Unit 8: Engineering Design

Unit code: Y/600/0258

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit gives learners the opportunity to explore the design process and how it is applied within an engineering context.

Unit introduction

An understanding of how the design process operates within an engineering business is important for anyone considering a career in the design and manufacture of products. This unit provides learners with the opportunity to consider design in a holistic way. It combines study of the technical aspects of engineering design with wider issues such as the environment, sustainability and legislation.

The unit introduces and develops the concept of design for manufacture. It is crucial that the design process be effective. Success in the marketplace can be achieved only if products are fit for purpose, marketable and meet customer requirements. The importance of market research, generation of new ideas and the consequences of poor design are investigated.

Learners will also investigate the issues which influence whether a design proposal should be developed into a final solution suitable for manufacture. These issues include the impact of legislation and standards, the need to conform to environmental and sustainability requirements, materials selection and the types of manufacturing process available. On completion of the unit learners will understand the wider implications of engineering design and the reasons why it cannot be carried out in isolation from the rest of the manufacturing/production process.

The unit content is linked together through a practical task which starts with learners interpreting the requirements of a customer and producing a product design specification (PDS). This is followed by an investigation into the legislation, standards and reference sources that are used by designers who work in manufacturing engineering. This knowledge is then used to influence the production of their own design proposals. These proposals are refined and developed into a final design solution which meets the requirements of the customer. Design ideas will have been communicated using a number of techniques including sketching and formal engineering drawing, design calculations and written commentary.

Learning outcomes

On completion of this unit a learner should:

1 Know how the design process operates when dealing with customers

2 Know the impact that legislation, standards and environmental and manufacturing constraints can have on the design function

3 Be able to prepare design proposals that meet the requirements of a product design specification

4 Be able to produce and present a final design solution.

Unit content

1 Know how the design process operates when dealing with customers

The design process: triggers eg market pull, demand, profitability, technology push, innovation, market research; process of design for manufacture; decision making; use of new technologies eg computer aided design (CAD), simulation, rapid prototyping, computer integrated manufacture (CIM); lines of communication

Customer: customer/client relationship; types of customer eg external, internal; requirements of customer eg performance specifications (physical dimensions, mass), compliance to operating standards, reliability and product support, end of life disposal, production quantities (custom built, modification to an existing product, small batch, large volume)

Product design specification (PDS): analysis of customer requirements; production of an agreed PDS; documentation eg physical dimensions, materials, mass, operation and performance

2 Understand the impact of legislation, standards and environmental and manufacturing constraints on the design function

Legislation and standards: relevant and current legislation, standards and codes of practice eg British Standards (BS), electromagnetic compatibility (EMC) directive, European legislation (European Conformity (CE marking))

Environmental and sustainable constraints: energy efficiency; environmental impact; constraints eg Environmental Protection Act, Waste Electronic and Electrical Equipment Directive; end-of-life disposal eg refurbishment, recycling, disassembly, material recovery, non recyclable components

Manufacturing constraints: availability of resources eg labour, material, equipment; influence of physical and mechanical properties of a material in relation to manufacturing methods; cost effective manufacture eg set up cost (jigs, tools), production quantities; health and safety in the workplace eg Health and Safety at Work Act, Control of Substances Hazardous to Health (COSHH) Regulations

3 Be able to prepare design proposals that meet the requirements of a product design specification

Requirements of a PDS: interpretation of technical requirements eg operating performance, physical dimensions; interpret economic requirements eg production quantities, product life, market place positioning

Prepare design proposals: ideas generation eg research into existing products, freehand sketching, simulation, flow charts; realistic design proposals eg fitness for purpose, manufacturability, aesthetics, ergonomics

Design reference material: manufacturers' catalogues eg screw fixings, bearings, seals, electrical connectors, drive belts, gear drives; materials databases eg mechanical properties, physical properties; design databases eg structural beam sections, corrosion protection, anthropometric data

