Edexcel GCE

Edexcel Advanced Subsidiary GCE in Engineering (Single Award) (8731)

Edexcel Advanced GCE in Engineering (Single Award) (9731)

For first teaching in autumn 2005

August 2005

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Teacher's guide

Edexcel GCE in
Engineering

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Contents

Introduction

This teacher's guide accompanies the Edexcel GCE specification for Engineering and has been designed to help teachers prepare their students for first teaching in 2005.

This guide should be used in conjunction with the specification. There are sections to help with interpreting the unit content in terms of breadth and depth of delivery, possible learning activities and managing the assessment requirements.

This guide also contains exemplar students' work with commentary on the assessment for *Unit 2: The Role of the Engineer*, *Unit 4: Applied Engineering Systems* and *Unit 6: Applied Design, Planning and Prototyping* — see the *Exemplars and Commentary* section. The section provides further guidance on the application of the mark bands in the assessment criteria grids and provides a first indication of the standards expected.

Specification summary

The Edexcel Advanced Subsidiary and Advanced GCE in Engineering in one of a suite of nine General Certificates of Education in:

- Applied Art and Design
- Applied Business
- Applied ICT
- Engineering
- Health and Social Care
- Leisure Studies
- Media
- Performing Arts
- Travel and Tourism.

They are designed to provide a broad introduction to a vocational area in an applied context. They are available for first teaching as two-year courses from September 2005 and as one-year courses from September 2006. First awarding of Advanced Subsidiary qualifications is in summer 2006 and Advanced GCE qualifications in summer 2007.

Specification structure

Comp = Compulsory

Unit	Code	Title	Level	AS	GCE	Assessment mode	Assessment availability
1	6931	**Engineering Materials, Processes and Techniques** In this unit students will learn about the different materials available, the properties these materials possess and how they are used in engineered products and systems. They will also learn how materials can be connected together in different ways to make products and the different ways in which materials can be converted into finished products.	AS	Comp	Comp	**External** This unit will be assessed through an examination set and marked by Edexcel. There will be a 1.5 hour examination paper. The paper will be a question and answer booklet. Each examination paper will have one or more themes. A theme will be a common engineered product. The product(s) will provide opportunities for the students to answer questions about the choice and application of particular materials, joining techniques and processing methods in the context of a specific application. Students will not require actual knowledge of the product(s) to answer the questions in the examination. The product(s) will merely give a context in which they can demonstrate their subject knowledge and understanding.	June
2	6932	**The Role of the Engineer** In this unit students will investigate the role an engineer has played when they have been responsible for designing **and/or** manufacturing an engineered product **or** service. Students will learn how different factors like new technologies, time and cost constraints, legislation and standards, and health and safety legislation have to be considered and how they influence the decisions made by the engineer during the design **and/or** manufacture of an engineered product **or** service.	AS	Comp	Comp	**Internal** A portfolio, submitted on A4 paper containing evidence of work carried out by the student that fulfils all the requirements of the assessment evidence.	Jan/June

Unit	Code	Title	Level	AS	GCE	Assessment mode	Assessment availability
3	**6933**	**Principles of Design, Planning and Prototyping** In this unit students will learn how to develop a design solution to an engineering problem. They will learn how to read, interpret, understand and produce their own engineering drawings. They will manage their own project ensuring it is completed on time. They will follow a formal process to develop the final design solution and then they will test their solution by making a prototype. At the end of their project, students will give a presentation to their peers summarising the activities they have undertaken.	**AS**	**Comp**	**Comp**	**Internal** A portfolio, submitted on A4 paper apart from the engineering drawings (A3 paper) containing evidence of work carried out by the student that fulfils all the requirements of the assessment evidence. Photographic evidence of the final prototype and a copy of their presentation material(s) will also be included in their portfolio.	**Jan/June**
4	**6934**	**Applied Engineering Systems** In this unit students will look at different ways in which engineering techniques and principles are applied in systems and how a systems approach can be used to solve engineering problems. The range they will cover includes static structures, pneumatic systems and the electrical lighting and power systems used in homes, offices and public buildings. They will also look at elements of the electro-mechanical and electronic systems found in everyday life and the means by which they are controlled.	**A2**	**N/A**	**Comp**	**External** This unit will be based on a practical activities brief set by Edexcel each year. This brief will be available on the Edexcel website in September in each examination year. Students will have the opportunity to carry out relevant research based on the content of the brief before they carry out their practical activities. Evidence to be assessed against this unit must be produced under examination conditions and meet the requirements of the brief. Students **cannot** take any of their research materials into the examination with them. Working under examination conditions, students will work independently to complete all three practical activities to fulfil the requirements of this unit. They must complete all activities in 10 hours or less.	**June**

Unit	Code	Title	Level	AS	GCE	Assessment mode	Assessment availability
5	**6935**	**The Engineering Environment** In this unit students will investigate an engineered product different to the one chosen in *Unit 2: The Role of the Engineer*. As part of their investigation students will learn how different regulations, standards and documentation impact on the way engineers design, manufacture and maintain products. They will study how engineering products and activities effect the environment and how technical advances effect the way products and systems are design, manufactured and maintained. At the end of their investigation, they will make suggestions for improving the design or performance of the product.	**A2**	**N/A**	**Comp**	**Internal** A portfolio, submitted on A4 paper containing evidence of work carried out by the student that fulfils all the requirements of the assessment evidence.	**Jan/June**
6	**6936**	**Applied Design, Planning and Prototyping** In this unit students will apply their knowledge, understanding and skills gained whilst completing Units 1-5 to design, develop and manufacture a solution to a client brief. They will carry out research, develop a technical design specification, and develop alternative design ideas and develop these ideas into a final design solution. They will then plan for production, manufacture a prototype and evaluate their final outcome against the specification.	**A2**	**N/A**	**Comp**	**Internal** A portfolio, submitted on A4 paper apart from the engineering drawings (A3 paper) containing evidence of work carried out by the student that fulfils all the requirements of the assessment evidence. Photographic evidence of the final prototype will also be included in their portfolio.	**Jan/June**

Delivery

Planning a teaching programme

This section contains diagrammatic illustrations of possible ways the programme can be delivered.

Single Award

Example 1

Advanced Subsidiary
Three AS units

↓

Example 2

Advanced GCE
Three AS units **plus** three A2 units

Example 1: Advanced Subsidiary GCE Single Award

Three AS units

Unit title	Type of assessment	Date
Unit 1: Engineering Materials, Processes and Techniques	External	June
Unit 2: The Role of the Engineer	Internal	January/June
Unit 3: Principles of Design, Planning and Prototyping	Internal	January/June

This can be taught as a one-year programme with an externally assessed unit available in June.

Example 2: Advanced GCE Single Award

Three AS units plus three A2 units

Unit title	Type of assessment	Date
Unit 1: Engineering Materials, Processes and Techniques	External	June
Unit 2: The Role of the Engineer	Internal	January/June
Unit 3: Principles of Design, Planning and Prototyping	Internal	January/June
Unit 4: Applied Engineering Systems	External	June
Unit 5: The Engineering Environment	Internal	January/June
Unit 6: Applied Design, Planning and Prototyping	Internal	January/June

This can be taught as a fast track one-year programme or more commonly a two-year programme. The AS units are taught in the first year and the A2 units in the second year.

Planning, delivery and assessing

Planning

Allow 6–8 weeks minimum for the assignments to be completed, marked, revisited and submitted for final assessing. Both portfolio units must be completed by the year of certification.

Most teachers prefer to set the assignments after the unit has been taught and pupils have gained valuable information from visiting speakers, vocational visits etc.

In general the specification lends itself to producing a concise series of tasks for students to use. However *Unit 3: Principles of Design, Planning and Prototyping* and *Unit 6: Applied Design, Planning and Prototyping* require an integrated approach and require a project to be set which will enable all of the evidence required to assess the unit to be generated. In all cases the tasks match all of the assessment evidence.

It is important to stress the vocational links in the assignments. Care should be taken in using published tasks in case they are out of line with the assessment criteria.

Assignments should be set in a vocational context, eg investigations of actual companies.

Where possible, the setting up of tutorial sessions for students will help in monitoring the student's progress (this becomes harder as class sizes increase). This will be critical for *Units 3: Principles of Design, Planning and Prototyping* and *Unit 6: Applied Design, Planning and Prototyping*.

Delivery

Students need to be involved in the planning of their assignments — which tasks they are going to cover first, how to extend the assignments to cover the higher grades.

All students should be given a copy of the assessment evidence and assessment criteria. This should help with the planning, and to make students aware of the need to work as independently as possible to achieve the higher marks.

All students are entitled to initial guidance in planning their work.

A copy of the witness statement can be found in *Appendix B* and must be completed and submitted with the student's work when recording observation of performance.

One suggestion for the final format could be a front page, contents page, assignment evidence in appropriate sections, a conclusion/analysis and a bibliography. For ease of marking and moderation, the assignments should not be sleeved in plastic wallets. See *Appendix I: A Guide for Students on Report Writing*.

Assessing

Students should be given clear deadlines for submission of assignment tasks. This should be followed by prompt feedback and, if necessary, a chance for students to improve their assignment before final marking.

Assignments should be marked strictly against the assessment criteria grid. Teacher annotation of where and how marks have been awarded is good practice.

Students can be awarded marks in different bands for each assessment criterion.

Units

This section looks at each unit in detail and provides information on the following:

- key areas to cover and possible learning activities
- what tutors need to be familiar with (details of the specification, assessment evidence and assessment criteria grids)
- mode of assessment.

The individual units within this section must be read in conjunction with the corresponding unit in the Edexcel GCE in Engineering specification.

Index of units

Unit 1: Engineering Materials, Processes and Techniques

Unit aims

The main aim of this unit is for students to understand the range of materials available to the engineer and why a specific material will be used for a particular component of an engineered product. Students will look at the different properties these materials possess and the joining or materials processing techniques appropriate to use with them.

The tables on the following pages are an expansion of the 'What you need to learn' section from the GCE in Engineering specification. Each section has been expanded to provide the following additional information:

- breadth and depth of delivery for learning
- possible learning activities.

This section must be read in conjunction with the corresponding unit in the Edexcel GCE in Engineering specification.

Section 1.1 Materials

Coverage and depth of delivery for learning	Possible learning activities
This unit is about the materials used in engineered products, how they are processed, joined and finally used to make finished products. There are clear links between the material, its properties (perhaps we should say scientific properties since we need to look at numerical values and units), how it is processed and how it is joined to other components or materials for different purposes. It is important that this set of interrelationships is explored and that the sections are not each studied in isolation. The term 'class of material' specifically refers to whether the material can be classified as a metal, polymer, composite, or ceramic material. Determining the class of a material can usually be done through a visual inspection or physical handling of the material in question. This section defines a range of materials students should be familiar with that are commonly used in engineering. **METALS** **Cast iron** Cast iron should be dealt with in a modern context, as it is still used in making many manufactured machines but the tendency towards modern manufacturing methods should be stressed. Sand casting not being a favourite because of limitations in accuracy and repeatability and as a labour intensive method that produces poor quality results. Die casting is preferred today, but is costly and requires larger production.	As far as possible, learning should take place in an active and experimental manner allowing students to investigate and draw conclusions before providing definitive answers. Students should have access to catalogues, data sheets, and manufacturers' specifications in the form of a library of resources. It would be useful for students to have access to internet resources and a list of relevant websites. Possible learning activities could be: • examining samples of actual materials in forms that allow them to be measured, weighed, scratched and bent • examining products where the material is used. For example electrical cable for copper, empty tin-plated food cans, tungsten car lamps, and poles from cheap play tents which are often made from pure aluminium • photographs of products being manufactured using specified materials • video clips of processes in action eg casting and moulding, extrusion and drawing processes.

Coverage and depth of delivery for learning	Possible learning activities
Copper Copper is an important material in electrical work and heating work due to its high thermal and electrical conductivity. **Aluminium** Aluminium is an important material partly because it is relatively cheap and plentiful. It is also recognised as lightweight, however the lower strength means that it may not on its own be the correct material for a particular application. Note that we are referring to the pure material here — very soft (malleable). So much so that the pure material has little practical use and it is usually an alloy that is used. **Zinc/tin** Zinc and tin have relevance, not as structural materials but as materials that can be used to protect steels from corrosion, either as a coating (galvanising and tin plate) or as anodes in a galvanic protection system. **Tungsten** Tungsten is relevant as a material for the filaments of light bulbs and electrical heaters. Its resistivity and high melting temperature being important properties.	Explore use of copper in household (thermal properties, soft soldering and compression fittings as joining methods, bending pipe referred to malleability and ductility) hot water and central heating plumbing. Experiments to determine the resistance of lengths of wire made from different materials would demonstrate the electrical properties of copper and aluminium. Reference should be made to published reference values as a comparison.
ALLOYS The concept of alloying is important and students should understand that different properties can be created by alloying different percentages of each material and that traces of a third and, perhaps a fourth, material can have dramatic effects on certain properties.	It would be useful to demonstrate the use of lightweight alloys in aircraft either through visits, video or digital photographs. Emphasis should be made on surface finish issues, joining alloy panels permanently and in ways that allow removal for maintenance.

Coverage and depth of delivery for learning	Possible learning activities
Low carbon steel/medium carbon steel/high carbon steel The definition of low medium and high carbon steels should be firmly linked to the differences in properties and uses. Low carbon steel being commonly used in most applications. Its use in say car bodies should be discussed in terms of strength, ease of working (pressed steel panels), relative cost of material and processing, and its properties in the product. It may also be good to include at this point manufacturing using welding, crumpling in accidents (note the shaping to help this), and corrosion. Students will need to relate the different steels and their properties in terms of hardness, ability to be hardened and annealed. The concept of creating a complex shape in a soft material (perhaps a gear) and then surface hardening certain areas to resist wear and to provide extra strength (in the gear teeth) is relevant. The use of certain steels as cutting tools is also relevant, for example high-speed steels. **Brass** The topic could be introduced by looking at brasses and bronzes and explaining the different characteristics of some different particular alloys. The idea that common brass is relatively corrosion resistant and widely used, but has limited strength, and that different compositions, such as naval brass can have high corrosion resistance in marine environments and in some forms can have high tensile strength. **Stainless steel** A discussion of how stainless steel is created by alloying and that there are different grades of stainless steel. **Aluminium alloys** A similar treatment should extend to the aluminium alloys, with particular reference to the structurally strong and hard alloys used in aircraft construction, for example duralumin.	Experimental work on the heating effect of different conductors including tungsten. Examination of alloys and physical comparison with their pure counterparts. For example comparison of malleability of pure aluminium compared to duralumin. Samples, digital photographs and video clips of alloys and their application in products, for example: • aircraft construction through video clips • examples of stainless steel car exhausts, and the use of higher grade materials in the food and marine industry. Examination in practical situations of the properties of different grades of steel, for example trying to file low and high carbon steels, hardening, toughening and annealing steel samples. Case hardening through digital photographs and video clips, with samples of products. Video clips of press steelwork and drop forging.

Coverage and depth of delivery for learning	Possible learning activities
POLYMERS Students will need to have an understanding of the simple molecular structure of thermoplastics and thermosetting plastics and be able to draw simple diagrams to show the significant differences between these molecular structures. Polymers are an important set of materials used in products. You only have to look at how plastics have replaced steels as the chassis and body of many domestic products to recognise how widely these materials are used in engineering. Note that many cars have plastics panels now, especially in the areas likely to be involved in collisions such as bumpers wings and protective trim. In exploring the different uses and properties of the different materials some examples of specific engineering uses can be examined. **THERMOPLASTIC POLYMERS** **Polycarbonates/acrylic** Polycarbonates and acrylics are used in lenses and diffusers as part of electric light fittings and windows because they can be transparent. Differences in strength and toughness as well as UV degradability are relevant. **Polyethene** The uses and properties of polyethene should be discussed with its advantages and disadvantages. **Polystyrene** Polystyrene as an expanded product widely used in industrial packaging and as an insulation material, but with major environmental and fire risk drawbacks. Perhaps the specialist use of polystyrene in manufacturing mass produced scale models (aircraft etc) should be mentioned and related to the ease of injection moulding. **PVC** PVC is probably most useful because of the way it can be manufactured into sheathings for electrical wires and cables, and as a waterproofing layer on woven fabrics.	The investigation of polymers is important and should have the same level of practical activity as the coverage of metals. Visits to see plastics components being manufactured and video clips to explain the processes used in industry. Samples of materials and finished products to examine. Experimental work such as impact testing of samples of different materials. Practical work with students manufacturing small GRP components in a workshop environment emphasising the health and safety and 'messiness' aspects of the process.

Coverage and depth of delivery for learning	Possible learning activities
ABS/nylon ABS is often used in cases for products — relate this to its properties and manufacture. Nylon can be used in different ways such as fabric coatings and as a material for components such as gears, bushes, and boat fittings. **PTFE** PTFE is widely used as a tape to seal threaded pipe joints and this can be related to the properties of the material. **THERMOPLASTIC POLYMERS** The use of thermosetting polymers is widespread and the way they are processed needs to be made clear. Thermoplastics can be shaped when hot, cooled quickly and then ejected as finished components but products produced from thermosetting plastics have, in general, to be allowed to cure in the mould. There is a clear link between thermosetting polymers and the creation of composite materials and this needs to be looked at. **Polyester resins** The use of polyester resins, as part of a composite, is almost universal in boat building, even including some small ships such as minesweepers (non magnetic hull). An investigation into the way these are made would be useful. The advantages being ease of constructing complex curved shapes, relative strength related to the design of the glass reinforcement. Introduce the use of carbon fibre as a method of adding additional strength to shaped components such as canoe bodies and sports car body panels when replacing some of the glass reinforcement with carbon fibres. It may be beneficial to mention the use of epoxy resins in the same context, but to note that although their properties are superior when incorporated into a composite such as a boat hull they are also expensive — use on lifeboat hulls being an example of where the benefit outweighs the extra cost. **Urea Formaldehyde** The mention of Urea Formaldehyde should be brief, as it only has limited use in modern engineering/manufacturing. One use is as petrol engine distributor caps. It might be worth discussing what properties it has that make it particularly suited to this specialist application.	

Coverage and depth of delivery for learning	Possible learning activities
ELASTOMERS	
Rubber/Neoprene	
The use of both natural and synthetic rubbers is widespread today. The use of these materials in a motor car is a good way of exploring the properties and uses of these materials. Door seals used to prevent water ingress and drafts, engine and exhaust mounts to minimise vibration and noise transmission to the body, and as a friction material, and flexible air seal in tyres.	Video and digital photographs to demonstrate materials and processes. Investigative work involving simple tests of properties such as measuring the force required to extend a sample of a rubber material by specific amounts. Comparing results of tests for different materials. Samples of finished products such as GRP, castings and mouldings, and car distributor caps. Samples of synthetic and natural rubber, and components made from these materials.
ADHESIVES	
Modern adhesives have altered many manufacturing processes. For example the chassis of some sports cars are now glued rather than welded together from component parts. The use of adhesives to prevent nuts and bolts shaking loose is also widespread. Epoxy adhesives are widely used in wooden boat construction and repair. The limitations and advantages of glues should be explored with particular reference to the importance of degreasing and preparing surfaces prior to gluing and the health and safety issues attached to the use of these materials.	Practical work to examine the properties, advantages and disadvantages of the use of adhesives. Using ‘locktight’ to secure nuts onto bolts and checking bond strength when cured. Use of Epoxy resins to bond various materials and experimental work to measure bond strength when cured.
COMPOSITES	
See 1.1 Thermosetting polymers.	
CERAMICS AND GLASS	
Porcelain	
In the context of engineering the use of porcelain is really about high voltage insulators widely used in the power generation and distribution industry and in spark plugs for petrol engines. However there are special applications where ceramic components are used because of their superior wear characteristics at high temperatures. The concept of the development of ceramic petrol engines is perhaps worthy of investigation. It is worth explaining the concept of toughened glass for use in house and car windows and relating this to toughening steels.	Examination of engineering components made from ceramics such as high voltage insulators and parts of miniature circuit breakers. Note that miniature circuit breakers are relatively cheap and most can be opened to reveal the internal workings — such as arc chutes that are made from ceramic materials.

