assessed through portfolio work. Your overall result for the unit will be a grade on the scale G to A*.

What you need to learn

Working safely in science

Scientific work can be dangerous, yet accidents among scientists are rare. This is because scientists are always aware of the hazards they deal with and of the need to work safely. You must be able to work safely and prevent accidents in the laboratory or wherever you are doing your scientific work. You must know what to do if an accident happens.

Hazards and risks

Potential hazards in scientific workplaces include:

- careless behaviour
- not using equipment properly
- not using protective and safety equipment
- not following correct procedures
- the possible risks that may arise from:
  - chemical substances classified as toxic, flammable, corrosive, oxidising and irritant
  - microorganisms
  - utilities (gas and electricity).

It is important that you are aware that workplaces are governed by health and safety regulations.

You need to be able to:
- identify hazard warning signs
- identify biological, chemical and physical hazards, including radioactive substances, and their associated risks
- follow health and safety procedures.

You need to be aware of the need to:
- carry out health and safety checks in the workplace
- carry out risk assessments for activities performed in the workplace.

You need to find out:
- what can be done to prevent accidents from hazards in a scientific workplace
- which emergency procedures to follow if an accident from these hazards happens
- about the safety measures employed for handling radioactive materials and the procedures adopted to ensure that people who work with radioactive materials are not exposed to unacceptable risk
- about how unwanted or waste materials, including radioactive substances, are disposed of safely.

First aid
Common injuries in laboratories are heat burns and scalds, chemical burns, injury from breathing in fumes or swallowing chemicals, electric shocks, cuts and damage to the eyes from particles or chemicals. For each of these injuries, you need to know:
- the basic first aid to give
- the situations in which it would be dangerous to give first aid.

You need to find out:
- why it is useful to have a first aid qualification
- the names of organisations which provide training for first aid qualifications and how to contact these organisations.

Fire prevention
In places of work, including your school or college, there are fire regulations. These regulations are to ensure that the numbers of casualties in fires are kept to a minimum. Although many people are killed or injured in fires each year, the vast majority occur in the home and only 6% of deaths and 10% of injuries occur in the workplace (*Fire Statistics United Kingdom 1999: L. Watson, J. Gamble and R. Schofield*). However, continued vigilance is essential if these figures are to be maintained or improved.

You need to know:
- what must be done if you hear a fire alarm or smoke alarm
- what must be done if you find a fire
- how fire doors function
- why different types of fire extinguishers (water, carbon dioxide, dry powder, foam, a fire-blanket) are used on different types of fires
- about the use of automatic sprinkler systems.

Carrying out practical tasks

You will perform a range of practical tasks to develop the skill areas detailed below.

Following standard procedures
Standard procedures provide explicit instructions on how to carry out an experiment. They are often called ‘protocols’ or ‘standard operating procedures’. Their use means that when you see the results, you know exactly how the observations and measurements were made, no matter who did it or where it was done. For these reasons, standard procedures are very important in the scientific workplace. The procedure may be to carry out measurements, to prepare and purify a compound, or to monitor a change. Standard procedures may be agreed within a company, or nationally, or internationally.

When following a standard procedure, you need to be able to:
- read the procedure, and check to see if there is anything you do not understand
- carry out a health and safety check of your working area

- carry out a risk assessment for the activity you are doing
- set out your work area and collect together the equipment and materials you need
- follow the instructions one step at a time
- make accurate observations or measurements, selecting instruments which give the appropriate precision
- identify possible sources of error and repeat observations and measurements, when necessary, to improve reliability.

Handling scientific equipment and materials

There are certain practical skills that scientists carry out everyday and practising them will help to improve your accuracy and build your confidence. It will also help you to use other, less familiar equipment and materials. You will need to become familiar with general laboratory equipment and to carry out general operations carefully and accurately.

You need to know how to:

- recognise and use the standard laboratory equipment and glassware provided
- select and prepare equipment safely for use, including datalogging equipment where appropriate
- calibrate instruments, when necessary.