4 Be able to produce and present a final design solution

Final design solution: evaluation of proposals and selection of most appropriate for further development eg suitability for available manufacturing processes, cost effectiveness, contribution to profits, visual appearance; development of design proposal into a feasible solution suitable for prototype manufacture eg specify materials, appropriate manufacturing processes, estimation of manufacturing cost, quality; conformity to relevant legislation and design standards

Presentation techniques: 2D engineering drawings eg general arrangement drawing, assembly drawing, detail drawings, circuit diagrams, flow diagrams, schematic diagrams; drawing conventions and relevant British Standards eg BS308, BS8888, BS7307, BS3939, BS2197; documentation eg design diary, logbook, product specification; design calculations eg sizes of materials to meet strength requirements, electric motor power, electronic circuit performance, battery life

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 describe the operation of the design process in an engineering company	**M1** explain the possible impact of a poor customer design process on customer relationships and requirements	**D1** evaluate the impact of legislation and standards on the design process in relation to the profitability of the business
P2 interpret the requirements of a given customer and produce a product design specification [IE1]	**M2** explain the importance of using a range of accurate design reference materials when developing design proposals	**D2** evaluate a final design solution against customer requirements and a PDS, and suggest improvements.
P3 describe the appropriate legislation and standards which apply to the design of two different products	**M3** explain the issues which influence whether a design proposal should be developed into a final solution suitable for manufacture.	
P4 describe the environmental, sustainability and manufacturing constraints which influence the design of a given product		
P5 produce design proposals which meet the requirements of a given PDS [CT1]		
P6 extract reference information from component manufacturers' catalogues and materials and design databases		
P7 use a range of techniques to present a final design solution which meets the requirements of a given PDS and relevant legislation and design standards [CT5].		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

There are strong links between the four learning outcomes and the delivery strategy should ensure that these links are emphasised. Learners need to gain a coherent view of the design process within engineering and understand that for a business to remain profitable it is crucial that the design process is effective. Learners must be made aware that success in the marketplace can be achieved only if manufactured products are fit for purpose, marketable and meet customer requirements.

Delivery of the unit should start with some case study analysis. This is best done in the form of a group discussion examining example products that learners are familiar with. It is important to contrast successful design icons, like the Dyson Vacuum Cleaner™ and the Apple iPod™, with those that have failed, such as the Sinclair C5. A wider discussion could follow about why some products are hugely successful whereas others are not. It would also be useful to provide an overview of the design process as it applies to automotive engineering, starting with the initial 'concept' and following through to the production model for the mass market. Why is the production model different to the designer's original? Tutors need to get across the idea of compromise in the design process – the trade off between what we would like and what we can actually have when economics, legislation, manufacturability etc are taken into account.

To effectively cover learning outcome 1, learners will benefit from a visit to the design department of an engineering company in order to find out about the systems in place and the links between design and manufacture. If learners are employed it may be useful to base their research on their own company. Delivery should be, as far as possible, activity based, but care must be taken when covering learning outcome 2. There is a huge amount of data available which relates to the impact of legislation, standards and the environment on the design process, so learners will need to be given guidance when searching for information. Tutors need to consider how this data will be presented as evidence because there is a danger that some learners might include large amounts of unedited material. Learning outcomes 3 and 4 are best covered by a learner-centered activity, based around a single assignment which will produce evidence for grading criteria P5, P6 and P7. Learners should be applying knowledge gained from *Unit 10: Properties and Applications of Engineering Materials*, particularly from the learning outcome covering material selection.