Coverage and depth of delivery for learning	Possible learning activities
Borosilicate glass (Pyrex) Special glasses for use at elevated temperatures should include examples such as cooking utensils. Also explain the stresses involved in rapid cooling and heating such items. **NEW MATERIALS** **Shape memory alloys**	
Use as a collapsing cage to insert into a void and then set to measure the shape of the void, collapse again to remove it, and then regain the memorised shape when removed. A way of creating a pattern for the inside of a pipe, such as an artery as part of a heart condition treatment.	Examination of samples of actuators, optical fibres and heat shrink materials. Video of the application of these materials. Examination of samples of such new materials.
Piezoelectric actuators Piezoelectric actuators as a miniaturised way to convert electrical signals (perhaps from a micro- computer) into physical movement. **Optical fibres**	
Optical fibres as a communication medium for high speed interconnection of computer systems over large differences.	Internet research. Samples of materials to examine. Samples of optical fibres and products using optical fibres. Video of the application of optical fibres to long distance digital communication.
Heat shrink material Heat shrink material as a sheath and protective coating for cables and connections.	Students could use heat shrink sleeving to form simple electrical harnesses, and use a heat gun to create the finished product. They could then be asked to identify advantages of using this material.

Section 1.2 Properties of materials

Coverage and depth of delivery for learning	Possible learning activities
We have already identified a range of common applications of the materials listed and stressed the significant properties of these materials in these applications in section 1.1 Materials. It only remains to emphasise that students need to be familiar with the following and how these properties are measured and the tests that are commonly carried out to determine these properties. Properties include: **MECHANICAL** • hardness • toughness • elasticity • plasticity • ductility • malleability • compressive strength • tensile strength. Relative values for properties and the relevant units are also important. All values and units should be based on the SI system of measurements. **PHYSICAL** **Density**	Standard machinery and equipment should be made available, either for industrial use or for teaching use. If you do not possess such equipment then access to such equipment may be organised through your local college or university. It is important that students carry out a range of tests rather than just learn about them. This is particularly relevant to the practical methods of finding values for stress and strain, and therefore Young's modulus. Standard laboratory experiments on magnetism would be useful if the equipment is available.
Some common properties are relatively easy to make measurements on such as density, melting point and resistance.	Experimental work using standard scientific laboratory equipment to measure density of various common materials, melting points of common materials and changes in resistance of copper wires with changes in temperature.

Coverage and depth of delivery for learning	Possible learning activities
THERMAL/ELECTRICAL	
The concepts of electrical and thermal conductivity are important and need to be explained carefully using practical activities. Take particular care to differentiate between heat (temperature) and the apparent temperature due to thermal conduction. The relationship between resistivity/conductivity and resistance are also important.	
MAGNETIC	
The treatment of magnetism should only be touched on. Distinguish between magnetic and non-magnetic materials and concentrate purely on ferromagnetism. Explain the difference between hard and soft magnetic materials and their use as either permanent magnets, such as those used to provide the fixed field in a motor, and soft magnetic materials such as those used to make transformers. It may be useful to introduce the concept of B/H curves but limit this to providing an explanation for the effect of magnetising hard and soft magnetic materials.	
MODIFICATIONS OF PROPERTIES	
The heat treatment of steels is fairly important and students should understand the concept of hardening and tempering including the work hardening effect. The purpose of annealing and normalising should be firmly grasped. It is important to distinguish between the forms of steel that respond to treatment as in low, medium and high carbon steels.	It would be useful for students to actually harden and anneal samples of carbon steels and for them to be able to carry out simple tests, such as bending tests, to test the properties of the samples.
DETERIORATION OF MATERIALS	
Most materials deteriorate with exposure to the elements in some way and students should have an understanding of how different materials react to exposure to the environment. For example the deterioration of the structural strength of Polythene until it becomes brittle and breaks, as opposed to the deterioration of carbon steels, stainless steels and aluminium alloys, and the effects on strength as well as other properties such as electrical resistance should all be covered.	The concept of deterioration of materials is important, samples of aluminium castings affected by sea water, corroded stainless bolts (crevice corrosion due to lack of oxygen), cracked domestic buckets, and the like to generate a discussion of the mechanisms and effects of such deterioration on properties.
RELATIVE COSTS OF MATERIALS	
Students need to refer to tabulated information on materials contained in written and computerised forms. Reference materials and internet data should be available to students. Typical information would be based on that provided by the manufacturer of the material itself. Students will need to interpret the implications of the values provided for particular properties, and select specific materials for common applications on the basis of a number of property values.	Exercises to use technical data to select materials for specified applications.

Section 1.3 Joining materials together

Coverage and depth of delivery for learning	Possible learning activities
Students will need to investigate the different techniques by which materials can be joined together and the advantages and disadvantages of different methods of joining materials in particular situations. For example two pieces of low carbon steel can be joined by welding, but a nylon clip cannot be joined to a brass chassis by welding. The effect upon the properties of the material after joining should also be considered.	Examination of products and how materials are joined in them, for example examination of welded joints in bicycles or cars, bolts holding engine assemblies together, clips and threaded fasteners holding electrical goods together. Examination of catalogues to investigate nuts and bolts, electrical crimp terminals and other fastenings.
THERMAL JOINING OF METALS AND POLYMERS **Metals** Students only need to be familiar with the different thermal joining methods for metals. To actually soft solder components into a circuit board, hard solder brass components, spot weld thin sheet steel and attempt MIG welding would be useful, but not to develop skills but to appreciate the skill required and how the technique is used. An appreciation of the application of the range of techniques available, in the context of their application is required. For example to appreciate that the valves used in car engines are made from two different materials and that the best way to join them is by friction welding. That TIG is used for welding aluminium alloys, and an indication of what the technique involves, why spot welding is widely used in car manufacture, and so on. **Thermoplastics** The application of welding techniques for plastics materials is important and students need to understand the method and limitations. Examples include repairing canoes and similar craft by welding. Students need to be aware which materials can be welded in this way and which cannot, for example not for use on GRP.	It is useful if students can be introduced to welding techniques and even try welding techniques for themselves.
MECHANICAL JOINING An understanding of the application of mechanical fixings is required and an understanding of the circumstances where these techniques are suitable.	Use fasteners and joining methods to experience simple techniques, and to examine the pros and cons of each fastening method for specific applications.

Coverage and depth of delivery for learning	Possible learning activities
Screws Machine screws as a dismantlable way to join cast components together, as in an engine. **Nuts and bolts** Nuts and bolts to join components together where periodic dismantling is required and each side of the joint is accessible. **Rivets** Rivets as a semi-permanent joint and often used where materials are not easy to weld — often used on aircraft wings and boat masts etc. The difference between traditional rivets and 'pop rivets' should be understood. **Crimping** Crimping as a way of making permanent joints between electrical cables and terminals, making eyes in structural wires and as a way of securing hydraulic hozes onto spiggots.	
ADHESIVE BONDING **Contact adhesives** In general students should be familiar with the use of adhesives, including the use of contact adhesive to secure trim, as in cars and boats, as well as to attach veneer in furniture manufacture. Students also need to be aware of the fume hazards associated with these types of adhesive.	Using 'locktight' to secure nuts onto bolts and checking bond strength when cured.
Cyanacrylate The use of cyanacrylate adhesives is now widespread, from fixing rear view mirrors to windscreens using an UV activated form of this adhesive; the use of 'locktight' to prevent mechanical fixings from vibrating loose, to permanently securing exterior car trim. Students need to be aware of the advantages, limitations, and health and safety issues involved.	
Epoxy resins Epoxy adhesives are widely used, for example constructing and repairing wooden boats and permanently securing components such as recording heads in electronic systems. They have significant health risks which students need to be aware of.	Use of Epoxy resins to bond various materials and experimental work to measure bond strength when cured.

Section 1.4 Materials processing

Coverage and depth of delivery for learning	Possible learning activities
Students do not need to have experience of working with each of these processes, but they do need to know when they are appropriate, what materials they can be used with and the ways in which these processes are used to make engineered products and systems. It is however, an advantage if students can actually use some of the processes themselves. **FORMING** Students should understand how press work is used and how drop forged spanners are made and why. **CASTING AND MOULDING TECHNIQUES** **Metals** Students should understand the limitations of sand casting and the advantages and costs of other casting methods. It is important to relate sand casting, gravity die casting and pressure die-casting to their applications, advantages and disadvantages. **Plastics** Students should understand the following ways of shaping plastics, what they are used for and which materials are suitable for each method: • injection moulding • extrusion • blow moulding • vacuum forming • compression moulding • GRP moulding.	Video clips to demonstrate the use of processes in industry. Samples of products manufactured by such processes. An opportunity to carry out some processes themselves, for example vacuum forming and GRP moulding. Computer simulation software to simulate the casting process. Opportunities to carry out simple vacuum moulding. Forming and casting processes are likely to be delivered through video and other means of demonstrating.

Coverage and depth of delivery for learning	Possible learning activities
They should know the type of components which are normally manufactured by injection moulding. They should understand the shapes created by extrusion, blow moulding, and vacuum forming, and how they can be used in an industrial context. They should be aware that compression moulding can be used to speed up the curing of thermosetting plastics and the typical use of GRQ moulding, perhaps using boat or sports car manufacture as an example. **MATERIAL REMOVAL** Most students will have had significant experience of sawing, drilling and filing and some will have used or seen turning and milling. Students need to have an understanding of techniques that can be used and their limitations. **Sawing** Students need to be aware that hand sawing is really only used in prototype work and repair work. They also need to be aware of the use of a mechanical hacksaw as a method of cutting stock material to length and the use of a band saw for cutting out material for prototype and small batch production. **Filing** Students should be aware of how files are used to finish prototype work and that they are unlikely to be used in production situations. **Turning and milling** Students need to know about parallel turning, milling operations, understanding of feeds and speeds, cutting tools, and the ways these techniques can be used to make more complex components. **Drilling** Students need to know about drilling of holes in sheet materials and use of drill bits and speeds. **Punching** Punching should be explained as a realistic method of working thin sheet metal and that jigs and fixtures are used to locate work against datum edges for punching, rather than marking out on the work itself.	Opportunities to try hand techniques like sawing and drilling operations. These should not be the traditional apprentice tasks but should be designed to demonstrate the skills required in manufacturing activities. Practical experience of using simple parallel turning techniques and simple milling techniques. Etching to create circuit boards. Video of circuit board production in industry. Video clips of processes in industry. Digital photographs. Samples of raw and processed products. Samples of self finished materials. Practical opportunities to plastic coat and paint components. Note the importance of preparation — surface cleaning, degreasing and priming.

Coverage and depth of delivery for learning	Possible learning activities
Chemical etching	
Chemical etching as a material removal process is used in manufacturing printed circuit boards and can be demonstrated or even carried out by students under supervision. It may be worth explaining to students the way in which brass model railway components, for example carriage bodies, can be accurately etched to show external framing and window openings as used on pre 1920 railways.	Students can etch simple circuit boards.
SURFACE TREATMENT AND FINISHING	
The need to protect engineered products and components from environmental degradation is important. Students will need to have an appreciation of what each process entails, how it is carried out, what materials and tasks it is suitable for and its limitations. Health and safety issues for operatives carrying out the processes need to be considered.	
Galvanising	
Galvanising as an 'agricultural' method of protecting steel fabrications such as trailer chassis from corrosion.	Visits or video clips showing anodising and galvanising processes in action. The use of video in these cases is particularly relevant because of the real health and safety issues involved in actually observing such processes.
Anodising	
Anodisation as a method of producing a corrosion resistant, shiny, coloured and durable finish on aluminium alloy items such as boat masts.	
Polishing	
Polishing as a method of treating edges on transparent plastics materials such as acrylic windows for caravans and boats.	Students could experience polishing edges of acrylic components.
Painting	
Painting as an aesthetic finish for products as well as corrosion protection for use in cars for example.	Students could experience painting and dipping simple components.
Electroplating	
Electroplating as a thin coating used in many products to provide a smooth and pleasing finish to internal working components but without the durability of galvanising (at least not in harsh environments).	

Coverage and depth of delivery for learning	Possible learning activities
Plastic coating Plastic coating for use in handles on tools such as pliers. **Self finishing** Self finishing metal sheet, either plastic coated as a permanent finish prior to manufacture, for example caravan body panels and electrical equipment casings, or as a polished finish protected by a plastic film until ready for use, for example stainless steel kitchen sinks in DIY centres.	Examining samples of materials or products which have such finishes, for example stainless steel kitchen appliances (cooker hoods) and items made from prefinished metal sheet, for example some car battery chargers.

Examination tips

This section contains some examination tips and it will be useful to pass these details to your students during their revision period.

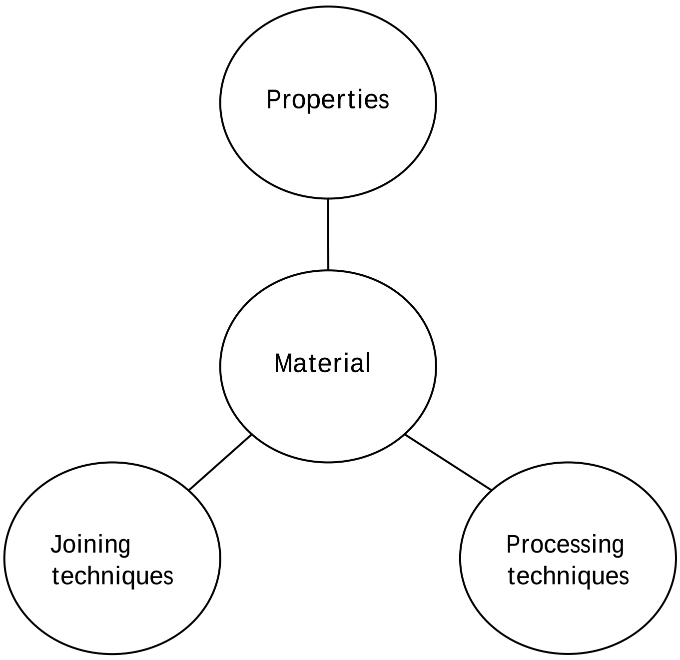
This unit is assessed through an examination set and marked by Edexcel. There will be a 1.5 hour examination paper and the examination will be available in the summer of each examination series. The paper will be a question and answer booklet.

Each examination paper will have one or more themes. A theme will be a common engineered product. The product(s) will provide opportunities for the student to answer questions about the choice and application of particular materials, joining techniques and processing methods in the context of a specific application. They will not require actual knowledge of the product(s) to answer the questions in the examination. The product(s) will merely give a context in which they can demonstrate their subject knowledge and understanding.

However students should practice looking at a range of products, they should consider how they were made, what techniques were used to make them, what materials were used in them and what properties the material has that makes it suitable.

As far as revision is concerned students will need to answer questions on the following topics in the context of how they might relate to the product in the examination. They should also refer to the Edexcel GCE in Engineering sample assessment material document. This document is designed to give teachers and students a feel of the areas within the specification being examined, the style of questioning, the level and expected responses from students.

Students will need to have a thorough understanding of how the different sections in the unit interrelate. The following diagram shows how the content of this unit revolves around the materials used to make engineered products.



Materials

Metals/alloys/polymers/elastomers/adhesives/composites/ceramics and glass/new materials

Classification of materials

Students will need to work out which class of material would be suitable for a particular application, for example if a component has to withstand high temperatures and be a good electrical insulator then it might be made from a ceramic material.

Selecting specific materials for specific applications

Students will need to look at products and decide which material(s) should be used to make a specific part. They will need to make these selections on the basis of the properties of the material(s). Before they can do this they will need to be familiar with the properties that different materials posses.

Applications of specific materials

Students will need to know the typical applications of specific materials in an engineering context. For example porcelain can be used to make high voltage insulators for use on overhead power lines and spark plugs. Low carbon steel is used for car body panels, copper is used as the conductor in electrical cables because it is a good conductor and it is malleable.

Properties of materials

Mechanical/physical/thermal/electrical/magnetic/modification/deterioration/costs

Relating properties of materials to applications of specified materials

This is the reverse of the last section — it is about being able to use information about material properties to work out what it could be used for.

Simple tests to determine the properties of given materials

Simple tests are the sort of thing students can do without using professional testing machinery. They can, for example handle the material to see how heavy it is, particularly if they can find a similar sized block of a different material that they are familiar with as a comparison.

The relationships between materials and their properties

Students will need to link materials and their properties together. For some obvious applications they would have come across them in so many product investigations. An example of this is the use of copper as a conductor because it has good electrical conduction (low resistivity) as well as being ductile so that it can be drawn into wires.

Use data on material properties and prices to select materials for given applications

Students will need to practice reading information from data sheets and tables of material properties. Students may be asked to read information on properties of a range of materials from a table in the examination. They need to understand the information in the table, select the best material for a particular application from the information in the table and explain why they have made that choice. This will require them to link the information in the table to their knowledge and understanding of engineering materials to justify that choice.

Simple sketches and descriptions of structures of given materials

There are certain structures that are described using simple sketches and these can be found in a range of textbooks. Students may need to sketch such diagrams and explain the significance of the structure shown in the diagram. Examples include the crystalline structure of steels before and after rolling, the folded molecular chains in elastomers and the cross linked chains in thermosetting plastics.

The effects of oxidisation on material properties

Surface damage can affect the strength of many materials, either by making the material thinner (as in the case of steels), by making the surface rough and creating stress concentrations (as in structural aluminium skins used in aircraft), or by changing the composition of the material (as in de-zincification of brass, which can seriously weaken brass fastenings used in a marine environment).

Students need to be aware of a range of these issues which affect both metals and plastics.

Joining materials

Thermal/mechanical/adhesion

Select joining techniques for particular applications

Students will need to work out which joining technique is appropriate in specific situations. For example if the assembly needed to be dimensionally accurate then a thermal method of joining might not be the best way to join two components because there is always some distortion when welding and to a lesser extent when soldering. The proximity of materials which are susceptible to damage when heated might also be something to consider. However, there are certain situations where welding is appropriate, for example when creating large steel assemblies which cannot easily be made in one piece and also needs to have the full strength of the material when finished.

Students will need to examine a range of manufactured products and work out why the various parts were joined the way they were. Remember that most mechanical fixings (such as nuts and bolts) can be disassembled. However, rivets are considered to be semi-permanent. Also note that pop-rivets are not very strong, unless specific high tensile rivets are used.

Design and sketch joining systems to connect specified components for specified applications

In the examination students may be asked to design some system to connect specified components together in an appropriate way. They may need to create brackets or some other interface between the given components and design an appropriate set of joints which meets the requirements of the question. They need to practice both designing the interconnection and sketching the idea.

Students need to consider how they would fix a circuit board into a box. The bought in box might have slots in its sides and a circuit board of the appropriate dimensions would fit into the slides. There might be threaded bosses moulded into the box and proper 'stand offs' designed to hold a circuit board. An alternative might be to drill through the bottom of the box and fit countersunk bolts into the bottom so that the circuit board could be bolted into the bottom using spacers to keep it from touching the box.

In a similar way there are a number of techniques which could be used to connect wires to a circuit board. The simplest way is to pass the wires through holes in the board and solder the wires in place. This is a very poor arrangement since every time the connections to the board have to be removed they have to be unsoldered. The wires are also left unsupported and are likely to fracture where they join the board. Such joints are best when there is both an electrical connection and a mechanical connection to support the wire. A better way to solve this problem is to solder special screw connectors onto the circuit board and then fix the wires into the screw terminals. It might be wise to arrange some form of mechanical connection to support the wires mechanically.