Recording and analysing scientific data

Standard procedures usually tell you how to obtain and record observations and measurements and what to do with them. However, you should know some basic methods for recording and presenting data and for carrying out calculations. ICT should be used, where appropriate, in this work. It is also important that you think about the results you obtain and are able to interpret them.

You need to be able to:

- present data in tables, bar charts, histograms, pictograms, pie charts, graphs and other visual images, as appropriate
- carry out simple numerical calculations
- analyse and interpret your results
- evaluate your investigation and suggest improvements.

Your practical tasks will be in the following broad areas of science:

Investigating living organisms

Scientists study living organisms to learn more about how they are composed, how they function and the way they behave. In their investigations of living organisms, they use standard equipment and techniques.

Microscopy

Investigating living organisms provides a range of challenges for scientists. Some of these challenges are to do with the small size of the organism. Some organisms are too small to be seen by the human eye. To solve these problems, scientists use microscopes. Microscopes are also used to study cells and tissues that make up living organisms.

You need to be able to:

- set up a light microscope ready to use, choosing a suitable objective lens for the task
- prepare samples for investigation, including making a temporary slide, using a staining technique.

Microorganisms

Scientists have developed the use of microorganisms to greatly benefit society. These uses include the production of bread, beer, wine, yoghurt and antibiotics. There are also microorganisms that cause harm to us, or to plants and animals, which are important to us. These therefore need to be handled carefully when used.

Microorganisms are found on our hands, on the laboratory bench, and almost everywhere. If scientists need to isolate a single type of microorganism, they need to make sure contamination from other microorganisms does not occur. They also need to avoid handling the organisms directly, as this may be dangerous. Using aseptic techniques ensures that both of these needs are fulfilled.

You need to:

- understand the importance of aseptic techniques and be able to use them to culture microorganisms and dispose of them safely
- investigate the effects of anti-microbial agents on the microorganisms
- set up a culture, which will produce a useful product, such as a food substance.

Chemical analysis

Analytical chemists need to be able to test for the presence of certain chemical compounds in substances and determine their concentration in solutions. This may be to find out what is present in a sample, or to test the purity of a substance, or to detect the presence of pollutants (eg in river water), banned substances (eg in athletes) or alcohol (eg those suspected of drinking and driving). Analysis is an important aspect of the work of the forensic scientist.

Qualitative analysis

The analytical chemist may simply need to find out which substances are present. This process is known as qualitative analysis.

You need to:

- separate mixtures by evaporation, distillation and chromatography to determine their composition
- carry out qualitative chemical tests for Na^+, K^+, Ca^{2+}, Cu^{2+}, Pb^{2+}, Fe^{3+}, Cl^-, SO_4^{2-}, CO_3^{2-} ions using reagents and/or flame tests
- draw conclusions from your results.

Quantitative analysis

Scientists may need to find out how much of a substance is present. This process is known as quantitative analysis.

You need to:

- prepare solutions of specified concentrations using the units: $g\ dm^{-3}$ and $mol\ dm^{-3}$
- carry out titrations
- carry out calculations to determine the concentration of a substance in solution.

Investigating materials

When scientists investigate the way in which materials behave, they may need to take measurements of certain physical properties. In deciding which material to use for a purpose, we may need to take account of more than one property. The size and shape of the material used may also be important.

Electrical properties

Electrical and electronic circuits use a wide range of materials. The different properties of materials are exploited to perform different functions.

You need to investigate how:

- the nature, length and thickness of materials influence electrical resistance
- current varies with voltage in a range of devices.

Other physical properties

Electrical properties are not the only properties a materials scientist has to consider. For example, if you were asked to select materials to build a house, some of the material properties you would consider would be thermal conductivity, density and strength.

You need to compare:

- the thermal conductivities of a range of materials
- the densities of a range of materials
- the strengths of materials of different size, shape and composition.

UNIT 2: SCIENCE FOR THE NEEDS OF SOCIETY

About this unit

In this unit you will learn about the materials and living organisms that scientists work with. You will learn about:

- living organisms
- obtaining useful chemicals
- materials for making things
- the importance of energy.

Scientists help to produce materials and goods for many commercial purposes. These include: food; medicines; health and hygiene products for humans and animals; clothing; building materials; household goods and appliances; vehicles for transport; and leisure equipment (eg sports equipment, musical instruments).