There is scope here for learners to be given a PDS that is tailored to their particular interest but it may be more interesting to give them all the same one and to treat the activity as a design competition. The tutor would assume the role of customer with each learner pitching to get their final design solution accepted. There may be scope to develop this activity into a group discussion with all the design solutions being evaluated and learners using it as a lead into what is required for the evaluation in criterion D2.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • introduction to unit content, scheme of work and assessment • introduction to the design process • the customer/client relationship, case studies of innovative design and the triggers and market conditions necessary • examples of customer requirements and the generation of a PDS. *Case study*: • generating a PDS from given customer requirements.
Preparation for and carrying out **Assignment 1: Design Report** (P1, P2 and M1).
Whole-class teaching: • standards and legislation. *Small-group exercise*: • researching relevant standards for given products. *Whole-class teaching*: • environmental and sustainable constraints. *Paired activity*: • researching and reporting on legislation and environmental issues for given consumer products. *Whole-class teaching*: • manufacturing constraints • an investigation into the appropriate manufacturing techniques for a range of component parts and assemblies including health and safety requirements.
Preparation for and carrying out **Assignment 2: Product Evaluation** (P3, P4, and D1).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • interpreting a PDS – key technical requirements and economic considerations • design proposals, methods for presenting solutions, worked examples and case studies. *Case study*: • presenting design proposals for a given PDS. *Individual activities*: • learners to generate design proposals from simple PDS requirements using a range of techniques. *Whole-class teaching*: • using design reference material • identifying components and data from reference material • final design solutions – evaluation of proposals and selection techniques. *Small-group activity*: • presenting design solutions and using appropriate techniques to evaluate and select a final design.
Topic and suggested assignments/activities and/assessment.
Preparation for and carrying out **Assignment 3: Design Proposals** (P5, P6, P7, M2, M3 and D2).
Feedback on assessment and review of unit delivery.

Assessment

Assessment of this unit could be covered through three assignments. To achieve a pass grade learners are expected to describe how the design process operates in an engineering company and its links to other aspects of the business. It is suggested that during the first assignment the evidence for P1 could be gained by learners visiting the design department of an engineering company, carrying out an interview with an engineering designer and preparing a short report. It is important that learners understand that design cannot be carried out in isolation and that it is an income-generating function with the customer having the final say.

After the visit or similar activity, a written task for P2 should be given that asks learners to produce a PDS from the requirements of a given customer.

A second assignment could involve a research activity. Two different products need to be given to each learner and research carried out to allow them to describe the legislation and standards that apply to each product (P3) and the environmental, sustainability and manufacturing constraints that influenced the design of one of these products (P4).

Learners will need to demonstrate a basic mastery of design and drawing skills and they should be producing sketches and drawings which are broadly in line with British Standards and which use simple drawing conventions. There should be some evidence of design calculations when presenting evidence for P5, P6 and P7.

For assessment of these criteria a third assignment could be set where a PDS should be given and learners asked to produce a range of design proposals (P5). Three proposals would generally be sufficient although, if the solutions are complex, two would be enough. In doing this, it is important that learners use design reference material (P6) and a range of techniques to present the final solution (P7). The techniques used are dependent on the solution (for example if it involves an electronic system then circuit diagrams will be needed as well as perhaps general arrangement drawings).

Learners will demonstrate a basic understanding of the use of information sources such as books, technical reports, data sheets, catalogues, CD ROM and online databases. They should be selecting, interpreting and applying data extracted from a limited range of sources and will have been given guidance on what to look for.

Design work must show good evidence of knowledge gained from the linked units so that learners can be critical about their evolving designs and adapt them, rather than pursue a single idea. Grading criteria P5 and P6 link the extraction of reference information about materials and components to the design proposals being put forward by the learner. This will give more focus when gathering resource material. It is intended that the assessment evidence for criterion P6 is based on development ideas generated in P5.

To achieve a merit grade learners will need to apply evaluative skills and explain the impact of poor design. To achieve M1 the manufacturer/client relationship should be explored in some depth with evidence supported by examples taken from case studies based on real products. These could be discussed during the visit in the first assignment.

M1 builds on knowledge used to achieve P1 and P2 and may be best attempted in the first assignment.

To achieve M2 learners should support their reasons for having accurate reference material by using examples taken from documented sources of products which are mission critical (for example correct specification of dimensions and material for a load bearing structure such as a roof beam). As such, a further written task could be set in assignment three to facilitate M2.

M3 builds on P5 and P7 and a further written could be set task in assignment 3. There should be evidence of thought being given to economic issues and the pressure on a designer to design to a price in order to be competitive. Explanations should be supported by examples relating to real products that learners are familiar with.