Looking at the different special fixings as well as the general fixings, which are in suppliers' catalogues, may help in the preparation for this.

Students need to remember that what they design and sketch must be appropriate for the materials to be joined as well as the nature of the joint.

Material processing

Forming/casting/moulding/material removal/surface treatment/finishing/health and safety

Students need to be familiar with how to make products and components. They need to practice looking at products and working out how each part was made, how the whole product was created. They will need to work out which parts are made from the different processes and techniques available.

Explaining how processes are carried out

Students will need to be familiar with the processes and techniques available in order to describe how any one of them is actually carried out.

Selecting processes and techniques for making specified components from specified materials and techniques for making specified components from specified materials

Students may come across a question in the examination that asks them to select specific processes and techniques to make specific components or assemblies. They will need to apply their knowledge on processes, material properties and fixings to specify how a particular component or subassembly would be made.

Using material properties and technical data to solve problems

Some part of the examinations may require the student to use information on materials by extracting information from a table. The best practice they can have for this is by using published data on the properties of actual materials, either from suppliers' catalogues or from reference books. They will need to use the data to select particular materials and components that are suitable for making the product.

Selecting and describing finishing techniques for components and materials to meet specifications

Students will need to select specific finishing techniques for particular components and materials as well as describe how they are created. This will help them to select appropriate finishes for specific components made from particular materials.

Unit 2: The Role of the Engineer

Unit aims

The main aim of this unit is to introduce students to the type of work that engineers carry out and the different ways in which they contribute to the economy and to society.

The tables on the following pages are an expansion of the 'What you need to learn' section from the GCE in Engineering specification. Each section has been expanded to provide the following additional information:

- coverage and depth of delivery for learning
- possible learning activities
- content mapping to the appropriate assessment criteria.

This section must be read in conjunction with the corresponding unit in the Edexcel GCE in Engineering specification.

Section 2.1 Engineering activities

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
This unit will require students to investigate the role of an engineer when designing **and/or** manufacturing an engineered product **or** service. The first section examines the wide variety of engineering disciplines, defining the most common branches of engineering and then exploring the range of career opportunities in each of them to encourage students to consider what branch of engineering they would like to investigate. The potential input from different levels of engineers is indicated by the job classifications introduced by the Engineering Council. Students should examine these categories and clearly identify each one. Details could be provided about recommended roles and responsibilities for the three levels of engineering qualifications standards — Engineering Technicians, Incorporated and Chartered Engineers. Job roles within engineering need to be defined. Students need to investigate the level of responsibility and authority necessary to achieve the aim of the job. A job role is usually defined within a written job description. It should also be explained that people with the same job title will not necessarily share the same job description. Engineering skills contribute to almost any function within businesses and can operate at any level. Clear definitions need to be given to students about an engineered product or an engineering service with examples, allowing students to make informed judgements about products or services in the future.	Students should be allowed to investigate and draw their own conclusions about the variety of job roles found in the many branches of engineering. Students should have access to engineers working in industry. This could be achieved by focused visits to local engineering companies or it could be achieved through the use of visiting engineers, which is to be encouraged. The optimum strategy is likely to involve both visits and visiting engineers. There are a number of organisations which specialise in facilitating such visits and these may be able to assist in arranging such contacts. It would also be useful for students to analyse job descriptions of a range of engineers, perhaps as part of a discussion with a visiting engineer. It would be useful for students to have access to internet resources and a list of relevant websites. Exploring the many branches of engineering and obtaining information about the variety of job roles available in these branches. Examine the Engineering Council job classifications: Engineering Technician, Incorporated and Chartered Engineers. Examples of engineering job descriptions could be used to show such documentation. Students while investigating job roles could produce a detailed job description. A range of engineered products could be used to show the diversity of engineering. Examples of engineering services could also be provided for this purpose.	(a)

Section 2.2 The application of technology in engineering

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Modern products, services and techniques do not only improve the lives of society in general, they also make the work of engineers more effective and efficient. Engineers must constantly be aware of developing technologies and be prepared to use them in their work. In this unit students will investigate how the following appropriate technologies, relevant to their engineered product or service, have influenced the work of the engineer. **Computer Aided Design (CAD) and Computer Aided Manufacture (CAM)** Computer aided design and computer aided manufacture should be defined and although the two areas are closely linked they are two different technologies. Computer aided design involves the creation of a design using a computer. Nowadays designing is often done graphically, using the computer screen as a drawing board. Designs do not necessarily have to be created in the traditional drawing style, they may also be very graphical, for example graphics for a company logo or in the form of a model of a product. The final design drawings must always make use of appropriate industry standards. CAM involves using a computer to control the operation of a manufacturing tool. This may be a computerised version of a traditional lathe or milling machine, but equally it could be a plotter/cutter, laser cutter or rapid prototyping machine. CAD and CAM have revolutionised industry, it has cut the time taken to bring new products to market; it cuts machining times and costs and improves accuracy and reliability. It also allows the development of products not possible using traditional manufacturing techniques.	Examine the advantages and disadvantages of CAD/CAM compared to the more traditional methods of manufacture. Give examples of different types of CAD/CAM from industry. Identify different types of machinery that are controlled by computers and how they have improved products or services. There is an opportunity for industrial visits to view such machinery and again have guest speakers to discuss their role.	(b)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Software applications There is an abundance of software available today that would give students ample opportunity to explore their use. When linking with a company, it is beneficial for students to be shown how the software is used by the engineer. Students need to gain an understanding of how the software application has been used to design and/or manufacture the engineered product or service. **Control systems** The focus of this section should be to ensure that students are aware of how control systems are used in modern engineering systems and products. Examples of products include car engine management systems, microprocessor controlled washing machines and PLC controlled production lines. **Communications** Students only need to have a general understanding of digital telephone communications, mobile telephones and satellite telephones.	Students should examine software used in engineering to design and manufacture engineered products or services, for example AutoCAD and Pro Engineer. Students should be given the opportunity to see how such software is used in real engineering companies. This would help them appreciate the benefits of such software. Investigations of say actual car engines, reference to manuals for the engine are beneficial. Investigations into the way communications systems are used by engineers in local industry and in products produced by local companies.	(b)

Section 2.3 Legislation and standards in engineering

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
It should be noted that this section is to provide students with an awareness of the different types of contracts and documentation available. Students need to be familiar with the different types of documentation that are used within engineering companies. An explanation of the most common types of contracts will need to be provided, for example drawings, procedures, work instructions, order forms, quotations, contracts of employment, contracts to supply goods, quality manuals, etc. They should then investigate the importance of the appropriate legislation and standards, relevant to their engineered product or service, that influence the way the engineer works. **Contracts** Contracts of employment are required to ensure that employer and employee have a common understanding of what each is committed to doing. Contracts to supply are required to ensure that work is carried out and bought-in parts or components are manufactured to a specific standard. Employers and employees have a duty to follow the guidelines laid down in their contracts to ensure all parties involved in the design or manufacture of the engineered product or service have conformed to their legal obligation. Contracts are there to provide a safety net for customers and employers. For example, if there were no contract to supply products or services then the customer could lose a great deal of money through an initial investment in a company to provide that service. All contracts define the financial reward in return for providing the specified services.	Guest speakers could talk about contracts used within their companies. They should be encouraged to provide examples of contracts used by their companies. Students could also carry out investigations to identify common types of documentation and legislation. Students could also analyse documents from local engineering companies.	(c) and (d)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Codes of practice Various codes of practice are present in engineering. They define how specific ranges of operations are carried out. Many of them are incorporated into British standards as British standard codes of practice. Codes of practice are not legal requirements themselves, but conformance to the relevant code of practice may ensure that an organisation is covered from having broken legal requirements when something goes wrong. For example, the Institute of Electrical Engineers produces a code of practice 'IEE Regulations' and describes rules for electrical circuits in buildings. Conforming to the IEE Regulations ensures that the electrical systems within a building are safe and will function correctly. **Standards** One of the most important standards for engineers is for engineering drawings. The standard defines the way engineering drawings are drawn. When drawings conform to this standard they can be understood in the same way by engineers all over the world. It's all about using a common language. A range of standards are defined by a number of organisations including American National Standards Institute (ANSI), International Standards Organisation (ISO) and British Standards (BS). They exist to make life safer, efficient and to facilitate trade. Standards cover all aspects of life from technical guidelines for the aerospace industry to guidelines for the manufacture of toys. Students should be introduced to the work of BSI. BSI is independent of the government and is recognised as an impartial body serving both the public and private sector.	Students should investigate familiar products that conform to British Standards. If possible Standards should be obtained and examined so students can appreciate the work involved in their production. When investigating their chosen product or service, students should produce evidence of Standards that their product or service must conform to. There is an opportunity for guest speakers or engineers to visit centres to discuss their role in working to British Standards. Students could examine familiar products and identify the markings used to declare the standards conformed to by a product.	(c) and (d)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
The definition of a standard could be examined. It is a published document that contains a technical specification or other precise criteria designed to be used consistently as a rule, guideline or definition. Standards help to make life simpler and to increase the reliability and the effectiveness of many goods and services we use. Standards are designed for voluntary use and do not impose any regulations. However, laws and regulations may refer to certain standards and make compliance with them compulsory. For instance, the physical characteristics and format of a credit card is set out in BS EN ISO/IEC 7810:1996, adhering to this standard means that the credit card can be used worldwide. Students should be made aware of the specific standards that products or services must comply with before they can be offered for sale. The term British Standard Kitemark should be examined. This is the world's premier symbol of trust, integrity and quality. The Kitemark on a product reassures customers and specifiers alike that a product has satisfied the most rigorous testing processes. Details on the widespread use of the Kitemark, from printed circuit boards to double-glazed windows should be covered. Students should be made aware of the CE marking on products. This is a manufacturer's declaration that the product complies with the essential requirements of the relevant European health, safety and environmental protection legislations. CE markings on a product indicates to governmental officials that the product may be legally placed on the market in their country.	When investigating their chosen product or service, students could identify specific standards that must be adhered to in order that it can be offered for sale. The use of visiting engineers is again to be recommended, since they can bring with them examples of standards and codes of practice which effect them, and explain what they are for and what effect they have on their company. Students could also investigate the various categories of products that require CE marking and give examples from each one. When investigating their chosen product or service they will need to identify whether CE marking is required for that product or service. Internet based research could be used to examine both the Kitemark and CE markings.	(c) and (d)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students should also be made aware of what products require CE marking. Businesses wanting to export products to the European Union and European Free Trade Association member states producing goods in one of the 22 groups of products may need to have CE marks on those products. The European Union's 'New Approach directives' are mandatory on all member countries to enact through national legislation. This legislation requires manufacturers to display CE Marking on their product, packaging and accompanying literature. Where a new approach directive is in force, it is, with few exceptions, an offence to place a product on the market without CE Marking. The manufacturer is legally responsible for ensuring that the product conforms to the requirements of the directive and for applying CE Marking. **Legal framework** With such an expanse of information relating to the legal framework governing Health and Safety in all places of work, students should be introduced to the most common areas. The Health and Safety at Work Act 1974 is the main act covering this area of law. This act aims to provide reasonable safety at all places of employment. It covers all people at work, including employers, employees and the self-employed. The Health and Safety Commission and Health and Safety Executive are responsible for enforcing the Act.	Students could carry out their own risk assessments, firstly in the centres workshop facilities and then when visiting a company that is developing or manufacturing their chosen product or service. Again internet based research could be another source of information. A visit to the HSE website will give access to a host of resources. Students should be shown records for portable appliance testing kept by companies. These could include records from the school or college or the company investigated.	(c) and (d)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
The Control of Substances Hazardous to Health Regulations (COSHH) applies to every workplace and form the work activity involving the use hazardous substances. The regulations require employers to protect employees from health risks arising from exposure to harmful substances. Employers are required to undertake an assessment of risks to health before implementing any work that is liable to expose employees to hazardous substances. Reporting of Injuries, Disease and Dangerous Occurrences Regulations 1985 (RIDDOR) require employers to notify the enforcing authority of an injury or accident immediately and to send a report to that body within seven days. The regulation also specifies that employers are responsible for keeping a record for three years of any major injury, condition or dangerous occurrence or disease. Electricity at Work Regulation (1989) focuses on precautions against the risk of death or injury from electricity in the context of work activities.	When visiting their chosen company, students could look for evidence of good practice in the work place and issues that surround their chosen product or service. Students could identify potential risks in an engineering based working environment and recommend precautions against those risks. Examples of risk assessments from industry could be used to inform students about health and safety issues. Students could investigate the terms major injury or condition, disease or dangerous occurrence as specified by the regulations and produce examples of each category. Internet-based research could be used to allow students to explore any of the major regulations associated with their product or service.	(c) and (d)

Section 2.4 Evaluation and modification

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students need to inspect, test, measure and compare products to their product specification to ensure that they comply with the standards required. They will need to learn how to use an evaluation matrix. This is an easy way to compare their final product with its design specification. Students will need to recall a variety of drawings techniques to enable them to show product modifications that will improve the design or performance of their engineered product or service.	Students can analyse a range of engineered products or services and offer suggestions for modifications. When visiting their chosen company students can discuss appropriate modifications with their engineer. When analysing products students could use an evaluation matrix to check fitness for purpose.	(e) and (f)

Requirements for each assessment criteria

Assessment evidence (a)

Evidence of the activities undertaken by the engineer in the design and/or manufacture of the engineered product or service.

The evidence for this section is likely to consist of written information on the different tasks carried out by the engineer responsible for the design **and/or** the manufacture of the engineered product **or** service. The information can be based on the engineers' job description with a series of descriptions and explanations to indicate what's involved in each task. An alternative approach could be to use a weekly diary provided by the engineer as a basis. However, if this evidence is generated it must include source information from the engineer, as well as explanations and examples written in the students own words. There should be clear links between the tasks carried out by the engineer and the relevance of those tasks to the product **or** service the engineer contributed to.

Assessment evidence (b)

Evidence of current available technologies used by the engineer including why they were selected as being appropriate to the process.

The evidence for this section is likely to consist of information gained when discussing the use of technology with the engineer. It may be based on notes taken by the student when on an industrial visit or on information provided by a visiting engineer. The student should identify technology used by the engineer as a working tool, and technology used by the engineer in the design **and/or** manufacture of the engineered product **or** service. The evidence should be detailed, written information in the student's own words and should include an explanation of why the technology was used by the engineer and its advantages over alternatives.

Assessment evidence (c)

Evidence of how appropriate legislation and standards influenced the design and/or manufacture of the engineered product or service.

The evidence in this section is likely to be based on the discussions with the engineer on the legislation and standards used when designing **and/or** manufacturing the engineered product **or** service. The evidence produced should consist of a written explanation in the students own words, which explains in detail how relevant legislation and standards influenced the design **and/or** manufacture of the engineered product **or** service. The student should also include a full explanation of the issues of compliance and non-compliance and how the engineer ensured standards were met.

Assessment evidence (d)

Evidence of how appropriate health and safety standards used by the engineer influenced the design and/or manufacture of the engineered product or service.

The evidence in this section is likely to be based on the discussions with the engineer on how health and safety standards influenced the design **and/or** manufacture of the engineered product **or** service. The evidence produced should consist of a written explanation in the students own words relating to how/why relevant health and safety legislation and standards influenced the way the engineered product was designed **and/or** manufactured and how appropriate standards were met.

Assessment evidence (e)

Evidence of evaluation of the performance of the engineered product or service investigated for its being fit for purpose.

The evidence in this section should be based on the student evaluating the performance of the engineered product **or** service. The student should show evidence of testing to ensure fitness for purpose. They should include objective statements which can be supported by third party feedback.

Assessment evidence (f)

Evidence of suggestions for possible modifications to improve the performance outcome of the engineered product or service.

The evidence in this section should be based on the outcome of the evaluation of the engineered product **or** service on its fitness for purpose. The student should provide suggestions that take into account all the different statements of the evaluation taken in part (e). Each suggestion should tend to improve the performance of the engineered product **or** service with a reasoned justification to support each suggestion.

Useful tips when undertaking this investigation

First and foremost careful consideration needs to be taken when identifying an engineer who will help in the delivery and assessment of this unit. It is important for both the teacher and the student to discuss the requirements of this unit with the engineer in order to ensure that the investigation carried out by the student will allow all assessment criteria at the high mark band level to be achieved.

When identifying an engineer, again careful consideration needs to be given to the depth of activities that the engineer has to perform. Careful planning and collaborative work between centres and industry need to be in place.

When investigating the engineered product, the engineer may have been involved with both the design and manufacture of the engineered product or service. Many engineers are involved with both aspects and this could provide more detail for the assignment.

For this unit to be successful, it is essential that company links are established. Students will need to interview the engineer. It may be possible for students to examine different products from the same company so as not to burden teaching staff with trying to create a multitude of industrial links for each individual student. When visiting their chosen company it is essential that students use the time of the engineer effectively due to their work commitments. At the same time, there needs to be flexibility in the approach to this unit as engineers may not be available at timetabled lesson periods. This could mean setting a specified time for an industrial work placement. Here students could concentrate on the unit and, if well prepared with specific questions that need to be asked to meet the assessment criteria, the student could then complete their assignment back at the centre.

However access to visiting engineers through one of the established schemes such as SETNET (www.setnet.org.uk) could provide regular access to a working engineer during specified timetable slots.

Information regarding legislation and health and safety may be obtained by researching on the internet. However, note that this alone will not provide the necessary evidence required for students to fulfil the requirements of the assessment criteria.

There are a number of useful websites that can provide information to assist with these areas:

www.bsi-global.com

www.ce-marking.org

www.healthandsafety.co.uk

www.hse.gov.uk

www.iee.org.uk

When students are evaluating their chosen product, they must remember that the product has already gone through a series of tests and evaluations. However the student may see the product from a different light and develop a feasible modification. It would be useful to provide details of these modifications in the form of written explanation supported by simple sketches to illustrate each point.

Useful tips when gathering evidence for each assessment criteria

Once the student has identified a product or service that will allow them access to the higher mark bands for all six assessment criteria, they will need to interview an engineer from that company to obtain vital assessment evidence for the investigation. It is very important that a company link be established to allow students to gain the maximum understanding of the role of an engineer. The investigation may require a number of visits in order to obtain all the necessary information needed to fulfil all the assessment criteria. It may be an idea to concentrate on a single criterion for each visit, combining criteria (e) and (f) to make a total of five visits. Students should plan their visits well in advance, examining the assessment criteria and developing questions that will meet the required evidence indicators.

Assessment evidence (a)

Evidence of the activities undertaken by the engineer in the design and/or manufacture of the engineered product or service.

Students need to question the engineer about the different activities that they undergo in the design/manufacture of the product or service. Some background information about the product or service should be given to set the scene for the assignment such as its function and relevant design specification points. The student should try to categorise the activities under major headings such as Design Development, Quality, Production and Manufacturing. Under these headings, details can then be given about what the engineer actually contributes to the product or service. Students could examine the job description of the engineer. Some areas to consider could be how the engineer interacts with others in the company or does the engineer perform a number of roles within the company. Once these activities have been established then the student then needs to provide details of each of these activities to build up a whole picture of the role of that particular engineer.

Assessment evidence (b)

Evidence of current available technologies used by the engineer including why they were selected as being appropriate to the process.

Students will again need to interview their chosen engineer to discuss the technologies they would use in the workplace. Students will need to analyse the four main groups of new technology provided in the specification, CAD/CAM, Software applications, Control systems and Communications. When visiting the company, students need to observe the engineer at work and identify these technologies. For example, how does the engineer communicate with colleagues and customers? How does the engineer carry out design activities and why do they use these methods? What type of software is used in the company for designing and how is this software used by the engineer? How have these technologies made the work easier or more difficult?

Assessment evidence (c)

Evidence of how appropriate legislation and standards influenced the design and/or manufacture of the engineered product or service.