Both living and non-living materials are used as starting points in the manufacture of more useful products. To be effective, scientists need to understand the relationship between the properties of a material and its uses, and its composition and structure.

The unit also links with units from other GCSEs in applied subjects, such as *Engineering* and *Health and Social Care*, and with some NVQs, such as *Laboratory & Associated Technical Activities* and *Laboratory Technicians: Working in Education*. Level 2 NVQs are required as part of a Foundation Modern Apprenticeship.

This unit is assessed through an external assessment. Your overall result for the unit will be a grade on the scale G to A*. You will take one of two tiered (ie foundation and higher) papers covering the grades G to C and D to A* respectively. The topics to be tested exclusively on the higher tier paper have been underlined in this unit. The remaining material may be tested on either tiered paper.

What you need to learn

Living organisms

We obtain many useful materials from living organisms. In order to maximise the production of materials, plants, animals and microorganisms must be cared for and nurtured so that they can make healthy growth. Scientists may help to achieve this by understanding how living organisms function. The things that you learn in this unit will help you to carry out your investigation of a living organism in Unit 3, Science at Work.

Most living organisms are made up of building blocks called cells.

You need to be able to:

- identify useful products that can be made from living things
- describe living organisms as being made up of chemical compounds, and the cell as the common feature of all organisms
- describe the similarities and differences between plant and animal cells
- explain how substances enter and leave cells by diffusion and osmosis
- <u>describe how cells divide by mitosis during growth</u>
- <u>describe how cells divide by meiosis to produce gametes</u>.

Agriculture and horticulture are concerned mainly with the production of food. However, other products include wool, silk, cotton and leather. In addition, pharmaceutical products and dyes may be made from substances extracted from organisms. Two contrasting approaches to farming are *intensive farming* and *organic farming*.

You need to:
- know that wool, silk, cotton, leather, pharmaceutical products and dyes are all obtained from living organisms
- understand how plants make food by photosynthesis, and know that plants use the process of respiration to release energy
- know that plants need, among other things, the minerals nitrates, phosphates, potassium and magnesium, which they obtain from soil, for healthy growth
- know that nitrates are required for proteins, which are needed for cell growth, and that magnesium is required for chlorophyll
- know the mechanism of monohybrid inheritance where there are dominant and recessive alleles
- understand that selective breeding involves selecting the parents with desired traits, crossing them, selecting from their offspring, and then repeating the process over several generations
- understand that genetic engineering involves the transfer of 'foreign' genes into the cells of animals or plants at an early stage in their development so that they develop with desired characteristics
- describe how intensive farming increases crop yields by using artificial fertilisers, pesticides, herbicides and fungicides, and increases meat production by using controlled environments
- describe how organic farming uses the alternative methods of natural fertilisers, natural pesticides and mechanical elimination of weeds in crop production, and keeps animals under more natural conditions
- compare the advantages and disadvantages of each type of farming.

Microorganisms, such as bacteria, yeasts and other fungi, play an important part in the production of some foods, beverages and medicines. Diseases may be caused by bacteria, fungi or viruses and may affect living organisms.

You need to:
- describe the use of bacteria, yeasts and other fungi in food (yoghurt, bread, beer, wine, protein) and medicine (antibiotics) production
- know that diseases may be caused by microorganisms and name some examples (measles, mumps, rubella, polio, tuberculosis (TB), foot and mouth, athlete's foot and skin infections due to Staphylococcus aureus)
- give examples of a range of methods of protecting against infection by harmful microorganisms in food production (personal hygiene, sterilisation, disinfectants, antiseptics)
- understand about the use of immunisation to protect humans and other animals from infection by specific microorganisms (MMR, TB, foot and mouth, polio)
- know that antibiotics may kill some bacteria, but not viruses.

Knowledge of first aid is important in the workplace and it is a vital part of many jobs in the emergency services. To understand how the first aid procedures are effective, you need to know about the workings of the human body.