To achieve a distinction grade learners should be able to focus on specific legislation and standards when working towards D1. There are strong links here to learning outcome 3 from *Unit 7: Business Operations in Engineering*. Learners should support their evaluation of the impact of legislation and standards on the design process with examples drawn from documented sources (for example businesses that have either lost market share by being caught out by changes in legislation or others that have benefited through anticipating changes and beating competitors in the market). As such, a task targeting D1 could be set as part of assignment 2.

To achieve the criterion D2, evaluation could relate to a design solution provided by the tutor but it may be better to link with P7 so that learners evaluate their own work. A written task in assignment 3 may be appropriate for this.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2 and M1	Design Report	An activity requiring learners to research and/or visit a design department and investigate the relationship between designer and customer.	A report containing written responses about the design process and its impact on customer relationships. In addition a PDS should be generated from a given customer specification.
P3, P4 and D1	Product Evaluation	An activity requiring learners to research legislation and standards that apply to two different products as well as the manufacturing, environmental and sustainability constraints for one of them.	A report containing written responses outlining legislation and standards that apply to two different products and an evaluation of the manufacturing, environmental and sustainability constraints for one of them in terms of profitability for the business.
P5, P6, P7, M2, M3 and D2	Design Proposals	An activity requiring learners to interpret a given PDS and, by using appropriate research techniques, present a final design solution from a selection of design proposals.	A portfolio of design solutions and a written report explaining how a final design solution has been selected. In addition explanations of the importance of accurate design reference materials and an evaluation of the chosen design solution with reference to the given PDS.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with the following unit titles in the Engineering suite:

Level 1	Level 2	Level 3
	Using Computer Aided Drawing Techniques in Engineering	Business Operations in Engineering
		Properties and Applications of Engineering Materials
		Engineering Drawing for Technicians
		Computer Aided Drafting in Engineering
		Engineering Secondary and Finishing Techniques and Processes
		Computer Aided Manufacturing

The unit has been mapped against the SEMTA National Occupational Standards and current NVQs at Level 3. Achievement of the learning outcomes of this unit will contribute skills, knowledge and understanding towards the following units from the Level 3 NVQ in Engineering Technical Support:

- Unit 2: Using and Interpreting Engineering Data and Documentation
- Unit 47: Producing Technical Information for Engineering Activities
- Unit 58: Developing and Maintaining Effective Customer Relationships.

Essential resources

To meet the needs of this unit it is essential that learners have, or have access to, some if not all of the following:

- a range of customer design requirements
- a range of products to investigate design requirement features
- manual drawing equipment
- 2D commercial CAD software
- extracts and illustrations from appropriate drawing standards and conventions
- access to reference material which provides information about the physical and mechanical properties of materials
- access to legislation and design standards
- component and material suppliers' catalogues.

Employer engagement and vocational contexts

The use of vocational contexts is essential in the delivery and assessment of this unit. Much of the work can be based around real engineering design requirements and drawings/specifications. In addition the use of engineering artefacts from local and national employers is to be encouraged.

There are a range of organisations that may be able help centres engage and involve local employers in the delivery of this unit, for example:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI, University of Warwick) – www.warwick.ac.uk/wie/cei/
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbooks

Dieter G and Schmidt L – *Engineering Design* (McGraw-Hill, 2008) ISBN 007126341 1

Simmons C, Maguire D and Phelps N – *Manual of Engineering Drawing* (Butterworth-Heinemann, 2009) ISBN 0750689854

Tooley M and Dingle L – *BTEC National Engineering* (Newnes, 2002) ISBN 0750651660

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	evaluating customer requirements to produce a product design specification
Creative thinkers	generating design proposals presenting final design solutions explaining issues which influence design solutions.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Reflective learners	reviewing the progress made against individual tasks and assignments.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	using a CAD system to create a variety of design solutions
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	using online or electronic reference materials
ICT – Develop, present and communicate information	
Present information in ways that are fit for purpose and audience	plotting/printing a variety of designs generated using CAD
English	
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing the design process writing a PDS describing environmental, sustainability and manufacturing constraints describing legislation and standards.