Here students need to identify any relevant British Standards to which their product or service must conform. Also there is usually a governing body that oversee standards and sets out regulations for that particular group of products or services. What type of tests are carried out on the chosen product or service and do they conform to required standards and regulations? Details could be provided of documentation used by the engineer such as working procedures, contract documents and confidentiality agreements. A visit to www.bsi-global.com could provide valuable information regarding standards. Also using internet search engines to find out about the chosen product or service.

Assessment evidence (d)

Evidence of how appropriate health and safety standards used by the engineer influenced the design and/or manufacture of the engineered product or service.

There is a vast array of information relating to health and safety available on the web. Students can again discuss particular issues relating to their product or service with their engineer. Does the product or service require special measures to ensure safe working practice? Are there factors that have influenced the design or manufacture of the product or service? For example has a manufacturing procedure resulted in the cost of the product having to be dramatically increased to meet health and safety requirements? Examples of risk assessments for particular parts of the production process could be included in the evidence. A visit to www.hse.gov.uk will provide a wealth of information relating to this section.

Assessment evidence (e)

Evidence of evaluation of the performance of the engineered product or service they have investigated for its being fit for purpose.

Students should provide evidence in the form of writing, drawings or photographs of how they evaluated their chosen product or service. An evaluation against the original specification could be used along with details of testing procedures. Typical questions to apply to the product or service could be:

- Does the proposal answer the brief?
- Does is it suit its proposed function?
- Is the design or manufacture a success?
- Were there any problems during the design and manufacture and how were they overcome?

Assessment evidence (f)

Evidence of suggestions for possible modifications to improve the performance outcome of the engineered product or service.

Here evidence could again be provided in the form of writing or drawings to show students' suggestions for modifications, giving reasons why these modifications will improve performance. Students should identify ways in which their product or service will help others and students may find it beneficial to consider the following points:

- Will their product or service make it easier for the customer to use or the manufacturer to produce?
- On reflection, are there any aspects of the design or manufacture that could be changed?
- Can alternative solutions be provided to the above problems?

Unit 3: Principals of Design, Planning and Prototyping

Unit aims

The main aim of this unit is for students to learn how to design and communicate solutions to engineering problems.

Students will learn how to read, interpret and produce engineering drawings, how to manage projects and how to follow a formal process that describes the stages by which a problem becomes a design solution. Students will learn how to test their design work by making a prototype. They will report on the overall project work by giving a presentation.

The tables on the following pages are an expansion of the 'What you need to learn' section from the GCE in Engineering specification. Each section has been expanded to provide the following additional information:

- coverage and depth of delivery for learning
- possible learning activities
- content mapping to the appropriate assessment criteria.

This section must be read in conjunction with the corresponding unit in the Edexcel GCE in Engineering specification.

Section 3.1 Engineering products

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
In this unit, students will focus on the principles of engineering design, planning and prototyping. They will design and manufacture an engineered product. The engineered product can be electrical, mechanical, fluidic, electronic or even a combination of these. Teacher intervention is important at the outset of this unit in order to ensure that the chosen focus for study is appropriate to students' abilities and allows access to the full range of assessment criteria.	Consider a range of possible contexts from which briefs for engineering designs can be derived, bearing in mind the required assessment evidence.	N/A

Section 3.2 Engineering drawings

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students need to learn how to read and interpret a range of engineering drawings and diagrams. They should be taught how to produce drawings that contain enough detail for a third party to manufacture independently their proposed product. Students must learn about and use the following conventions: • standard drawing sheets showing frame, title block and other markings • recommended scales • standard line types and thickness • leader lines, arrows and dimensions • sections and hidden details • first or third angle projection • pictorial drawings — isometric or oblique. When using CAD, students should be taught to produce original engineering drawings and not to generate orthographic views from previously produced 3D CAD sketches. All engineering drawings, hand drawn or computer generated should be done using current industry standards and conventions.	Students must have access to the guidance document for schools published by British Standards when they are working on engineering drawings. Use a CAD program to produce engineering drawings that can be retrieved and modified or produce engineering drawings by hand using appropriate drawing tools and instruments.	(a)

Section 3.3 Project planning

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
This section should be covered after section 3.4 — Design. Students should be taught to consider their design proposals holistically and to produce a plan for production that acts as a guide through all important aspects of product manufacture, so that time and resources are always under control. Planning may be for a one-off prototype, but consideration should be made for larger volume production, too. Students should be taught that the use of planning tools is a forward-looking activity, not a retrospective diary of events. It is good practice for students to record their progress and to modify their plans when unavoidable changes have taken place.	Select a range of engineered products and describe in the form of an outline plan how each would be manufactured. Use a work order or schedule in the form of a flow chart that shows the order of assembly of parts and components. Include the order in which equipment and processes are used during manufacture. Investigate realistic timings attached to manufacturing processes. Identify quality control points and checks for a range of engineered products. Identify safety considerations for a range of engineered products during manufacture. Consider the differences between planning for a one-off prototype and batch production of an engineered product.	(b)

Section 3.4 Design

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
This section should be covered before section 3.3 — Project planning. The design brief will be presented to students by a 'client', so it is important that its focus is well thought through in order to ensure that there are opportunities to achieve maximum credit in all assessment criteria. The brief must allow students to respond through engineering activities based on functional scientific and mathematical principals, rather than aesthetic outcomes only. **UNDERSTANDING THE CLIENT BRIEF** Students should be taught that a design brief is a guide to a client's needs and is a starting point from which to progress. Students should understand that the design brief will be simple and concise and will explain what needs to be done, without pre-determining a solution. It will give direction, but not be so prescriptive as to leave no room for interpretation and development. Students should be taught to analyse the given brief and to record basic statements considering the following identified 'key requirements' of the brief: • the function of the product • what it should look like • the materials it should be made from • the technology necessary to produce it • costs • number required • completion date.	Analyse a range of design briefs to identify key points and what needs to be found out in order to make progress. Use diagrams that identify and highlight relevant considerations regarding the task in hand and focus closely on it. Use analysis of existing similar products to gather information on materials, processes and construction methods. Use research that is focused and succinct to gather information to inform the specification for the proposed engineered product. Use research areas such as product analysis, market research, materials and component research which relate closely to the design brief.	(b)/(c)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Wider implications need to be considered in terms of: • scale of production and the implication for manufacturing methods • health and safety issues • quality. Students should understand that the analysis will be used to inform the specification to ensure that all important points of consideration are included. **CREATING A TECHNICAL DESIGN SPECIFICATION** Students should learn that the specification is based upon the information gathered previously and should be written in consultation with the client, who may have suggestions to make regarding the final list of design parameters to be considered. Students should understand the importance of developing a strong specification, as it is influential in determining the success of design proposals, product outcome and final evaluation. Students should be taught to produce a specification that is concise and well organised, so that it is easy to follow when reviewing designs against its design requirements. Students should be taught to organise a specification into sub-sections to prevent rambling, repetitive statements that are difficult to follow. Sub-sections could include: function, user requirements, performance requirements, materials and size, safety and quality, costs, scale of production. Students should understand that a specification should include technical, measurable points that can be used to evaluate the final outcome against.	Produce a range of technical specifications for different design briefs that are based on analysis of research and the essential requirements of the design brief. Use short, succinct statements organised under sub-headings. Identify and use technical points that are measurable and can be evaluated against the final outcome. Use a range of existing products and write technical specifications for each one.	(b)/(c)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
PRODUCING INITIAL DESIGN IDEAS Students should understand that their design activities must be underpinned by engineering principles and each design decision should be taken with consideration of scientific and mathematic reasoning. Students should be taught to select materials for their particular properties and working characteristics and that alternative designs should consider engineering approaches that ensure the functionality of a product. As part of the overall design of a product, students should be taught to consider ergonomics and aesthetics where appropriate, but they should understand that these aspects should enhance an engineered product and not dominate its outcome. During design activities, students should be taught to consider how each of their design ideas would be made as a one-off prototype and also in larger numbers (batch production). When producing alternative design ideas, students should be taught that each design should be realistic and workable and should closely match the product specification.	Use a range of topics to practice quick 3D representation of ideas that focus on the key points of the technical specification. Identify where scientific and mathematical principles could be used to justify engineering decisions made. Explore a range of approaches to work ensuring knowledge of proposed technical detail, materials, techniques and processes are appropriate to the demands of the specification.	(b)/(c)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
FORMATIVE EVALUATION/PRODUCING A FINAL DESIGN SOLUTION Students should be taught the value of reviewing each design idea against the specification in order to test its viability as a potential solution to a problem. They should understand that objective evaluation, using specification statements and third party formative feedback is a key tool in informing the further development of engineering designs. Students should understand the difference between objective evaluative feedback, discussing whether specification points have been met, and a non-critical description of how a product is meant to operate. Students should be taught that the development of a final design solution involves change and does not simply involve re-drafting an initial design to add dimensions, further details of materials, construction processes etc. Change, or moving the design on, is best done through using or adapting a range of engineering features considered in more than one previous design idea, to produce the most appropriate solution to the problem in hand and students should be taught to use such strategies to produce a final design solution.	Show evidence of the developed design having moved on from an original idea through the results of evaluation and testing. Include as much detailed information on all aspects of the developed design as possible, to illustrate knowledge and understanding of engineering activities. Model aspects of design development to test features such as proportions, scale, and technical details. Use traditional materials, and/or 2D and 3D computer simulations for rapid representation of the proposed solution. Present evidence of 'real-world' modelling through clear, well-annotated photographs. Produce a clear and detailed final design proposal that includes technical details, justified by appropriate scientific and mathematical consideration, of materials, processes, techniques, fixtures and fittings that will be used during product manufacture.	(b)/(c)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
COMMUNICATING DESIGNS Students should be taught to produce a range of appropriate engineering drawings sufficient in their number and quality to enable their designed product to be manufactured effectively. Students should understand that it is not necessary to produce examples of all types of drawing listed below and they should avoid repeating information wherever possible. Types of drawing: • freehand sketches • general arrangement drawings • detail drawings • circuit diagrams • flow diagrams • schematic diagrams. Students should be taught the importance of always using the correct conventions when producing engineering drawings, so that they can be universally understood.	Present work using high quality communication skills. Practice skills developed in section 3.2 — Engineering drawings. Use 2D and/or 3D CAD to communicate details and features of the final design proposal. Ensure CAD programs match standard drawing conventions eg style of dimensioning, page layout.	(b)/(c)

Section 3.5 Manufacturing a prototype

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students should be taught to justify their selection and use of materials, components and processes based on their knowledge of scientific and mathematical principles. They should learn that although advanced engineering procedures are not required, high levels of manufacturing skills demonstrated through the use of workshop tools and equipment should be demonstrated wherever possible during product manufacture. Students should understand that the final prototype should closely match the final design solution and function as intended. Students need to apply high levels of safety awareness to their working practices to ensure the safety of themselves and others.	Produce a high quality product that meets the requirements of the specification and fully matches the final design proposal. Demonstrate an understanding of a range of materials through selection and appropriate use. Justify selection using scientific and mathematical reasoning. Demonstrate demanding and high-level making skills appropriate to the expected level of response. Use clear photographs to record enough detail to support the credit awarded during centre assessment. Use a series of photographs taken over a period of time during manufacture to highlight processes used and provide examples of precision and attention to detail that may not be readily noticeable in an image of the finished product. Record evidence of having understood the safety precautions required for use during product manufacture, which relate to personal and general safety and focus on specific materials, tools, equipment and processes. Use photographic evidence to support awareness of health and safety issues when working.	(d)

Section 3.6 Project presentation

<table>
<tr><th>Coverage and depth of delivery for learning</th><th>Possible learning activities</th><th>Assessment criteria this section links to</th></tr>
<tr><td>Students should be taught to prepare and present a short oral presentation that describes the design, manufacture and evaluation of their product.

The use of ICT resources, such as PowerPoint will enhance students' presentations.

Each student's presentation should be no more than 15 minutes long and should cover as succinctly and informatively as possible:
• the brief — explain the problem set
• the specification — identify and explain key, measurable points
• design ideas — explain the thinking behind each design proposal and subsequent evaluations
• development of final proposal — describe and justify the final proposal using the specification as reference
• product manufacture — briefly explain and justify materials, processes etc, including any scientific principals used
• product evaluation — feedback from peers, teachers and/or visiting engineers and explain any objective testing against the specification to judge the success of the product.</td><td>Prepare and deliver a series of short presentations on individual aspects of the engineered product to a limited number of peers.

Use feedback from peers to refine presentation technique.

Deliver more than a single aspect of the engineered product to an increased audience to gain confidence and refine technique.

Build on experience by increasing length and detail of presentation to achieve objectives and timing.

Use ICT to enhance the presentations made.</td><td>(e)</td></tr>
</table>

Requirements for each assessment criteria

Assessment evidence (a)

Evidence of a portfolio of engineering drawing.

Evidence for this section will consist of a range of accurate engineering drawings in either 1st or 3rd angle orthographic projection. The drawings should be detailed enough to enable a skilled third party to manufacture the designed parts without further consultation and should use industry standard symbols and conventions.

Each drawing sheet should be standardised to include a border, title block and any other relevant details to communicate necessary information.

Where pictorial views are used, students should ensure that they conform to isometric or oblique conventions.

Where hidden detail is a feature of a set of drawings, students should consider using sectional views and exploded views to make constructional details clear and easy to follow.

Formal parts lists and cutting lists should be included as part of the set of engineering drawings presented.

When using CAD programs to produce engineering drawings, students should use them appropriately, for example to produce details that may need to be replicated, mirrored and manipulated in ways that hand-drawn projections cannot. Dimensioning in CAD should be checked to ensure that the style conforms to standard conventions. 3D CAD programs that generate 2D views in appropriate projections should be avoided as the set of engineering drawings presented is expected to be wholly generated by the student.

Assessment evidence (b)

Evidence of project planning and a design specification that meets the client brief.

Students should produce a work order or schedule. This could be done in the form of a flow chart or table and should include the order of assembly of parts or components, tools, equipment and processes to be used during manufacture.

Quality control points should be identified and quality checks should be described, which could be done through feedback loops as part of a flow diagram. Similarly, safety checks should be considered as part of planning for manufacture.

Planning implies the consideration of time, and it is essential that references are made to timings and deadlines during manufacture. If a Gantt or time chart is used as part of this section, it is important that students' chart activities relate to the manufacture of their product, and consider manufacturing processes in relation to realistic deadlines.

It is acceptable to plan only for one-off prototype production, but it is beneficial to students if they consider the changes they have to make to their planning for batch production of their product. If commercial processes are considered, students should ensure that they focus specifically on how they would be used with regards to their product and not in generic terms.

Students should develop a technical specification that is based on an analysis of research and what essential requirements are necessary to achieve a successful engineered outcome.

In order to avoid a rambling collection of points, a specification should be organised logically and this can be achieved by using sub-headings such as purpose, user requirements, performance requirements, materials/components, size, safety and quality, scale of production and cost.

Specification points should contain more than a single piece of information, so that each statement is justified.

Points of specification should be technical and measurable where possible, so that testing and evaluation can be realistic. They should not be superficial and general.

A specification should include technical/scientific and measurable points wherever possible, so that ideas and their development can be objectively evaluated using clear design parameters.

Assessment evidence (c)

Evidence of initial design ideas and their development that have been evaluated against the requirements of the client brief leading to the final design solution.

Students should explore a range of approaches to their work in this section, using their knowledge of technical detail, scientific and mathematic application, materials, techniques and processes to produce realistic design proposals that match the points of the specification.

Students should avoid producing lots of work in this criterion that does not progress beyond the same point of engineering design content for each alternative offered. It is better to produce fewer ideas that are technically sound and concentrate on detailed well thought through scientific concepts.

As work progresses, students' alternative designs and details should become linked and strands of continuity should be seen in higher quality responses as one idea moves to the next to be improved on.

Communication skills are important in conveying ideas and students should be encouraged to use any appropriate means of illustrating their work at this rapid development stage that they are comfortable with, as long as their results are clear and easily understood.

Effective annotation is an important feature of this section to enable students to explain details of design thinking and to offer evaluative statements regarding their design ideas.

In evaluating each alternative idea, it is important that they refer to points of specification objectively and avoid using tick-boxes or marks out of ten as a deciding factor in which design to select for further development.

Ideas can be sub-systems or part-ideas of a product and there should be a strand of continuity and progression running through this section that shows their train of thought.

Development of the final design solution should bring together the best or most appropriate features of their previous design ideas into a coherent and refined final design solution that meets all of the requirements of the product specification.

There should be evidence of the developed design having moved on from an original idea through to the results of evaluation and testing. It is not acceptable to simply take an initial idea and make superficial or cosmetic changes to it and then present it as a final developed solution.

Students should include as much detailed information on all aspects of their developed design as possible, as this is an opportunity to demonstrate their knowledge and understanding of engineering principals and design and make activities.

Modelling is an important aspect of design development and students should use this to test features such as proportions, scale, mechanical details, sub-systems etc. Modelling can be done through the use of traditional materials, or through the use of 2D and/or 3D computer simulations/rapid representation techniques.

Assessment evidence (d)

Evidence of a prototype which demonstrates the effectiveness of the final design solution.

In this assessment criterion, students are asked to produce a high quality product that meets the requirements of the specification and fully matches the final design solution in terms of function, sizes, finish etc.

During manufacture, students should demonstrate their understanding of a range of materials by selecting and using those that are appropriate to their needs in terms of properties, working characteristics and scientific/mathematical information that was detailed in the specification and work-plan.

Students should show demanding and high-level making skills in order to achieve the high category of marks in this section, so it is essential that the product under construction offers enough complexity to allow access to high marks. The level of complexity will already have been established at the design development stage, so it is important that students are guided towards appropriate levels of response at an early stage in their work to ensure their success.

As evidence of the quality of manufacture, photographs should be submitted that show enough detail to support the credit awarded during centre assessment. As photographic evidence is the only proof of manufacturing quality, it is essential that the images convey details of levels of difficulty and complexity of construction, so it is unlikely that a single image will achieve this. A series of photographs taken over a period of time during manufacture is the ideal way of highlighting processes used and providing examples of precision and attention to detail that may not be readily noticeable in an image of the finished product.

Photographic evidence can also be employed to support a student's awareness of health and safety issues.

Assessment evidence (e)

Evidence of an oral presentation of the project.

When students have completed all aspects of their project in criteria (a)–(d), they should give a visual and audible presentation to the rest of their group and their teacher, explaining the activities and details involved in reaching a successful conclusion to their work.

During their presentation, students should aim to explain what their project was, where it originated, how they set about gathering information to help them, what were the most important technical considerations they had to make and how they achieved a successful outcome.

Students should highlight any problems that arose that were not planned for and how they dealt with these and they should be as objective in their presentation as possible, using the results of testing and evaluation to support their commentary.

Students should try to focus on the technical aspects of their work, always using appropriate and accurate technical vocabulary. Their presentation should be succinct and to the point and should not include any unnecessary or irrelevant information that will not gain marks when their presentation is assessed.

Students should use ICT to enhance their presentation so that they can make their points and convey their information as professionally as possible. This is an opportunity to use the transferable skills they may have gained in other areas of their studies.

Students should practise their presentation enough times so that they are confident in its delivery and that they have anticipated any difficulties that may arise.

It is essential that students manage their time allowance effectively for this assessment criterion. They should try and take no more time than they need, but should make sure that they have enough information to use comfortably in the allowed time, especially if they intend to answer questions at the end of their presentation.

Suitable projects

The following suggestions for projects are not meant to be prescriptive and centres and students are encouraged to generate their own ideas for projects where possible, as they are more likely to be of focused interest when developed in this way.

Whatever project titles are chosen it is the level of response produced from students that make them appropriate, or not, to the expectations of the standards set at AS level.