You need to know:
- the structure of the human circulatory system, including the function of the heart, and the composition and functions of the blood
- how the structure of the thorax enables ventilation of the lungs
- that respiration may be aerobic or anaerobic depending on the availability of oxygen, and that 'oxygen debt' may occur in muscles during vigorous exercise
- how humans maintain a constant body temperature (by sweating and changing the diameter of capillaries)
- how the blood glucose levels are controlled by the hormone insulin.

Obtaining useful chemicals

Scientists work to obtain useful chemicals from natural raw materials. The vast majority of chemical substances are found in the earth as compounds. A very small number exist as elements, in other words, not combined chemically with other elements (eg gold, some sulphur, some copper). Some deposits consist mainly of one compound (eg limestone, marble), while others consist of mixtures of compounds (eg granite, rock salt, crude oil). Some substances are used as they are (eg limestone and marble for building), some are separated from their natural mixture before use (eg salt from rock salt, the fractional distillation of crude oil), and some are used as the starting material to make other useful substances (eg metals are extracted from their ores).

You need to be able to:

- classify materials as elements (metals and non-metals), compounds or mixtures, using information provided or obtained by experiment
- give examples of substances used straight from the ground (gold, sulphur, limestone, marble)
- describe how some substances are separated before use (salt from rock salt, fractional distillation of crude oil)
- describe how a metal may be made from its oxide by reduction using carbon (iron from iron oxide and lead from lead oxide).

Chemicals are often classified as *organic* (ie those based on the element carbon and mainly originating from living things), for example, petroleum products, pharmaceuticals, polymers, or *inorganic* (ie those containing elements other than carbon and mainly originating from non-living things), for example, metals, ceramics, and fertilisers. Those manufactured on a large scale are known as *bulk chemicals*, for example, ammonia, sulphuric acid and polyethene, while those produced on a small scale are referred to as *fine* or *speciality chemicals*, for example, medicines, dyes, pigments.

You need to be able to:

- classify chemical compounds as inorganic or organic, when provided with their formulae
- identify examples of bulk chemicals (ammonia, sulphuric acid and polyethene) and of fine/speciality chemicals (medicines, dyes, pigments).

Many materials that are used in society consist of one substance finely dispersed in another. The substance dispersed may be solid, liquid or gas and the medium in which it is dispersed may also be solid, liquid or gas. The different types of mixture are solutions, suspensions, gels, emulsions, foams and aerosols. Examples of these mixtures are cola, cosmetics, paints, toothpaste, hair gel, medicines, glues, foods and food mixes, jewels, stained glass, deodorant sprays and shaving cream.

You need to be able to:

- explain the composition of a solution, suspension, gel, emulsion, foam and aerosol
- give an example of each type of mixture and explain why each is useful.

The structure of the atom helps to predict the way in which atoms behave. Chemical compounds are held together by bonds, either ionic or covalent. The bonding in a compound affects its physical and chemical properties. Chemical symbols are the international shorthand notation for elements used by scientists. These symbols are put together in formulae to represent the atoms that are joined together in compounds.

You need to:

- describe the structure of the atom in terms of *protons*, *neutrons* and *electrons*
- <u>have a basic understanding of ionic bonding as involving transfer of electrons (sodium chloride, magnesium oxide) and of covalent bonding as involving sharing of electrons (hydrogen chloride, water)</u>
- <u>know that energy is required to break chemical bonds and is given out when new bonds are formed</u>
- know that the meanings of the terms *exothermic reaction* and *endothermic reaction*
- know the chemical symbols for 20 common elements (see *Annex B*)
- name some simple compounds, when provided with their formulae, and state the formula, when provided with the name of the compound (see *Annex B*)
- write symbol equations for chemical reactions in this unit.

Materials for making things

All of the products that we use in our everyday lives (for example, for buildings, clothing, trainers, mobile phones, surfboards, household goods and leisure products) are constructed from materials. There are four important types of manufactured material: metals; polymers; ceramics; and composites. Scientists need to know how to match the properties of manufactured materials to their composition, structure and uses.

You need to be able to:

- classify materials as metals, polymers, ceramics and composites
- describe the uses of these materials and their advantages and disadvantages over naturally-occurring materials
- use sources of data (tables, graphs, CD-ROMs, databases, the internet) to find the physical properties of materials.

We can explain the differing properties of solid materials from their structure. The way their atoms are arranged, and the strength of the bonds joining them, determine their properties. Once scientists understand the links between properties and structure, they can design materials with the properties we want, for example, by mixing materials to make composites or by re-designing materials at the molecular level.

You need to:

- know the characteristic properties of metals (electrical conductivity, malleability and hardness) and be able to relate them to a simple model of metallic structure in terms of positive ions in a sea of electrons
- know the characteristic properties of polymers (flexibility, behaviour on heating, and hardness) and be able to relate them to a simple model of long chains entangled with one another, and sometimes cross-linked, and in terms of the side groups on the chains
- know the characteristic properties of ceramics and be able to relate them to simple models of giant structures to explain the effects of firing clay, and explain the properties of silicon oxide (sand) and aluminium oxide as giant molecular and ionic structures
- explain the properties of composites in terms of the properties of their components, including the effect of plasticisers on polymers
- explain the effect on the properties of a material of modifying it at a molecular level (cross-linking, side chains and chain length in polymers, and alloying in metals)
- select materials for a particular product when provided with a specification for the product.

The importance of energy

Energy resources

We need a source of energy to change things or make things happen. Fossil fuels are examples of primary energy resources. They are valuable because they are concentrated sources of energy, which is released by burning them in oxygen. There is, however, only a limited amount of fossil fuel in the Earth's crust. We can use nuclear fuels or renewable energy resources instead of fossil fuels.

You need to:

- know that fossil fuels (natural gas, oil, coal) are useful energy resources
- appreciate the problems of using fossil fuels (global warming, limited deposits)
- know that nuclear fuels and renewable energy resources (wind, solar, hydroelectric power, wave, tidal) may be used as alternatives to fossil fuels
- appreciate the problems of using nuclear fuels (problems of radioactive emissions, disposal of waste) and of using renewable sources (unreliability and possible effects on the environment).

In every process, energy is conserved. If one part of the system loses energy, another part of the system gains the same amount. Energy, however, becomes spread out and is then less useful. This 'lost' energy heats up the surroundings.

You need to be able to:

- describe how, in processes of energy transfer, energy is conserved but tends to spread out and become less useful.

Energy efficiency

Electricity is a means of transferring energy and is generated from a primary source. In most power stations, this is done by using a fuel to boil water, and then using the steam to turn a turbine, which rotates a generator to generate electricity. The efficiency of a power station (or an electrical appliance) is the percentage of the input energy that is converted to useful output energy. Generating electricity from a primary energy source is not usually a very efficient process. In other words, only a relatively small percentage of the energy in the primary source is converted to electricity. This results in electricity being relatively expensive.

You need to:

- know how electricity is generated from the burning of fossil fuels
- be aware of the relative costs of various energy resources (natural gas, mains electricity, batteries)
- explain why an appropriate source of energy is selected for a particular task (natural gas for general heating in the laboratory, electrical heating for flammable liquids, batteries when working in the field).

As energy is an expensive commodity, it is important that it is not wasted in industry. There are a number of measures, which may be taken to reduce energy costs. It is important to distinguish between the two uses of the term *energy efficiency*. One refers to the percentage conversion of energy from one form to another. The other refers to minimising the energy wasted through heat losses.

You need to:

- understand the meaning of the term *efficiency* when applied to simple energy transfers in mechanical and electrical appliances
- understand the advantages to the user, and to society, of making and using devices with high efficiency, by considering the benefits of low energy lamps compared to filament lamps
- know how heat losses by conduction, convection and radiation may be minimised
- explain the use of heat exchangers to enable waste energy to be captured and re-cycled
- compare the relative merits of water and anti-freeze in terms of their heat capacities and appreciate why both have a role to play as coolants.

Heating systems at work

Industry makes use of many electrical appliances. It is useful to be able to compare the cost of running them. The cost of running an appliance may be calculated using the idea of power, which is the rate of using energy.