1	Air circulation in conservatories is important to users.
	Design and make a system that will monitor the temperature in a conservatory and will switch on an oscillating fan automatically when a pre-set temperature is reached. The fan should move through an angle of about 90^o and should oscillate through a complete cycle once every four seconds.

2	Babies waking in the night and needing entertaining is a problem suffered by many parents.
	Design and make a device that detects audibly when a baby is awake and turns on an action toy that will entertain the baby for a period of time before turning off automatically. The device, once triggered should be adjustable for time periods of up to 20 minutes. The device should entertain at night when it is dark, as well as during daylight.

3	As part of their GCSE course, students of textile design are required to carry out comparative wear tests on different fabrics to test their suitability for use.
	Design and make a device that will compare the rate of wear of various fabrics through abrasion. The device should use time or a counting system to compare robustness of fabrics and should stop its activity as soon a fabric has been worn through.

4	When soldering components into Printed Circuit Boards (PCBs), it is often difficult to hold the PCB under control while working on it.
	Design and make a mechanical device that will hold PCBs of different sizes securely, so that effective soldering of through-hole components can take place. The device must be stable so it does not fall over in use and it must accommodate a range of sizes of PCB from 30mm square to boards measuring 100mm x 160mm.

5	Musicians often need to ensure that they keep to the correct tempo when playing their instruments.
	Design and make a portable device to be used to give both an audible and visual output. The device should be capable of operating over a range of frequencies, so that tempos can be selected. The device should be calibrated accurately and should produce a consistently accurate tempo despite fluctuations in power supply performance. A feature of the device should be that it can be used either audibly, visually, or in both modes of operation.

6	Shaking spray-paint cans when painting models or small objects can become tedious and tiring.
	Design and make a can-shaking device that will hold a spray-can conveniently and securely and will agitate the contents effectively in readiness for use. The device must accommodate a range of can sizes that vary in length and diameter and should use either linear reciprocating or oscillating motion as the agitation motion. Once triggered, the device should operate for a timed period that can be easily adjusted for user preference.

7	Houseplants often suffer when people go on holiday and neighbours are relied upon to water them.
	Design and make a monitoring system that will detect when soil moisture levels are low enough to require water. The output of the system should switch on a gentle sprinkler system that will either operate for a limited period, or until the soil is moist enough to require no more water. The device should be freestanding and portable and should be large enough to accommodate a dozen medium sized houseplants.

8	Student accommodation is often cramped and storage space is at a premium.
	Design and make a storage device for a portable television that is capable of being fixed to a wall. The unit should swing out from its parked position and be adjustable in the horizontal and vertical axes so that an infinite range of viewing positions can be achieved for the convenience of the user. Safety considerations must be of paramount importance when considering methods of securing a television to the device and how it attaches to a wall.

9	A workshop has a number of large electrically powered machine tools. Each machine has to have its oil changed after 200 hours use. Unfortunately the workshop is so busy that the operator can easily forget that the 200 hours have expired. The machines are used for approximately 6 hours each day, six days per week. However, on some days a particular machine may be used for less or more time depending on the type of work going through the workshop at the time.
	Design and make a device that could be added to a machine that would provide some form of warning when the oil needs to be changed. If the prototype is successful then the manager may want to buy a batch of 20 of the devices. It would be an advantage if the time between oil changes could be altered in a way that could not be accessed by the operator, so that the correct oil change intervals for different machines could be pre-set.

10	A school workshop has a pillar drill, permanently mounted half way along one wall. There is a marked area on the floor, which indicates that students should not enter the area when the machine is in use. Because the machine is situated close to a marked walkway through the workshop there is a tendency for students to take a short cut through the marked area, and risk knocking the machine operator, or distracting their attention.
	Design and make a device that will shut off the machine if anyone enters the marked area around the drilling machine. The drilling machine is a standard commercially available machine operated from a single-phase mains supply.

Unit 4: Applied Engineering Systems

Unit aims

The main aim of this unit is for students to investigate static and dynamic mechanical systems, electrical and electronic systems and measurements. Students will carry out calculations involving a range of engineering systems. They will also investigate electrical systems, mechanical systems, pneumatic systems and control systems.

The tables on the following pages are an expansion of the 'What you need to learn' section from the GCE in Engineering specification. Each section has been expanded to provide the following additional information:

- coverage and depth of delivery for learning
- possible learning activities
- content mapping to the appropriate assessment criteria.

This section must be read in conjunction with the corresponding unit in the Edexcel GCE in Engineering specification.

The assessment will be based on a brief set by us each year. The brief containing **three** practical activities will be similar each year but the topic/product selected will vary.

The brief will be available **only** from the Edexcel website (www.edexcel.org.uk) and will be available from September for each year.

Students should carry out relevant research on the content of the brief before they complete the activities. They **cannot** take any of their research materials with them when completing their practical activities.

The three practical activities may be started at anytime after the brief has been published, at centre discretion.

Students should spend no more than 10 hours in completing the three practical activities.

Working under examination conditions, students will work independently to complete all three practical activities to fulfil the requirements of this unit.

A deadline date will be set and issued with the brief.

Assessment will be carried out by centre assessors, whose decisions will be subject to moderation by Edexcel's external moderators. For this purpose, Edexcel will require a sample of student's work from a centre and moderation will take place during the June examination series.

Students' marks must be entered on the appropriate OPTEMS form and returned to Edexcel by the published deadline.

Section 4.1 Static structural systems

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
There are three separate themes within this section. Firstly the theory of forces, stresses and strains, secondly the use of test equipment to measure stresses and strains in actual samples of materials, and thirdly the analysis of pin jointed structures. **BASIC CALCULATIONS** As far as the first section is concerned students need to be aware of the relevant relationships and how to calculate the tensile and compressive stresses in structural members, the change in length caused by these stresses and the factor of safety in operation. The basic formulae for these are: • Direct stress = Force/Cross-sectional area • Factor of safety = Allowable stress/Working stress • Direct strain = Change in length/Initial length • Modulus of elasticity = Direct stress/Direct strain.	This section could be delivered primarily through the experimental work with supporting activities to introduce the formulae, and then encourage students to work out their own results to create graphs. Students can use a spreadsheet or graphical calculator. However, note that the external assessment will require students to produce graphs by hand, so this is a skill that should be practised.	(a)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
TENSILE TESTING It is important that students have the opportunity to use the following experimental equipment: • Hounsfield tensometer or other tensile testing machine for carrying out destructive tests • extensometer, incorporating a micrometer, vernier scale or dial-test indicator for recording changes in length • standard test specimens for common structural materials. Students will need to know how specimens are tested and how the recorded data is used to obtain the following: • load v extension and stress v strain graphs • ultimate tensile strength • modulus of elasticity. Note that the equipment which automatically plots graphs on pre-printed forms will not provide all of the answers that students need. Students need to create the graphs of stress, strain and modulus of elasticity. The experimental work is intended to support and embed learning. The relevance of an automatic plot of force against change in length may not be immediately apparent, even if it is proportional to modulus of elasticity.	The equipment specified in the content is required to deliver this unit. However, lack of this equipment should not be an obstacle to delivering this unit — since most colleges and universities with engineering departments may be willing to undertake (subcontract) this section of the unit by arrangement. Students need to use experimental apparatus to investigate the properties of typical metals such as low carbon steel, aluminium and copper.	(a)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
FRAMED STRUCTURES Students will need to know the names of the different types of member in a framed structure. They are: • ties • struts • redundant members. Students will not be expected to investigate structures with more than four members, which are pin jointed at their ends. Students will need to investigate and carry out calculations on a range of structures of different shapes and proportions. Typical structures include ships derricks, engine cranes and roofing systems. Much of this analysis relies on an ability to resolve forces into mutually perpendicular forces and this is a technique that may also have to be taught. This can be done using graphical methods, drawing to scale or by mathematical analysis. Students will have to calculate: • stress in members • factor of safety in operation • change in length of members.	Worked example calculations and problem sheets providing a range of pin jointed frame problems for students to solve.	(a)

Section 4.2 Electro-mechanical systems

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Depth of study should be sufficient for students to analyse the function of a given system and draw block diagrams of it. Students could investigate the way in which these systems are used in real engineered products, to relate the theory to practice. The formulae and relationships should be familiar to most students, it is the application of them to place numerical values on forces and currents which may be new. **Basic calculations** Students will need to calculate force, work and power using the following basic formulae: • Force = Pressure x Area • Work done = Force x Distance moved • Average power = Work done/Time taken • Instantaneous power = Force x Instantaneous velocity • Electrical power = Current x Voltage.	Examination of products and systems — there are many domestic appliances and power tools, which can be examined. Many of these are available at low prices, or as non-functional items for free. Problem solving using assignment or problem sheets. Investigation of systems — examples of suitable systems include winches used on 4x4 vehicles (available as mechanical, electrical and hydraulic versions), fishing boat pot hydraulic equipment, bow thrusters and anchor winches used on yachts, and many automotive systems such as windscreen wipers and electric windows. Worked examples of calculations — calculations involving the listed relationships and relevant to products investigated. Investigations of products to practice producing block diagrams to describe energy flows and conversions. As far as the electro mechanical is concerned there are many examples of products which use these techniques. It could be anything from a radio controlled model aircraft to a washing machine. In fact the motor car provides many opportunities to investigate these systems. Windscreen wipers, electric windows, cruise control etc. As far as pneumatic systems are concerned these are more likely to be restricted to industrial production machinery. However, the cruise control system fitted to many modern cars is an example where air is actually used to control something — although it is a negative air system.	(b)/(c)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
ELECTRO-MECHANICAL SYSTEM ELEMENTS Students need to cover operation and construction principles for all motors. They need to know about the following: • theory on the operation of simple DC motors, including windings and field interactions, commutation and simple treatment of distributed winding arrangements • AC motors — including cover universal motors, synchronous motors • stepper motors and their control • mechanical principles of linkages including motion in terms of timing and distance travelled • gear trains different arrangements involving gearboxes. They also need to cover velocity and power ratios • the arrangements of belts and chains, velocity ratios and gear ratios, power transmission characteristics • carden shafts and associated joints. Students need to be familiar with the standard symbols for components defined in this section of content and they should also describe how these components are used within a system.	Investigation of a range of practical systems which involve the power transmission elements in the content section. The compressed air suspension system used on some cars are suitable systems to examine. Industrial process equipment would also be suitable. Large earth moving machinery use electrical transmission systems, which might be interesting topics for investigation. Ships and locomotives also use a range of transmission systems, including mechanical, hydraulic and electrical transmission systems. There is currently interest in electrical drives for cars and boats which incorporate hybrid battery and engine systems — these may also be interesting topics to investigate. Information on electric motors could come from textbooks or internet sites. Information on belt and chain drives from manufacturers' data sheets, engineers' handbooks and catalogues. Information on gear trains from many of the above sources. An investigation of 4-wheel drive power transmission systems that incorporate cardan shafts, could be appropriate.	(b)/(c)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
BASIC PNEUMATIC EQUIPMENT Student are expected to know the symbols used in circuit drawings for the following components and explain the operation of a simple pneumatic circuit: • compressor • compressed air receiver • pressure regulator • single acting cylinders with spring return • double acting cylinders • control valves such as a 3-port (3/2) valve and a 5-port valve for bi-directional control with push-button or solenoid actuation.	It may be better to deliver the pneumatics section through an investigation of a simple pneumatic system. An automatic door opening system — like that used in railway carriages — may be a suitable system for investigation. Investigation and experimental work can be carried out using commercially available teaching systems.	(b)/(c)

Section 4.3 Power and lighting systems

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
The systems to be investigated in this section are all single phase AC systems and there is no need to introduce three-phase power systems. The similarities with DC systems should be emphasised, but it is important that students are aware that there are differences, and that inductance, resistance and capacitance have different effects in an AC circuit. Since the components mentioned in this section do not all behave as pure resistances in an AC circuit it is essential to introduce simple AC circuit theory and the concept of inductive reactance, capacitive reactance, power factor, real power and apparent power. Running costs should be covered in the context of domestic and small business industrial tariffs, with calculations of consumption of typical loads used to predict actual bills. **BASIC CALCULATIONS** Students should be familiar with Ohm's law and be able to calculate: • current and voltage in series and parallel circuits • electrical power, ie Power = Current x Voltage • running costs.	Experiments on low voltage AC circuits involving resistance, capacitance and inductance on their own, inductance in series with resistance, inductance in parallel with resistance capacitance in series with resistance, and capacitance in parallel with resistance. Experimental results to be confirmed by calculation and illustrated with appropriate phasor diagrams. Case study or problems involving running costs for domestic and light industrial users based on typical loads appropriate to the case study.	(c)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
LIGHTING AND POWER CIRCUIT COMPONENTS Students should gain familiarity with the operating principles, construction, and application of the following: • tungsten filament lamps • tungsten halogen lamps • fluorescent tubes • sodium lamps • switches and dimmers • sockets • plugs. In the context of lighting devices, the advantage of each device suggests its application, such as the use of sodium lamps in street lighting — partly for running costs, but largely because the wavelength aids sight without impairing night vision. The plug and socket should be treated as a method of temporarily connecting portable electrical appliances to the mains electricity supply in a convenient and safe way. The construction and operation of these devices should be in this context with reference to safety features incorporated, including the moulded plug as an aid to safety in preventing incorrect connection by the user.	Examples of different types of lamp and light fitting, and control switch for students to examine. Students to research operating principles and advantage of each type of fitting.	(c)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
CABLING AND CONNECTIONS Cabling and connections can only be covered with some reference to cabling and protective systems as defined in the IEE regulations. The use of an earth cable as a protective device as in British practice, should be compared with the use of residual current protection as common in Europe. This should be related to the two-pin European plug and socket as compared to the British three-pin plug and socket. Students should be introduced to steel wire armoured cable, mineral insulated cable, and domestic flat twin and earth cables. The size of cables required to carry particular loads are determined by a number of factors and students should be introduced to the tables published in the IEE regulations. Actual values and examples can all be drawn from reference to one appropriate table, which will be sufficient to illustrate the principles. Students need to understand how two-way switching is achieved, and they should be able to draw the schematic diagram to represent the operation of the circuit. Students need to be familiar with the ring main circuit and its use to provide parallel current supply paths and therefore supply a given load with the smallest practicable cable size. Students need to be aware that British electrical systems distinguish between the two wires in an AC electrical supply, in that one of them may be held at earth potential, and the implications of this practice with regard to three-pin plugs and sockets, wiring plugs and sockets correctly, switching the live conductor, and placing fuses in the correct line. The use of the earth cable, and earthing of exposed metalwork, as a primary safety device (forcing fuses to blow on a fault to earth before injury can occur) should be emphasised. The idea that the earthing of metalwork will maintain the voltage on the metalwork close to earth potential even when the fault is present is also important.	Examination of samples of different types of cable. Students will need to have access to extracts from the IEE regulations and, in particular, copies of appropriate tables. These tables specifically relate to cable sizes, fuse ratings and circuit breakers. It is not intended that students use these tables to select appropriate devices but they should be aware that it is necessary to refer to the information and not just select protective devices at random. The concept of cable sizes to satisfy specified current capacities as well as voltage drops over length is important. Students need to select cables for simple situations using the table. Experiment to create a low voltage equivalent of the two-way switching circuit under DC conditions.	(c)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
CIRCUIT PROTECTION Students need to know the ways in which lighting and power circuits are protected and made safe to use. Again, reference should be made to the IEE regulations and the tables for fuses and circuit breakers. It is important that students understand that a correctly sized fuse will always disconnect a faulty circuit, and within a very short time. Students should be aware that circuit breakers have to be carefully selected for the circuit or they may not disconnect the faulty circuit. They should also be aware that circuit breakers are electromechanical devices which may or may not function correctly, since they can go wrong just like every other manufactured product. The use of residual current circuit breakers to detect loss of energy from a circuit is also important and should be emphasised in the context of portable power tools, which may be used outside.	Selection of fuses and circuit breakers, including some dismantled for investigation into the construction and operating principles of the devices.	(c)

Section 4.4 Electronics, instrumentation and control

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Electronics, particularly the use of microelectronics, provide very sophisticated ways of monitoring and controlling a wide variety of equipment. A monitoring or measuring system usually comprises three major elements — a sensor or transducer, a signal conditioner and a display unit or recorder. It is useful to display the elements of a monitoring system in the form of a block diagram. Block diagrams consist of a sequence of rectangular boxes, each representing a stage in the process, and interconnected by single lines to indicate the connections between each stage. There are standard engineering conventions for drawing these diagrams that are well covered in textbooks. Students should be encouraged to use stencils to create these diagrams or to generate them using a computer package.	Worked examples of block diagrams representing given systems. Problem sheets describing systems and requiring block diagrams to be created and vice versa.	(e)
Sensors and transducers		
Students need to know how the following sensors/transducers operate: • thermocouples, resistance thermometers, thermistors and bi-metallic strips for sensing temperature change • light-sensitive resistors for sensing changes in illumination • piezo-electric devices and electrical resistance strain gauges for sensing force and pressure • linear and rotary potentiometers for detecting changes in linear and angular displacement. Students will need to understand the way these devices work and the form of signal they produce and how it can be used in a control system. Students should have access to a range of sensors and connect them up in simple experimental circuits to observe their operation.	Experiments to investigate simple sensors. Experimental investigations involving thermocouples, thermistors, light dependant resistors, strain gauges, and potentiometers.	

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
SIGNAL CONDITIONERS Students need to know how the following devices are used to change or modify the signal from a transducer into a more usable form: • mechanical levers • gear trains • voltage amplifiers • electrical noise filters • wheatstone bridge circuits • analogue-digital converters. Mechanical levers and gear trains are used in radio control servos and examining such a device should provide a good idea of how these are used including the drawbacks of backlash and lost motion. The way these electrical devices operate as a black box is more important than the actual operating principles of the device itself. You might want to discuss how a transistor is used as an amplifier, particularly if this is a topic that students have already covered in previous courses. The concept of a certain voltage level AC signal as an input and a larger signal within limits being the output is sufficient for this purpose. The circuit for a simple filter is also not a problem if students are familiar with electronics, but definitely treat the analogue to digital conversion as a black box process.	Experiments using gears, levers, amplifiers, and filters to condition and modify signals.	(e)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
DISPLAY UNITS AND RECORDERS Students need to be aware of how the following items of display/recording equipment operate and how they are used: • analogue scales and pointers eg moving coil meter • digital displays • cathode ray oscilloscope • visual display units (VDUs) • chart recorders • X-Y plotters • data loggers. This section introduces students to a range of different ways of displaying information about a control or monitoring system. Students will need to see examples of such displays and compare their suitability for displaying different types of information. For instance the VDU, for showing multiple graphs of system parameters as they occur and displaying the values for the last three hours as opposed to the chart recorder providing a long-term auditable record of the parameters, that can be archived. Note that it is worth emphasising that the analogue display is not to be disregarded as old fashioned. Use the clock as an example where a value can be read without thinking about it, but a digital display has to be read and interpreted consciously. There are also situations where digital displays provide incorrect readings yet look as if they are providing real information.	Investigations looking at the different ways information is displayed in different situations, ranging from simple indicator lights through to computer tracking of complex processes. Visits to local process industries could be beneficial, perhaps power stations, breweries, refineries, or even examination of standby power plant. Do not forget to look at the way information is displayed in motor cars and other vehicles.	(e)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
REFERENCE SOURCES Measuring systems need to be calibrated. This involves checking them against a reference source that is known to have a higher degree of accuracy. Students need to be aware of the following references: • standard pressure gauges • standard thermometers • standard sources for voltage comparison eg Cambridge potentiometer • standard sources for current comparison • signal generators, frequency references and cathode ray oscilloscope for frequency comparison, for example in the production of Lissajous figures. Introduce the concept of national standards for measurements and reference values based on calibration sources held at a central point. Describe the 'pyramid' of standard reference measurements, which can be traced back to the central standard. Use one measurement, say length or voltage and explain how this is related back to the 'master' reference. Students need to be aware of how these references work with the parameters stated in the content section.	Experimental work to compare a number of measuring devices with a calibration source. The calibration source does not have to be accurate for the principle to be established. The usual arrangement whereby it is not necessary for teaching equipment to be calibrated applies.	(e)/(f)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
CONTROL SYSTEMS Students will need to know the meaning of the following terms: • open-loop control • on-off closed-loop control • hysteresis in on-off control systems eg thermostat • set point • proportional closed-loop control. They should investigate the way systems are controlled. The operation of a car alternator voltage regulator is one appropriate closed loop system which can be explained in a straight forward manner. Circuit diagrams of such voltage controllers are available from many sources but it should be treated as a block diagram.	Investigations into control systems such as central heating room thermostat, speed controller, voltage regulator or other appropriate systems. There are a number of proprietary systems which can be used to demonstrate different control systems.	(e)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
CONTROL ELEMENTS Computer control is important and students should be made aware of the need to convert signals into digital information and interface them with a computer as a stream of discrete pieces of information. They should be aware of the need for both interface hardware and software to achieve this and that the input is likely to appear in the computer as a virtual 'com port' (or via a separate interface card). They should also be aware that output information to control the process is likely to follow the reverse of the input route, via a virtual 'com port' (or via a separate interface card), output hardware and software, and be sent to the controlling device as a stream of discrete digital values, which have to be converted into instructions for the control element. It is not intended that students should build or programme such a system but for them to demonstrate an understanding of the principles of the system. Again, the use of a block diagram would be useful. It is possible to use the PLC as a method of dealing with this section but the emphasis should be on the principles. Note that the software and hardware in a PLC is provided ready for the control system to be connected. Students need to understand what is in the black box in principle, but not in detail. Do not use this as an opportunity to spend time connecting and programming PLCs.	Investigation into computer control of systems using a PC such as domestic intruder alarms. Investigation into a PLC-based control system.	(e)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
COMMUNICATION Students will need to know about the different methods of communication. This topic can be delivered in the context of modern data communication. The twisted pairs, used for short distance computer networking, fibre optic cables for long distance networking, radio waves for wireless networking, and infra red beams for connecting notebook computers to printers. Students need to be familiar with the advantages and disadvantages of each system. They should know how communication systems operate, in particular the need to know about: • analogue and digital systems and conversion • modulation and demodulation • bandwidth. The operating principles of modems and cellular phones are well documented, and a block diagram approach is appropriate. As far as mobile phones are concerned the ideas of cells centred on a radio mast, with the phone being passed from cell to cell as it moves, the concept of packaging voice data into small packets and sending each packet separately, and then rebuilding the voice signal is important. The concept of frequency hopping is also important.	Investigation into computer communication via cable radio and fibre optics. Investigation into modems and cellular mobile phones. Note that there is little information to be gained from taking such devices to pieces since the information that the student needs is all about the function of the electronics and its programming. www.howstuffworks.com provides a good starting point for this section on communication.	(e)

Section 4.5 Health and safety factors

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Health and safety issues are a key consideration in the design and production of engineered products. For each of the systems students investigate, they must be aware of the relevant health and safety factors and how these must be taken into account in the product design. Some form of introduction will be needed to this topic, perhaps early on in the delivery of the unit, flag up the issues and identify that the subject will be considered in the context of the other topics covered in the unit. There are two elements to the health and safety topic with regard to the design and manufacture of engineered products and systems. Firstly the health and safety issues involved in making the product, and secondly the health and safety issues involved in using the product. The issues of making products are related to the issues covered in *Unit 1: Engineering Materials, Processes and Techniques*, namely the risks of injury from working in workshops and factories. This covers all the usual items from tripping over boxes left in walkways to the need for guards on machinery and personal protective equipment (PPE). Clearly certain processes involved in certain products involve specific risks such as spray painting cars. The risks associated with using products, on the other hand, are dependent upon the product in question and will vary from product to product (say one is an electric drill and the other a mobile phone). In the case of the mobile phone there is the often-aired potential risk from electromagnetic radiation.	When investigating and covering the other topics in this unit the issues of health and safety should be covered. This is not a section to be delivered on its own, in isolation from the other sections.	(e)/(f)

Requirements for each assessment criteria

NOTE: The requirements for each assessment criteria may refer to the example brief given in the GCE in Engineering sample assessment material.

Students will need to submit evidence of their work for each of the following practical activities using the brief given to them.

Activity 1

(a) Measure and record the behaviour of a structural material when subjected to a destructive tensile test. Process the data and determine the tensile strength and modulus of elasticity of the material. Determine the internal forces present in a loaded-framed structure. Calculate the factor of safety in operation and the dimensional changes caused by the loading.

Note: It is expected that students should have used the equipment individually and that a timetable will be generated to allow each student access to the experimental equipment for sufficient time for them to make the required measurements on their own. It is not acceptable for students to carry out this work as part of a group.

Tasks 1 and 2

For this section, students should measure the length and diameter of the sample to be investigated. They should note the accuracy of the measuring instruments and note any calibration information, even if this is to note that the instrument is not calibrated. They should determine and indicate the tolerances on these measurements.

Using proprietary test equipment they should measure the extension of the sample as force is applied to it. This should be recorded either as a table of results or as graphs produced by the equipment. Note that this is not the final outcome. It is for the student to decide how best to take into account the variations in values recorded for the specimen. The final values used to plot the graph described in the next paragraph should reflect the limitations of the measurements taken.

For selected values of force and extension, students should determine by calculation, and using the measurements made earlier, the appropriate values of stress and strain for the sample at each value of force. They should then produce a graph, by hand, of stress against strain in a conventional format. All values should be expressed in engineering format and have appropriate SI units attached.

The graph should be produced to an appropriate scale and be clearly labelled showing scales, units, values, labels and title. The graph should indicate the accuracy of the measured results, in a conventional format.

The student should use the experimental results and graph produced to determine a value for the ultimate tensile strength and modulus of elasticity of the material tested. The values quoted should be accompanied with an indication of the experimental error. This value should be compared with published values and some judgement on the likely accuracy of the experimental work given. Values should all be expressed in engineering format and have appropriate SI units attached.

Task 3, 4 and 5

For this section, students should analyse the pin jointed framework shown in the task and use the values for the sample analysed in tasks 1 and 2, as well as the information presented in the task to determine the forces present in each member of the framework. Students should use either a scale drawing to analyse the structure, or mathematical analysis to determine the values. They should indicate clearly which members are in tension and which are in compression.

Students should identify which member of the framework is most heavily loaded and, therefore, they should work out a factor of safety for the framework as a whole.

Students should calculate a value of extension for each member within the framework. Values should all be expressed in engineering format and have appropriate SI units attached.

Activity 2

(b) Explain the function of a given electro-mechanical system.

Task 1

For this section, students should provide a detailed analysis of the purpose and function of the electro-mechanical product stated. They should indicate how well the product fulfils the purpose in terms of function, aesthetics, price and availability. For example, using the oscillating fan, students may state that the oscillating fan is intended to make people in a hot room feel cooler and that it works by moving still air, making the room feel cooler to the occupants without actually reducing the temperature. They should then compare it with other products that potentially serve the same purpose.

(c) Investigate the sub-systems and elements that comprise the given electro-mechanical system. Describe using a block diagram, their function, relationships and the transfer or conversion of energy that might occur.

Task 2

For this section, students should produce a well-presented block diagram which broadly follows the normal engineering standards. The block diagram should cover all energy conversions and all aspects of the function of the product, as well as indicating all inputs and outputs. For example, in the case of the oscillating fan it will not only include the rotation of the fan but also the mechanism by which the fan is made to oscillate. It will include heat losses in the motor and friction in the mechanisms but not necessarily heat lost to the air caused by the fan blades.

Students should also produce an analysis of the health and safety issues involved in the use of the product. In this example this should include issues such as risk of electric shock and injuries due to contact with moving parts. It should also take into account hazards which are under the control of the user, such as the extra potential danger attached to the use of the product in for example the kitchen or bathroom.

(d) Provide an alternative design solution that fulfils the basic functions of the system.

Task 3

For this section, students should compare the stated product with another product that potentially serves a similar purpose. For example, they may state that the oscillating fan is intended to make people in a hot room feel cooler and that it works be moving still air, and making the room feel cooler to the occupants without actually reducing the temperature. They may identify that by oscillating, the device attempts to provide an equal movement of air in all parts of the room. They might compare it with a portable air conditioning unit in terms of function, purchase price and running costs.

Activity 3

(e) Respond to a design specification for a monitoring or control system by producing an appropriate and feasible design solution that takes account of its operational requirements and health and safety considerations.

Task 1

For this section, students should provide evidence of having approached the design task in a logical manner, indicating the steps that they took in producing the design. The design information may include information on different sensors, signal conditioning devices and output devices, which can be used. There should be a general block diagram showing the outline of the system and a detailed block diagram indicating the particular design solution adopted. There should be an explanation indicating why certain components or techniques were used in the design rather than alternative components or techniques.

A detailed explanation of how the system works should be provided, which refers to typical components and their responses to changes in the measured variable. Students should also provide a detailed explanation of how and why the proposed system compares with the design specification, and in particular how it will function within the tolerance stated in the brief.

(f) Select suitable materials and components for the design solution taking into account possible production and cost constraints and health and safety considerations.

Task 2

For this section, students' designs should include the use of components, materials and techniques which are fit for the stated design and its purpose. To come to a final detailed design solution students should select a specific set of components.

Students should be given a copy of the brief, so they can carry out relevant research before they start their examination. They may select specific components from catalogues and find relevant information in data sheets, but they are **not** allowed to take any of that research into the examination. This will have an effect on the level of detail that they include in the examination itself. Part numbers and exact characteristics do not need to be remembered, but more general information about the components will need to be remembered.

For example, students may choose to use a thermistor as a temperature sensing element. They may justify this in terms of function and price. In this case, an explanation of the tolerance of the measurement possible with this device should be part of the explanation. In other words, will it respond to temperature changes of $\pm 2.0^0$C. Students should also indicate how the design would be manufactured, perhaps as a one off, or in a small batch (unless the task specifies the quantity). Any issues that make this design easy, or otherwise, to produce should be indicated. The overall cost of the solution should be estimated and compared with proprietary methods of achieving the same function.

Health and safety issues in manufacturing and using the system should also be outlined. For example, in this case the risk when soldering components together for example, burning fingers, ingesting lead and fume inhalation, should be stated and the need to ensure that any mains voltages, output signals, need to be isolated to minimise the risk of electrocution when the system is in use.

Unit 5: The Engineering Environment

Unit aims

A key aim of this unit is for students to gain a deeper understanding of how legislation and documentation of various types impact on the way engineers design, manufacture and maintain products. Students will study how engineering products and activities affect the environment, and investigate how technical advances affect an engineered product or service. Students will also have a fuller opportunity to make suggestions for improvement on the basis of a technical investigation of an engineered product or service.

The tables on the following pages are an expansion of the 'What you need to learn' section from the GCE in Engineering specification. Each section has been expanded to provide the following additional information:

- coverage and depth of delivery for learning
- possible learning activities
- content mapping to the appropriate assessment criteria.

This section must be read in conjunction with the corresponding unit in the Edexcel GCE in Engineering specification.

Section 5.1 Legislation and documentation in engineering

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
REGULATIONS AND STANDARDS Regulations and standards define how a product should perform. These normally include safety standards, codes of practice, international and national standards and standards of performance. Many of the areas covered in *Unit 2: The Role of the Engineer* regarding legislation will provide students with a base from which they can then examine and produce evidence of relevant regulations and standards appropriate to the engineered product or service they are investigating. During their investigation, students may need to consider one or more of the following as appropriate to their product.	When visiting the chosen company, students should obtain blank copies of typical contracts that are used in the design or manufacture of their product. For instance, sample job descriptions and contracts of employment. When producing their assignment, students could provide details of typical contracts for their product or service.	(a)/(b)
Electromagnetic compatibility (EMC) Electromagnetic compatibility is the ability of a device or system to function without error in its intended electromagnetic environment. Students could look at examples of electromagnetic compatibility problems such as a computer interfering with FM radio reception, operating a vacuum cleaner causing 'snow' on a TV, or a radio buzzing when driving under a power cable. There are three essential elements to any EMC problem. There must be a source of an electromagnetic phenomenon, a receptor (or victim) that cannot function properly due to the electromagnetic phenomenon, and a path between them that allows the source to interfere with the receptor. Each of these three elements must be present although they may not be readily identified in every situation.	Identify a variety of problems associated with electromagnetic compatibility using some of the examples shown opposite as a starting point for their studies. Students could attempt to solve EMC problems by identifying at least two of the three elements shown opposite.	

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Electromagnetic compatibility problems are generally solved by identifying at least two of these elements and eliminating (or attenuating) one of them. Potential sources of electromagnetic compatibility problems include radio transmitters, power lines, electronic circuits, lightning, lamp dimmers, electric motors, arc welders, solar flares and just about anything that utilizes or creates electromagnetic energy. Potential receptors include radio receivers, electronic circuits, appliances, people, and just about anything that utilizes or can detect electromagnetic energy. **Radiation emissions** A simple definition of radiation should be given here with an explanation of the main sources and the effects it has on the environment. Radiation is energy moving through space. Sunshine is one of the most familiar forms of radiation, but it also comes from other natural and some man-made sources. The most familiar and the largest source of man-made radiation is medical X-rays, although people often think of radiation from nuclear power stations. There is a range of different radiation. The lowest energy and least harmful are radio waves. Higher-energy level sources include cosmic radiation that passes through our atmosphere from outer space. We are also exposed to radiation from certain rock types, radon gas and radioactive material in our food and drink. Students should be aware of the most common sources of radiation emissions from devices such as televisions, microwave ovens and mobile phone masts.	Students could produce detailed explanations of natural and man-made types of radiation. Internet-based research could be very useful including an examination of nuclear power plants. Recent news events could promote class discussion to raise an awareness of radiation emissions and the controversy surrounding this issue such as mobile phones and the building of new masts. Students could examine issues surrounding their product or service and include these in their assignment.	(a)/(b)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Energy efficiency Students need to be aware that by being energy efficient, they can reduce their energy needs and reduce their contribution to climate change. There are many ways this can be achieved, but their contribution will make a difference. Just over a quarter of the UK's carbon dioxide emissions every year originate from the energy used to heat and light our homes, and run an increasing number of household appliances. Almost all energy comes from fossil fuels. Burning fossil fuels releases harmful gases that change our climate.	Students could investigate the many ways of saving energy and becoming energy efficient. Students could carry out an activity to examine the energy efficiency of their home. When examining their product or service they could identify elements of efficiency or inefficiency. The Energy Saving Trust website — www.est.org.uk will provide a wealth of useful information regarding the issue of energy efficiency. Students can visit the Envirowise website — www.envirowise.gov.uk to access legislation relevant to engineered products.	(a)/(b)
Waste disposal Students need to be aware that every company has an impact on the environment and environmental legislation has been developed to ensure that the impact stays within acceptable limits. Students could be taught about the two approaches to reducing environmental impact: • eliminating or reducing the environmental impact • treating the cause before it can effect the wider environment. In England and Wales alone, over 400 million tonnes of waste are produced every year. Students should be aware that careful management of waste is needed so its effect on the environment and human health is minimal. Waste management has improved over the past 25 years as a result of better regulations and positive responses from industry. Students should be made aware of the government's policy on waste management and the role of the environmental agency.	Students need to discuss environmental issues with their chosen company and provide evidence of the issues involved in the design or manufacture of their engineered product or service. A visit to the Environment Agency website — www.environment-agency.gov.uk will provide information on areas surrounding waste management and disposal. Students need to identify the category of the product or service that requires CE markings and then provide evidence of how it meets those requirements.	

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students should also be aware of the different types of waste that is disposed by industry and in the home, for example oils and household materials. Hazardous and non-hazardous waste should also be investigated. Students should be reminded of the purpose of CE marking on products. This is a manufacturer's declaration that the product complies with the essential requirements of the relevant European health, safety and environmental protection legislations. CE markings on a product indicate to government officials that the product may be legally placed on the market in their country. Students should investigate a range of products requiring CE marking. Businesses wanting to export products to the European Union and European Free Trade Association member states producing goods in one of the 22 groups of products, then CE markings are required. The European Union's 'new approach directives' are mandatory for all member countries to enact through national legislation. This legislation requires manufacturers to display CE marking on their product, packaging and accompanying literature. Where a new approach directive is in force, it is (with few exceptions) an offence to place a product on the market without CE marking. The manufacturer is **legally responsible** for ensuring that the product conforms to the requirements of the directive and for applying CE marking.	Students could examine the ways in which our environment is polluted. They could also give real-life examples of such forms of pollution and look for issues surrounding their own product or service. Students could examine the legislation surrounding pollution such as the Control of Pollution Act, Environment Protection Act and the Noise Statutory Nuisance Act, and apply it their product or service. Students could investigate the causes of global warming and create discussion on this very important issue. How can we help to reduce the greenhouse effect and what is industry doing to assist? What are the pros and cons? Discussion could be started with the engineer for your chosen product or service about what effect it has on the environment. As part of the student's assignment, alternative forms of energy could be discussed in manufacturing their product or delivering their chosen service.	(a)/(b)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
DOCUMENTATION There are many forms of documentation that are used during manufacturing and other engineering activities, to support engineered products and services. For example, during their investigation, students may need to consider one or more of the following as appropriate to their product. **Work procedures** Students should be introduced to work procedures carried out in industry by examining the key functions in business such as manufacturing/production, planning and control, purchasing, finance, distribution, marketing, sales, quality, personnel and design development. Students need to understand why there are work procedures in place. They need to understand that products need to be tracked during production and who is accountable for each particular area associated with that product or service.	In examining work procedures, students could identify those procedures that relate to their product or service and produce examples for their assignment.	(a)/(b)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Engineering drawings In studying this section of the unit, students should be reminded of the standards required when producing drawings. These can be found in the following documents. PP 8888-1:2005 Drawing practice: a guide for schools and colleges to BS 8888:2004, technical product specification. PP 8888-2:2001 Engineering drawing practice, Part 2: a guide for higher education to BS 8888:2000, technical product documentation. Students should also know about procedures for monitoring engineering drawings. Typically, a drawing has a drawing file card that records data related to the product. A drawing can be issued uncontrolled, which means that it is guaranteed at the date of issue and anybody can have one with a legitimate reason. If a technical controlled drawing is issued, anyone who needs to use this drawing will be named on the drawing file card and any amendment will also be given to that person at a later stage. The old drawing would then have to be returned. Copies returned are stamped superseded with a date and all copies, except the master which is archived, are destroyed. If a company has a new employee then everything is in place. The new employee should be completing procedures the same way as their predecessor. Also, documents are signed-off by at least two people to ensure that somebody else knows what's going on or at least what is happening. More often than not, many companies now hold review meetings to discuss ongoing work.	Students could attempt to produce drawings to a required standard as an activity. When discussing their chosen product or service, students need to identify how the drawing is tracked or monitored throughout its life.	(a)/(b)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Quality manuals Students should understand that a quality management system will provide an organisation with a set of processes that ensure a common sense approach to the management of that organisation. The system should ensure consistency and improvement of working practices which, in turn, should provide products and services that meet the customer's requirements. ISO 9000 is the most commonly used international standard providing a framework for an effective quality management system. **Repair manuals** Students should be aware of Preventative Maintenance Programmes. These maintenance checks can be done on daily, weekly and longer intervals to prevent unscheduled stops in production due to breakdown. Many organisations will also have repair manuals, where set procedures need to be followed when a machine malfunctions. **Operating manuals** Operating manuals are usually supplied with the machine upon delivery. Many machine suppliers also provide training as part of the package. These give details of starting up and maintenance requirements. They are there as a back up after initial training or installation of machinery.	When visiting their chosen company, students need to take part in discussions with the engineer regarding the systems that are in place to assist the engineer in producing the product or service, including examples of documentation relating to the companies' quality, maintenance and operating manuals. Students will not be required to produce details of whole manuals, but samples of the relevant sections appropriate to their product or service.	(a)/(b)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Product specification Students should be taught how to read and use product specifications. Having all the right information is vital if an engineered product or service is to match the client's requirements. Key areas need to be discussed, such as size, shape, form, materials, components, process methods, quantity requirements and timescales. Many organisations have documentation relating to product specifications, for example a Master Quality Specification would describe the product or service, then provide details of any engineering drawings or specific materials used for the product or service. It will also provide details of the product's function and methods of inspecting or testing the product or service.	Students could produce examples of product specifications and then examine specifications used for their product or service. When tackling section 5.2, the environmental impact of the engineering activities, students could investigate local environmental issues and use them to initiate discussion amongst colleagues. Again, are any of these issues relevant to their product or service? Details of these issues will need to be produced for the assignment.	(a)/(b)