You need to:

- recall and use the formula *power = (voltage* x *current)* to calculate the power of an electric circuit
- carry out simple calculations using the formula *power = energy/time* to calculate power in watts *(W)* and to calculate the energy usage in kilowatt-hour (*kWh)* for electrical appliances
- compare the costs of using different electrical appliances.

UNIT 3: SCIENCE AT WORK

About this unit

In this unit you will find out how science may be used to the great benefit of industry and society. You will learn about:

- science in the workplace
- making useful products
- instruments and machines
- monitoring living organisms.

Scientists often make use of information/data already obtained by other scientists. In this unit you will be carrying out tasks and investigations which may require you to use information/data from other sources.

You need to be able to:

- identify when you need more information/data
- identify likely sources of this information/data, including CD-ROMs and the internet
- select the information/data you need from these sources.

The unit also links with units from other GCSEs in applied subjects, such as *Engineering* and *Health and Social Care*, and with some NVQs, such as *Laboratory & Associated Technical Activities* and *Laboratory Technicians: Working in Education*. Level 2 NVQs are required as part of a Foundation Modern Apprenticeship.

This unit is assessed through portfolio work. Your overall result for the unit will be a grade on the scale G to A*.

What you need to learn

Science in the workplace

GCSE in Applied Science is the science and skills used by people in a wide variety of jobs. Those with a major job role in science may classify things, obtain or make things, and monitor and control changes. The more scientists know about the materials and equipment they work with, the more effective they can be. Scientists tackle problems, sometimes straightforward, often complex. This requires employing scientific skills and knowledge, coupled with imagination and curiosity. However, there are many people, who use science in their work, that we do not think of as scientists. For some it is a significant part of their work (eg nurses, engineers), whilst for others it plays a smaller part (eg photographers, chefs, gardeners).

You need to:

- identify local, national and international businesses and service providers that use science
- put their employees into one of three classes: major; significant; and small users of science
- find out where the organisations are located and why
- identify the types of scientific activity that are carried out and the job titles and qualifications of the people who perform them
- find out what skills scientists need in addition to their qualifications
- find out what careers are available in science and science-related areas.

Making useful products

Naturally-occurring materials such as metals, rocks and minerals can be made into more useful products by physical or chemical change. Industries have to make profits and need to maximise the amount of product produced from the starting materials. For this reason, scientists often have to work quantitatively - that is to accurately measure the amounts of chemical products and calculate the yield.

You need to:

- describe the factors that affect how quickly a reaction occurs
- explain the terms: *actual yield*; *theoretical yield*; and *percentage yield*
- explain that some processes are based on reversible reactions and that the conditions affect the yield of the products.

Useful products are made in industry by using many different types of chemical reaction.

You need to:

- prepare pure, dry products using three different types of chemical reaction
- explain the underlying chemistry involved in each type of reaction
- explain the industrial importance of each reaction.

For each preparation you carry out, you need to:

- know the type of reaction used
- measure the actual yield
- present the product in a suitable sample tube, with its name, date of preparation and relevant hazard warnings
- write balanced chemical equations to describe reactions, when provided with the formulae of reactants and products
- calculate the mass of product that could be obtained from a specified amount of reactant (theoretical yield)
- calculate the percentage yield of a reaction from the theoretical yield and actual mass of product obtained
- calculate the costs of making a given amount of product.

Instruments and machines

Scientists produce many machines and devices to measure, to observe, to move things, and to change materials for their use and for the use of the general public. A vast number of gadgets, often electrical or electronic, are used in our homes, at work or during our leisure time. All must be designed and built to do their job.

You need to:

- describe the use of electrical or electronic devices for:
    - sensing, monitoring and controlling electro-mechanical devices or machines
    - generating pulses of light that are transmitted through optical fibres in communication
    - controlling movement
    - monitoring and controlling physical conditions
- explain the functions of the following components in an electrical or electronic device:
    - power source
    - processor
    - input components
    - output components
- assemble and assess the effectiveness of one electrical or electronic device by:
    - selecting the components you need
    - safely assembling them to build the device
    - testing the assembled device under conditions of normal use
    - evaluating the performance of the device and commenting on its fitness for purpose
- identify a range of components in mechanical machines used in the workplace, explain how they work, and be able to:
    - measure the applied force and the force produced by the machine

- calculate the amount the machine multiplies force
- calculate the work done by the machine and its efficiency
- understand the advantages and disadvantages of friction in machines.

Monitoring living organisms

Organisms are adapted to survive within a range of conditions. When scientists grow organisms to obtain products from them, they must provide the organisms with the conditions most suitable for them, in order to maximise the amount of product obtained. This involves monitoring the activities/responses of the organism, and the conditions in which it is kept. Human organisms also operate best within a range of conditions. Athletes can improve their physical and mental performance by training, and maintaining their health by monitoring their own activities.

You need to investigate the growth and/or development and/or responses of an organism under controlled conditions. (It is important that you show appropriate care and consideration to living organisms during this activity and follow procedures which are ethical.) Possible investigations may be to:

- improve the yield of a plant/microorganism
- monitor the performance of a person in a physical or mental activity
- monitor the effects of changing the environment on the behaviour and/or growth and/or development of an organism.

You need to:

- select an organism for a particular purpose, which you can monitor
- produce a plan for your investigation that includes information about:
  - the type of organism
  - the purpose of your monitoring activity
  - how you have considered the welfare of the organism, where appropriate, and taken into account any ethical issues
  - the conditions you will be providing and controlling
  - how you intend to monitor the organism's growth/development/responses
  - a monitoring schedule for the duration of your investigation
  - how you will evaluate the results of your investigation
- carry out the investigation, recording relevant data
- analyse your results and explain what they show
- evaluate your investigation.

Annex B

You need to know how to measure and/or calculate the following quantities, using the correct units and their symbols:

Quantity	Units/symbols
mass	kilogram, kg; gram, g; milligram, mg; microgram, μg
length	kilometre, km; metre, m; centimetre, cm; millimetre, mm; micrometre, μm
volume	cubic metre, m^3; cubic decimetre, dm^3 (litre, l); cubic centimetre, cm^3 (millilitre, ml)
time	hour, h; minute, min; second, s
temperature	degrees Celsius, °C
chemical quantity	mole, mol
potential difference (voltage)	volt, V
current	ampere, A; milliampere, mA
resistance	ohm, Ω; kilohm, kΩ; megohm, MΩ
force	newton, N
energy/work	kilojoule, kJ; joule, J; kilowatt-hour, kWh
power	kilowatt, kW; watt, W
density	gram per cubic centimetre, $g\ m^{-3}$; kilogram per cubic metre, $kg\ m^{-3}$
concentration	gram per cubic decimetre, $g\ dm^{-3}$; mole per cubic decimetre, $mol\ dm^{-3}$

You need to know the chemical symbols for the following elements and be able to classify them as metals or non-metals:

Metals		Non-Metals	
Element	**Chemical Symbol**	**Element**	**Chemical Symbol**
Aluminium	Al	Bromine	Br
Barium	Ba	Carbon	C
Calcium	Ca	Chlorine	Cl
Iron	Fe	Fluorine	F
Lead	Pb	Hydrogen	H
Magnesium	Mg	Nitrogen	N
Potassium	K	Oxygen	O
Silver	Ag	Phosphorus	P
Sodium	Na	Silicon	Si
Zinc	Zn	Sulphur	S

You need to know the names and formulae of the following chemical compounds:

Compound	Formula	Compound	Formula
Ammonia	NH_3	Barium chloride	$BaCl_2$
Carbon dioxide	CO_2	Sodium chloride	$NaCl$
Methane	CH_4	Calcium carbonate	$CaCO_3$
Water	H_2O	Copper carbonate	$CuCO_3$
Hydrochloric acid	HCl	Sodium carbonate	Na_2CO_3
Sulphuric acid	H_2SO_4	Potassium nitrate	KNO_3
Calcium oxide	CaO	Silver nitrate	$AgNO_3$
Iron oxide	Fe_2O_3	Barium sulphate	$BaSO_4$
Lead oxide	PbO	Copper sulphate	$CuSO_4$
Sodium hydroxide	$NaOH$	Sodium sulphate	Na_2SO_4