Section 5.2 The environmental impact of engineering activities

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
All engineering activities have an impact on the environment. For example, during their investigation students may need to consider how their engineered product or service impacts on the environment by considering some of the following as appropriate to the product. **Energy efficiency** Much of the work discussed in section 5.1, legislation and documentation in engineering, referring to energy efficiency is relevant for this section. **Design consideration** Students should be made aware of the effect that industry has on the environment and how they then need to make appropriate considerations at an early stage when designing. Students should be taught to explore a range of alternative methods of manufacture or choice of material, no matter how obscure, to protect their environment. **Pollution** Pollution of the environment encompasses pollution of the air, land and water. A major concern in relation to pollution focuses on the harm that can be caused to living organisms. Students should be made aware of the Environmental Protection Act (1990) that defines pollution of the environment in relation to humans as including offence to any of our senses or harm to our property. A link can be established with the Environment Agency as this body is responsible for the environmental protection of air, land and water in England and Wales. Students should explore the causes of air pollution such as harmful gases which are formed from the degradation of waste on waste tips and in landfill sites and carbon dioxide which is created as a result of burning fossil fuels.	Comparison of energy efficiency of computer monitors would be a suitable investigation for students to carry out. Students could look at the maker panels on a standard cathode ray tube monitor and a flat screen monitor, with a view to comparing the power consumption of each. They could also consider the various power saving options available via the control panel in windows, which enable the monitor to operate in a standby and power saving mode, to see what effect this has on power consumption. Students can, therefore, analyse the energy efficiency of each device. Similar comparative activities could be carried out on a range of other products such as mobile telephones and laptop computers. While investigating the work of engineers and products or systems they are associated with, students can research the environmental impacts associated with these activities.	(c)/(d)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students should also explore the causes of land pollution. One of the major causes is the disposal of materials that do not degrade. Students should also be made aware of the engineering skills required to ensure the safe treatment of water and waste water from both domestic and industrial sources. **Global warming** Global warming and the causes of the 'greenhouse effect' need explanation. They are understood to have resulted from high levels of carbon dioxide, methane and chlorofluorocarbons (CFCs). **Renewable resources** Through earlier studies, students should be aware of the need to use renewable sources of energy, as our main sources of energy such as coal, gas and oil are slowly depleting. Students should examine renewable sources of energy such as wind power, tidal flow and solar energy from the sun's rays. **Impact on local residence** Students should be aware of the effects that industry has on local residents. When teaching this section, high-profile incidents could be used as a source of discussion, such as landfill sites, nuclear power stations and overhead electric cables. **Transport infrastructure** Students should be taught about the effects of the transport infrastructure. Again, high-profile incidents could be used as a topic of discussion. Also, the ageing rail network and its need for updating, along with the need for more runways to cope with the increasing amount of air travel.		(c)/(d)

Section 5.3 The application of technology in engineering

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
The development of technological advances and the development of new materials and techniques have an impact on the products and services that engineers create or modify. For example, during their investigation, students need to consider some of the following as appropriate to their engineered product or service. **Mobile communications techniques** The industry has experienced remarkable growth in the last decade or more and the prospect is for even more growth in the future. Students should be made aware of the fact that there is a wealth of employment in this area with a serious shortage of suitably qualified technicians and engineers. Students should be made aware of the variety of mobile/wireless technologies and the key benefits, particularly the increased efficiency, greater flexibility and mobility for users, reduced costs and the ability to stay in touch without carrying cables or adaptors. The types of technology that need to be considered are Local Wireless or Personal Area Networks, Wireless Networks and Mobile Phone Networks. In considering Local Wireless or Personal Area Networks, cordless products such as mice and keyboards that use radio or infrared technologies should be discussed. Also, the relatively new and versatile short-range radio technology called Bluetooth. This wire-free connection between mobiles, PDAs, keyboards, laptops and printers increases flexibility and convenience. Connected Bluetooth devices can synchronise downloads and uploads in the exchange of information. Wireless networks enable workers to share a single connection across the office or company and to remain online if laptops/PDAs are moved around the wireless-enabled space.	Students are probably best placed to understand such a topic as mobile communication techniques with many of them owning some form of system. Students could draw on their own experiences with this technology and form discussions with colleagues. There is an opportunity to contact the retail industry to identify the latest communication techniques. When working with their engineer, techniques need to be identified that have aided the design and/or manufacture of their chosen product or service. When analysing products students could use an evaluation matrix to check fitness for purpose.	(e)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
The mobile phone networks are increasingly used for much more than voice calls. The improved data transfer speed capability of handsets and networks enables the development of increasingly sophisticated mobile phones and handheld PCs. Mobile handsets can now offer access to email, short messaging service, instant messaging, WAP, multi-media services and global positioning systems (GPS). Students should consider what technologies are used when their product or service is being designed and/or manufactured. **Computer networks** Students need to understand the basics of a computer network and that it is formed when computers are connected together or to peripherals such as printers, scanners or modems. Students also need to be aware that businesses need to invest in more computers as it is more practical and cost effective to share resources such as printers and access to common files. Students need to understand what a computer network does, its advantages and disadvantages and the types of networks available. Computer networking is one of the key ways in which information can be shared to make a business more efficient and profitable. The financial benefits are reduced costs of hardware and centralised database to improve productivity. The practical benefits are simultaneous access to data files, standard versions of manuals that can be made available to everyone, fewer IT technicians required as work can be centralised, and data can be backed up from a single point regularly. Types of network that need to be considered are Local Area Networks (LAN) such as peer to peer and client/server types. Also Wide Area Networks, Virtual Private Networks, intranets and extranets.	Scenarios could be set for students to identify the appropriate type of network, giving reasons for their choice. Scenario: David's business doesn't have a network. His staff each have their own printer attached to their own PC. They transfer data amongst themselves via floppy disk with some employees backing up their data, but not all. Everyone has a copy of everything, the trouble is nobody knows who has the most up-to-date version. How can these problems be solved? Also, when visiting their chosen company or interviewing their engineer, it is important to identify the system used by the engineer to assist with the design and or manufacture of their product or service.	(e)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
New and smart materials		(e)
Students should understand that a smart material responds to environmental stimuli with particular changes in some property. Sometimes they are referred to as responsive materials. Smart materials change their properties (either mechanical, electrical or appearance), their structure, composition or function. Students need to understand that these materials are embedded inside systems or products. They change the way these systems perform in ways which can vastly improve the performance of the product as a whole. Students should be aware of the range of materials available such as photochromic, thermochromic and electroluminescent materials. Also materials such as polymorph, magnetic sheet, shape memory alloys, metal paper and quantum tunnelling composites. When examining these materials, students should be made aware of their uses throughout industry.	Centres could supply a range of smart materials for students to analyse and develop possible ideas for their use. A visit to the Technology Enhancement Programme website — www.tep.org.uk can prove a very useful resource. A definition of each of the smart materials can also be found on the Design Insite website — www.designinsite.dk.	
Electronic components		
Students should be made aware of the fact that electronics and the development of sophisticated components underpin life in the 'Information Age'. Electronics is all around us. It is pervasive across all levels of society; in our day-to-day lives, in education and in medical science, to name but a few. New technologies are continually emerging and being developed into products and services that we use and interact with. Within industry in the UK, electronics plays a vital role as the basis for innovation, and sustaining competitiveness in the global marketplace. With the reduction in size of many components and the production of powerful integrated circuits, the technology is delivered to our fingertips in the form of smaller mobile phones, PDAs, video phones and portable DVD players.	Students could investigate the development of electronics over the past decade and examine some of the latest technology available. A visit to the Department of Productivity, Energy and Industry website — www.dti.gov.uk will generate interest and provide links to further sites of relevant information. Again, links should be made to the student's product or service.	

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Optical materials Students should be made aware of the different types of materials used in the design and/or manufacture of engineering products or services. Students are not required to explain how these materials work. Students should be made aware of materials such as fibre optics that are used as a means for 'piping' light, and information in the form of encoded signals, over very long distances. It is used over long distances because it gives very low light loss or signal attenuation. Other materials to consider are liquid crystal displays, used in the displays of calculators, laptop computers, and television sets; they are an important component of high-strength fibres and they occur naturally in cell membranes of biological systems. Their greatest technological impact has been in displays, where liquid crystals are second only to the cathode ray tube in a multi-billion dollar market. Their greatest potential is in flat-panel television, optical computers, and integrated optical devices for communications. Also, students need to consider mirrors, reflectors, lenses and phototransistors as used in common optical products such as torches, cameras, CD players and measuring instruments.	When investigating optical materials it is stressed that great depth is not required but simply an awareness of such materials. A visit to the Technology Enhancement Programme website — www.tep.org.uk will provide resources for optical systems. Again, students can analyse a range of engineered products or services and offer suggestions for modifications. When visiting their chosen company, students can discuss appropriate modifications or improvements with their engineer.	(e)

Section 5.4 Evaluation and modification

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students should use their knowledge and understanding of *Unit 2: The Role of the Engineer*, Section 2.4 to inspect, test, measure and compare products to their product specification to ensure that they comply with the standards required. Students will also need to be reminded how to use an evaluation matrix. This is an easy way for students to compare their final product with its design specification. Students will need to recall a variety of drawings techniques to enable them to describe product modifications that will improve the design or performance of the engineered product or service.	Students can analyse a range of engineered products or services and offer suggestions for modifications. When visiting their chosen company, students can discuss appropriate modifications with their engineer. When analysing products, students could use an evaluation matrix to check fitness for purpose.	(f)

Requirements for each assessment criteria

It is essential that students choose a different engineered product or service from that investigated in *Unit 2: The Role of the Engineer*. It is important that students have access to a wide range of engineering contacts and this unit provides an opportunity for students to widen their engineering experience. Students will need to identify an engineering product or service that will allow access to the higher mark bands in all of the assessment criteria.

Assessment evidence (a)

Evidence of standards and regulations that govern the engineered product or service, and their influence on the engineering activities.

For this section, students' evidence should include information about the engineered product or service and information about the standards and regulations which impacted on the engineered product or service. This evidence should consist of a well-reasoned explanation. Students should identify relevant regulations and standards and explain and justify how the regulations and standards impact on the engineered product or service.

Assessment evidence (b)

Evidence of the types of documentation used to support the engineered product or service during its development, manufacture and use.

In this section, students' evidence should consist of information about the different types of documentation used by the company to support a particular engineering product or service. This evidence should consist of a well-structured explanation. It should identify, describe and justify the relationships between the documentation and the engineered product or service.

Assessment evidence (c)

Evidence of how the requirement for energy efficiency is taken into consideration and its effect on the manufacture of the engineered product or service.

For this section, students' evidence should consist of information about the product and how it related to energy efficiency. This evidence should consist of a well-reasoned explanation written in the student's own words. Students should describe, explain and justify the energy efficiency measures taken by the company that are relevant to the product or service and how they impacted on the manufacture of the product or service.

Assessment evidence (d)

Evidence of the environmental impact caused by the manufacture or maintenance of the engineered product or service.

For this section, students' evidence should consist of information about the impact of the manufacture **or** maintenance of the engineered product or service on the environment. It should be based on the information obtained from the company, and consist of a well-reasoned explanation. Students should identify, describe and justify the environmental effects of the manufacture or maintenance of this product or service.

Assessment evidence (e)

Evidence of the technology and techniques used within the engineered product or service during its development, manufacture and maintenance.

For this section, students' evidence should consist of information about the technology and techniques used within the engineered product or service or its manufacture and maintenance. It should consist of a well-reasoned description, explanation and justification of the technology involved with the product. Students should discuss in detail the benefits of the technology and techniques that are within and associated with the engineered product or service.

Assessment evidence (f)

Evidence of an evaluation of the engineered product or service, and suggestions for modification to improve its design or performance.

For this section, students' evidence should consist of information about the engineered product or service and modifications which can be made to improve the engineered product or service. Students should produce a well-reasoned description, explanation and justification. The evidence should be based on a structured evaluation of the engineered product or service and may include sketches. The suggestions should be realistic and justified and on the basis of how they improve the design or performance of the engineered product or service.

Useful tips when gathering information for each assessment criteria

It is essential that students choose a different product or service from that investigated in *Unit 2: The Role of the Engineer*. However, the company could remain the same but then students have to ensure that there is no duplication of work across the two units. If there are a number of industrial links, then students could switch companies to gain an even wider experience of the engineering environment. Students will need to identify a product or service that will allow access to the higher mark bands in all of the assessment criteria.

Assessment evidence (a)

Evidence of standards and regulations that govern the engineered product or service, and their influence on the engineering activities.

Having established the activities carried out by the engineer that are centred around the product or service, students will need to examine the relevant standards and regulations. Students will need to draw on their knowledge and understanding of *Unit 2: The Role of the Engineer* and provide details of the standards and legislation. When interviewing the engineer or contacting them via email, questions need to be asked that will give the student a category that the product or service will fall under. The company may have documentation about their standards and legislation, therefore students will need to ask permission to summarise this information for their assignment providing details, for example, of the testing standards, any government bodies that have an influence of the product and why these standards and legislations are in place. When interviewing the engineer, students could get a real-life perspective of how the standards and legislation affect the product or service and the way the engineer performs their duties. Students should focus on at least one of the four areas in the specification — electromagnetic compatibility, radiation emissions, energy efficiency and waste disposal. Question the engineer about the most appropriate aspect to the product or service.

Assessment evidence (b)

Evidence of the types of documentation used to support the engineered product or service during its development, manufacture and use.

Students need to obtain documentation but with the company's permission. Using the six areas in the specification — work procedures, engineering drawings, quality manuals, repair manuals, operating manuals and product specifications, students could select at least one of these areas and investigate how it relates to their product or service. For example, how does the engineer track and control drawings throughout the design and manufacture of the product or service? Are there any manuals within the company that the student could extract appropriate details from?

This section requires students to record how their product or service is monitored throughout the company.

Assessment evidence (c)

Evidence of how the requirement for energy efficiency is taken into consideration and its effect on the manufacture of the engineered product or service.

When visiting their company, students should look closely at the working environment and try to identify energy efficiency considerations for their product or service. For example, where does manufacturing take place? How does the engineer try to minimise energy loss? Students should discuss these issues with the engineer and then carry out their own research in to energy efficiency.

Assessment evidence (d)

Evidence of the environmental impact caused by the manufacture or maintenance of the engineered product or service.

Students should use their knowledge and understanding of the many forms of environmental problems and apply it to their product or service by examining the processes used within the company. How has the performance of the product or service been influenced by design or manufacturing processes? Does the product or service impact on the environment through aspects of waste disposal and materials use?

Look at the location of the company and how it affects local residents and the transport infrastructure. Have there been any major transport developments as a direct result of the company establishing itself in the area? If possible, it would be ideal to select a company in the local community to allow students to interview residents about the effect it has had on their environment.

Assessment evidence (e)

Evidence of the technology and techniques used within the engineered product or service during its development, manufacture and maintenance.

Students should examine the five areas in the specification — mobile communications techniques, computer networks, new and smart materials, electronic components and optical materials. What technologies are in place at the company? What type of computer network does the company use? Are there any ongoing developments in materials? How does the engineer keep in touch when off site?

Assessment evidence (f)

Evidence of an evaluation of the engineered product or service, and suggestions for modification to improve its design or performance.

Students should provide evidence in the form of writing or drawings of how they evaluated their chosen product or service. Typical questions to apply to the product or service could be:

- Does the proposal answer the brief?
- Does is it suit its proposed function?
- Is the design or manufacture a success?
- Were there any problems during the design and manufacture and how were they overcome?

Suggestions for modifications could again be provided in the form of writing or drawings to show suggestions for modifications, giving reasons why these modifications will improve performance. Students should identify ways in which their product or service will help others.

- Will their product or service make it easier for the customer to use or for the manufacturer to produce?
- On reflection, are there any aspects of the design or manufacture that could be changed?
- Could you provide alternative solutions to the above problems?

Unit 6: Applied Design, Planning and Prototyping

Unit aims

The main aim of this unit is for students to demonstrate that they can apply all of the information they have learned while studying this programme by managing and completing a final project.

The tables on the following pages are an expansion of the 'What you need to learn' section from the GCE in Engineering specification. Each section has been expanded to provide the following additional information:

- coverage and depth of delivery for learning
- possible learning activities
- content mapping to the appropriate assessment criteria.

This section must be read in conjunction with the corresponding unit in the Edexcel GCE in Engineering specification.

Section 6.1 Research

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students should be taught to analyse the design problem they have been presented with by contextualising it and describing it in appropriate detail. The problem should have a real commercial use and should not be based on subjective personal choice. Students should use a 'client' whose design needs are directly linked to the described problem and reference should be made to the client, their needs and their opinions at various stages throughout the design and make process. Initial analysis of the problem should focus a student on what they need to find out in order to progress with their work, and starting points for this procedure should include an interview or discussion with the client to establish preferences and parameters that will be used to guide analysis activities. When analysing the problem, students must ensure that they focus closely on their client's needs, avoiding superficial and general statements that could be applied to any design situation. Students should be taught to analyse existing similar products in order to find out about materials, processes, construction methods and scientific and mathematical principals used in producing similar commercially manufactured products and it is important that evidence of high level technical understanding is shown and recorded by students. Students should be taught to use analysis of research, in order to inform the specification so that it is as relevant and meaningful as possible. Students should learn to focus closely on being highly selective in their research to ensure that the gathered information is useful in informing subsequent stages of design development and is directly relevant to the client's needs.	Consider a range of design problems and develop realistic briefs from them. Use peers as clients and establish the essential user needs of the briefs. Use peers as clients to develop relevant questionnaires and interviews to gather detailed information on user and performance requirements. Use a range of reference sources to collect relevant information on particular aspects of a chosen problem — only consider information that is directly relevant and will inform the specification. Examine a range of similar existing commercial products. Disassemble products where appropriate. Carry out market research to establish user preferences and the viability of the proposed product. Gather technical information on materials, systems, components etc from technical sources such as manufacturers' data sheets. Select only information that is relevant, informative and pertinent to the problem in hand.	(a)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Research notes should be focused and succinct and contain no worthless padding. Students should learn that appropriate research areas that could be useful to them include product analysis, market research, materials and component research scientific/engineering principals applied etc.		(a)

Section 6.2 Technical specification

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students should be taught the importance of developing a strong specification, as it will be influential throughout the design process because ideas and their development will be referenced to it to check that the design requirements and client needs are being fulfilled. Similarly, testing, evaluation and suggested future modifications will be referenced to the points of specification to check the success of the final outcome. The specification should be developed from the analysis of research and what essential requirements a student has decided must be included after studying the information gathered. The student should consult with the client to ensure that the specification points are mutually agreeable and that they meet the needs identified earlier. The specification should contain information on: • function of the product • user requirements • performance requirements • material and component requirements • quality and safety issues • scale of production and cost.	Produce a range of technical specifications for different design briefs that are based on analysis of research and the essential requirements of the design brief. Use short, succinct statements organised under key-point sub-headings. Identify and use technical points that are measurable and can be evaluated against the final outcome. Use a range of existing products and write technical specifications for each one. Identify measurable points that can be included and used to evaluate the developing design and the completed outcome against.	(a)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Any changes made to the initial specification should be justified and referenced to any compromises made as a result of client suggestions. Students should be taught that the specification should be organised logically and this could be achieved by using sub-headings for key points such as purpose, user requirements, performance requirements, materials/components, size, safety and quality, scale of production and cost. Points of specification should be technical and measurable where possible, so that testing and evaluation can be realistic.		(a)

Section 6.3 Generation of alternative ideas and their development

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
ALTERNATIVE DESIGN SOLUTIONS Students should be taught to use their creativity and technical skills in the use of engineering, scientific and mathematical principals to produce at least three alternative designs that address the design needs of the written specification and the client needs. Each idea should be realistic and different to each other and students should consider the following when producing your solutions: • the selection of appropriate materials from the information gathered in your research • how you will manufacture the product with the facilities available to you, but you also need to consider how it would be manufactured on a larger scale • ergonomics — safety, effectiveness and comfort for use. You need to consider regulations, codes of practice and standards that would apply to your initial ideas. Students should evaluate each idea produced against the specification and should use client discussion and feedback to ensure its suitability for its intended purpose. Students should be taught that it is not always necessary to produce complete solutions in their alternative ideas and depending on the complexity of a design proposal, high credit can be achieved by focusing on sub-systems or parts of design proposals. Students should be taught to explore a range of approaches to their work in this section, demonstrating their advanced knowledge and understanding of scientific and mathematical principals, technical detail, materials, techniques and processes used in the design and manufacture of commercially viable engineered products.	Use a range of topics to practice quick 3D representation of ideas that focus on the key points of the technical specification. Identify where scientific and mathematical principles could be used to justify engineering decisions made. Sketch part-designs to explore possible alternatives for sub-systems and individual design details. Consider and justify all design decisions using advanced technical expertise relating to scientific and mathematical data where possible.	(b)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
FINAL DESIGN SOLUTION Students should be taught that in developing a final design solution, they should bring together the best or most appropriate features of their design ideas into a coherent and refined final design solution that meets all of the requirements of the product specification and matches the client needs. Students should be taught to present evidence of the developed design having been altered and improved on in comparison to the original idea, which it may be based on. There should be evidence of evaluation and testing and client feedback influencing any design decisions made. It is not acceptable to simply take an initial idea and make superficial or cosmetic changes to it and then present it as a final developed solution. Students should be taught to include as much detailed information on all aspects of their developed design solution as possible, including choice of materials, processes etc. Students should be taught to use modelling as an important aspect of design development which could be used to test features such as proportions, scale, mechanical details, calculations and component values, sub-systems etc. Modelling can be done through the use of traditional materials, or through the use of 2D and/or 3D computer simulations/rapid representation techniques. Evidence of 'real-world' modelling should be presented through clear, well-annotated photographs. Development should produce a clear and detailed final design solution that includes technical details of materials, processes, techniques, fixtures and fittings that will be used during product manufacture.	Annotate accurate and detailed drawings to show how the design has moved on from an original idea through the results of evaluation and testing. Include as much technical, detailed information as possible, to illustrate knowledge and understanding of engineering activities one year on from the AS standard. Model aspects of design development to test features such as proportions, scale, and technical details Use traditional materials, and/or 2D and 3D computer simulations for rapid representation of the proposed solution Present evidence of 'real-world' modelling through clear, well-annotated photographs. Produce a clear and detailed final design solution that can be used to match the final outcome against. Present work using high quality communication skills that should have built upon those gained at AS level. Use 2D and/or 3D CAD to communicate details and features of the final design solution. Ensure CAD programs match standard drawing conventions.	(b)

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Where numerical values are included as part of the proposed solution, students should show how they applied their scientific and mathematical understanding to arrive at their outcome. Where materials are selected for use because of their scientific properties, they should show any relevant scientific and mathematical data they used in selecting the material. Students should present their work in this section using communication skills of high quality. Most students are skilled users of ICT and it is at this point that the use of 2D and 3D CAD would be appropriate, in displaying design details and features that can be highlighted and viewed from several angles easily and conveniently by using the power of ICT.		(b)

Section 6.4 Formative evaluation

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students should be taught to evaluate and use objective feedback from more than one source regarding the final developed design proposal to test the viability and workability of the final proposal. Evaluative statements should be based on points of specification and the client needs to justify the design decisions taken and recorded in detail by students. Constructive feedback should be referenced in detail at this point in order to justify and clarify final design details that may be compromises between the student's ideals and objective evaluation of the review body. Students should be taught the importance of effective annotation as a feature of this section to enable them to explain details of design thinking and to offer evaluative statements regarding design proposals.	Use peers to set up a constructive feedback group. Discuss and comment objectively on a range of design proposals from the teaching group. Assimilate evaluative comments and discuss how the final design proposal could be modified to improve its performance in light of the objective comments made from within the group. Plan for possible changes to the final design proposal and consider the implications in terms of cost, materials, components etc. Make detailed notes of any proposed alterations or modifications to be made.	(c)

Section 6.5 Planning for production

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students will need to produce a plan for production that considers all the manufacturing processes that would be involved in the manufacture of your product on a commercial scale. Students should be taught to produce a work order or schedule for the production of their engineered product and this could be done in the form of a flow chart or table and should include the order of assembly of parts or components, tools, equipment and processes to be used during manufacture in higher volume than 'on-off' production. Students should learn that, when commercial manufacturing processes are considered, they should ensure that they focus specifically on how they would be used with regard to their own product and not in generic terms. Students should learn that quality control points should be identified and quality checks should be described, which could be done through feedback loops as part of a flow diagram. Similarly, safety checks should be considered as part of planning for manufacture. Relevant British/European Standards and regulations for specific activities should be identified where appropriate. Students should be taught how to work out proposed costs for the production of their product. Students should be taught that planning implies the consideration of time, and it is essential that references are made to timings and deadlines during manufacture. If a Gantt or time chart is used as part of this section, it is important that students only chart activities relating to the manufacture of their product and not the whole of their design activities. Students must realise that planning is a forward-looking activity and this should be reflected in their use of language. Statements must not imply retrospective activities.	Investigate the order in which materials and components are prepared and processes carried out for a range of similar products during their manufacture. Investigate realistic timings attached to manufacturing processes. Identify quality control points and checks for a range of engineered products. Identify safety considerations for a range of engineered products during manufacture. Plan for commercial production in batch volumes. Investigate what regulations and standards should be applied to the product manufacture, and at what points they should be considered. Investigate how realistic costs are established and what difference high volume production makes to the cost of materials and components and to the end product.	(d)

Section 6.6 Prototype production

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students will produce a working prototype that fully matches your final design solution. A prototype is a first attempt at a representative-working product. Its primary function is to prove the design principles and to demonstrate how the product will look and function. Students should ensure that their final outcome relates fully to all of the features they have specified in their design solution, for example material, construction, finish. During manufacture, students should be taught to demonstrate their understanding of a range of materials by selecting, using and justifying those that are appropriate to their needs in terms of properties, working characteristics and scientific/mathematical data that were detailed in the technical specification and work-plan. Students should be taught demanding and high-level making skills in order to achieve the high category of marks in this section and to ensure that the final project outcome is fully functional. Students need to have a high level of safety awareness when working with machinery, tools and equipment. As evidence of the quality of manufacture, clear photographs must be submitted that show enough detail to support the credit awarded during centre assessment.	Produce a high quality product that meets the requirements of the specification and fully matches the final design proposal. Demonstrate an understanding of a range of materials through selection and appropriate use. Justify selection using scientific and mathematical reasoning Demonstrate demanding and high-level making skills appropriate to the expected level of response one year on from the AS standard. Record evidence of having understood the safety precautions required for use during product manufacture, which relate to personal and general safety and focus on specific materials, tools, equipment and processes. Use a series of photographs taken over a period of time during manufacture to highlight processes used and provide examples of precision and attention to detail that may not be readily noticeable in an image of the finished product.	(e)

Section 6.7 Final evaluation

Coverage and depth of delivery for learning	Possible learning activities	Assessment criteria this section links to
Students should be taught to test and evaluate the project outcome to check its fitness for purpose using commercial techniques where possible. They should learn that during manufacture, changes may have been made to the product and these should be recorded on the work plan, so that they can be referred to during evaluation. They should be taught to describe in detail any testing they carry out and results should be objective, and considered by the client or user group for their effectiveness. They should be taught to use field trials carried out by potential users over time as a reliable way of gathering objective feedback. They should be taught to use the results of testing as a basis for summative evaluation so that comments are as objective and unbiased as possible. Reference to specification points should form a significant part of the evaluation and detailed client/user group feedback should be used to determine the success of the final outcome. They should be taught to use information from testing, evaluation and client/user group feedback as a basis for suggesting modifications and future improvements to the product. Suggestions for modifications should focus on improving the performance of the product, or its quality and should avoid superficial, cosmetic changes.	Describe in detail, tests carried out — they should be focused on the performance or quality of the engineered product and justified to say why they are being carried out. Focus testing on the measurable points listed in the technical specification. Develop tests to use over an extended period of time and monitor results. Use test results and the views of potential users to inform the evaluation of the engineered product. Evaluate the product against the measurable points of the technical specification as objectively as possible. Ensure that statements are supported with evidence. Organise evaluation statements to avoid rambling and repetitive accounts that are descriptions of actions regarding problems encountered during manufacture, rather than evaluative statements based on previous tests and checks. Suggest modifications for improvement to the performance or quality of the engineered product using evidence from testing and evaluation and user-group feedback. Each suggestion should arise from a different evaluation or test. Record suggested modifications using sketches and annotation.	(f)

Requirements for each assessment criteria

Assessment evidence (a)

Evidence of appropriate research and the development of a technical specification.

Students should gather information from a range of different sources to help them with the problem they are dealing with, but they must focus closely on being highly selective in their research to ensure that they gather information that can be used to produce a strong and relevant specification. Their research should be focused on the problem and it should not contain any worthless padding. Lots of information downloaded from the internet, or cut and pasted from catalogues and databases without explaining or justifying why this has been done, will gain no credit and will waste time and effort.

Students should include information from areas such as product analysis, market research, materials and component research, but they must make sure that all information relates closely to the needs of their client and should contained technical information that shows their knowledge and understanding of materials, processes and scientific/mathematical principles.

The research and analysis of the information gathered must result in a technical specification for students' proposed engineered product and this should be done in consultation with the client to ensure that all important points are covered. Any changes that are made to the initial specification should be explained and referenced to any compromises made as a result of client suggestions.

The specification should be organised logically and this could be achieved by using sub-headings such as purpose, user requirements, performance requirements, materials/components, size, safety and quality, scale of production and cost.

The points of the specification should be technical and measurable where possible so that testing and evaluation can be realistic.

Assessment evidence (b)

Evidence of generation of at least three alternative design ideas and their development into a final design solution using appropriate current industry standards and conventions.

In this section the student's evidence should include realistic ideas that offer different proposals for different elements of the product requirements.

Students should include detailed, well-thought through work that is well annotated to include good technical understanding of materials, techniques, processes and scientific/mathematical content. Ideas can be sub-systems or part-ideas of a product and they should show continuity and progression in their work as one idea flows to the next.

The evidence should convey information to others of students' thinking so good quality graphical and annotation skills should be employed. Effective annotation is important in order to enable students to explain details of their design thinking and to offer formative evaluation of each design as it develops. They should include a review of each alternative idea, and should refer to points of the specification to ensure that the designs are appropriate to the needs of the client.

Students should justify their choice of materials, processes components etc with reference to scientific and mathematical data where appropriate.

From the range of alternative ideas, students should develop their final design solution that considers and uses sub-systems and/or part designs from previously considered alternative ideas, but which is significantly different. Students should show how the design has moved on and refined into a workable final engineering design solution that matches the points of the technical specification.

Students should produce a clear and detailed 'final design solution', which consists of a set of fully-detailed engineering drawings that complies to current standards and conventions.

Students' evidence may include the use of modelling as a development tool to test ideas for form and function and this can include the use of 3D materials (evidenced via photographs) or 2D and 3D CAD to test ideas against the specification requirements. There must be a point to modelling and students should explain why they have used it, for example to test proportions, materials systems etc.

The final design should include details of dimensions, materials, processes, equipment and calculations to be used during product manufacture, students should include enough information in this section to enable a skilled third party to make their product, as well as considering how the product would be produced commercially.

The final engineering design solution should be reviewed objectively against the points of technical specification to justify students design decisions and they should present this information in the form of detailed annotation.

Assessment evidence (c)

Evidence of discussions with other engineers (peer group) on your initial design solutions.

In this section the student's evidence should include discussions of their progress made so far in their work with other engineers or peers to clarify design details and decisions and to establish whether the final design solution meets the needs of the technical specification.

Students should organise their discussion in a logical way, so that it can be recorded and used appropriately as a reference tool if required.

The evidence should consider each point of technical specification, particularly those that are measurable and seek the opinions of others with similar levels of expertise to see whether the requirements of each point have been met. Feedback and objective evaluation of each point should be recorded in detail.

The evidence should assess the results of the discussions and feedback gathered, to determine the likely success of their final design solution. Any proposed modifications that arise from this should be added to their design solution at this stage.

Assessment evidence (d)

Evidence of planning for production.

In this section the student's evidence will likely include a plan for production for their engineered product that takes into account the manufacturing procedures, materials, deadlines, quality control, budgetary constraints and regulations and standards that need to be considered to produce a successful product.

Students should consider the scale of production and they should ensure they have focused only on a plan for manufacture that does not include any other aspects of the design activity.

Students should design a work order or schedule that shows the sequence of events followed during manufacture. This could be in the form of a flow chart or table and could include the order of assembly of parts or components, tools, equipment and processes to be used during manufacture in higher volume than 'one-off' production.

Students should identify quality control points and describe what checks would be made and they should also considered safety precautions and how they would be included as part of the plan for manufacture.

Students should identify any relevant regulations, standards and documentation that need to be considered and conformed to during manufacture and they should explain why they are important.

Students should make reference to realistic timings and deadlines during manufacture. This should be in the form of a Gantt chart or a time chart to give detailed information regarding activities and timings.

Students should remember that planning is a forward-looking activity and this should be reflected in their use of language. For example, terms such as 'the next step in the sequence will be' or 'the component is then bored' implies occurring in the future, which is appropriate. However, to say 'the next stage in the sequence was' or 'the component was then bored', are statements that imply activities that have already taken place, which constitutes a retrospective diary of events, this is not a plan and cannot be credited as such.

Assessment evidence (e)

Evidence of prototype manufacture.

In this section students will produce a high-quality prototype that is fully functional and matches all aspects of the final engineering design solution. Students will demonstrate high-level making skills that show precision in handling tools, equipment and processes and their selection of materials and components should be based on a sound understanding of scientific and mathematical information where appropriate.

Students should demonstrate their understanding of a range of materials by selecting and using those that are appropriate to the needs of their project in terms of properties, working characteristics and scientific/mathematical information that was detailed in the specification and work-plan.

Evidence of the quality of manufacture should include photographs that clearly show enough detail to support the credit awarded during the centre assessment. As photographic evidence is the only proof of manufacturing quality, it is essential that the images convey details of levels of difficulty and complexity of construction, so it is unlikely that a single image will achieve this. A series of photographs taken over a period of time during manufacture is the ideal way of highlighting processes used and providing examples of precision and attention to detail that may not be readily noticeable in an image of the finished product.

Photographic evidence together with a witness statement, can also be employed to support students' awareness of health and safety issues when working.

Assessment evidence (f)

Evidence of testing, evaluation and suggestions for modifications to improve the performance of the engineered product.

Students will include tests to use on their finished prototype that can be carried out under realistic conditions to see how successful their outcome is. Students should use the measurable points of their technical specification to check their product's performance and its quality.

Students should include a detailed description of the tests carried out and justification of their use.

Students should include field trials involving potential users to gather objective feedback.

Students should then use the results of testing as a basis for their final evaluation, so that their comments will be as unbiased and objective as possible. Their evaluation should refer to points in their technical specification and they should use detailed client feedback to support their commentary.

Students should use information from testing, evaluation and client feedback when making suggestions for modifications and future improvements to their engineered product. Suggestions for modifications should focus on improving the performance of the product, or its quality, and should avoid superficial, cosmetic changes that are subjective.

Suitable projects

The following suggestions for projects are not meant to be prescriptive and centres and students are encouraged to generate their own ideas for projects where possible, as they are more likely to be of focused interest when developed in this way.

Whatever project titles are chosen it is the levels of response produced from students that make them appropriate, or not, to the expectations of the standards set at A2 level.

1	ICT departments in schools often teach 'control technology' using expensive interface devices and buggies that are attached to the interface by umbilical wires that limit its ability to move freely.
	Design and make a free-roaming buggy that can be programmed to teach control technology without the use of expensive interface equipment.

2	Elderly or infirm people often have difficulty in switching on electrical equipment that involves physically moving to a device to operate it.
	Design and make a remotely controlled system that will allow one or more electrical devices to be switched on remotely. The system must operate reliably from a range of at least 15 metres.

3	Greenhouses rely on control of their environment to ensure that plants survive and prosper.
	Design and make a monitoring system that can automatically control the air temperature, humidity and soil moisture levels in a greenhouse. The system must be capable of being adjusted for different levels of sensitivity and should control the environment by switching on and off appropriate output devices.

4	Children who do not have the full use of their legs do not have access to pedal or treadle-driven toys.
	Design and make a small vehicle that is powered and steered using hand and arm operation only. The vehicle must be robust enough to support at least a weight of at least 40 kg.

5	A school design and technology department has a range of portable electric drills that are used by students. Sometimes it is necessary to drill holes more accurately than can be done by hand.
	Design and make an adjustable drill-stand that will accommodate a portable electric drill. The stand should allow easy movement of the drill in the vertical plane so that the holes can be drilled at right angles to the horizontal plane.

6	Some people with disabilities are unable to turn the pages of a book when they are reading.
	Design and make a device that will turn the pages of a book when activated by an electronic/electrical signal. The device should accommodate several sizes of book and should be portable.

7	Many minor but expensive accidents occur when reversing cars into private garages.
	Design and make a parking aid that will give a clear warning when the rear of a car reaches a pre-set distance from a garage wall. The warning may be detected from either inside or outside the vehicle.

8	Personal fitness has become an important goal for many people who visit gymnasiums on a regular basis, but this can be an expensive pastime.
	Design and make a 'bleep-test' fitness aid to improve stamina. The device should be programmable for up to 10 repetitions and 10 different levels of difficulty. Once started, the sequence of timings and increased levels of difficulty should progress automatically. The device must be portable so that it can be used anywhere and each level of difficulty must be clearly displayed.

9	A danger to people who take caravan holidays is the possibility of faulty portable gas bottles leaking poisonous gas into caravans, particularly at night when windows are likely to be locked and people are asleep.
	Design and make a device that will sense the presence of poisonous gas and give a warning to the occupants of a caravan that there is imminent danger. The design should take into account that some caravanners may be deaf.

10	A manufacturing company currently transfers billets of steel from their storage bay to CNC machining centres by hand and this has led to injury in the past when machinists have attempted to carry too many billets, or have dropped one on themselves.
	Design and make a transport trolley that is structurally triangulated with a factor of safety of 10, that will carry up to 20 billets at a time that are 150mm in diameter and 100mm in length. Each billet weighs 5 kg. The trolley must be no wider than 500mm for easy negotiation of factory walkways. It should be capable of being steered and braked and there should be no bending needed by machinists to load or unload the billets.