SQA Advanced Unit Specification

General information for centres

Unit title: Engineering Design Process: Mechatronics

Unit code: HV5A 48

Unit purpose: This unit has been designed to introduce candidates to the iterative design process. It presents engineering design in its holistic sense giving an overview of the design process and modern design methodology. The aim of this unit is to enable candidates to develop a thorough understanding of engineering and mechatronic design and apply that understanding to the design of products, processes or systems at an overall or detail level

On completion of the unit the candidate should be able to:

1 define the stages in the design, development and production of a new product/process/system
2 investigate, analyse and evaluate the benefits of utilising concurrent/simultaneous/parallel engineering for a mechatronic design process
3 develop a partial product design specification (PDS) from customer/user requirements

Credit points and level: 1 SQA Credit at SCQF level 8: (8 SCQF credit points at SCQF level 8*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from National 1 to Doctorates.*

Recommended prior knowledge and skills: Access to this unit is at the discretion of the centre. The unit has no prerequisites; however, it would be beneficial if the candidate has a basic understanding of design methodologies and/or processes. Entry requirements are at the discretion of the centre.

Core skills: There may be opportunities to gather evidence towards core skills in this unit, although there is no automatic certification of core skills or core skills components.

Problem Solving	SCQF level 6
Communication	SCQF level 6
Working with Others	SCQF level 6

Context for delivery: If this unit is delivered as part of a group award, it is recommended that it should be taught and assessed within the subject area of the group award to which it contributes.

Assessment: The assessment for Outcomes 1 and 2 of this unit should be integrated into one assessment paper. This paper should be taken by candidates at one single assessment event that should last two hours. The assessment paper should be composed of a suitable balance of short answer, restricted response and structured questions covering the content of Outcomes 1 and 2. This assessment should be closed book and conducted under controlled and supervised conditions.

The assessment for Outcome 3 of this unit should take the form of a partial product design specification assignment in which the candidate is given user/customer requirements of a final product/process/system. This assignment draws together the design concepts and methodologies developed in Outcomes 1 and 2 and should be developed during the delivery of the unit's content. This assessment should be completed in the candidate's own time.

Centres should make every reasonable effort to ensure the assignment solution is the candidate's own work. Where copying or plagiarism is suspected candidates may be interviewed to check their knowledge and understanding of the subject matter. A checklist should be used to record oral evidence of the candidate's knowledge and understanding.

SQA Advanced Unit specification: statement of standards

Unit title: Engineering Design Process: Mechatronics

The sections of the unit stating the outcomes, knowledge and/or skills, and evidence requirements are mandatory.

Where evidence for outcomes is assessed on a sample basis, the whole of the content listed in the knowledge and/or skills section must be taught and available for assessment. Candidates should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

Outcome 1

Define the stages in the design, development and production of a new product/process/system.

Knowledge and/or skills

- Essence of the product design process (PDP)
- Limitations of design process models
- Importance of iteration during design
- Five phases of the product life cycle including disposal/recycling
- Purpose and rationale for writing a product design specification (PDS) from customer/product requirements
- The approaches of top-down design and bottom-up design
- Traditional/sequential engineering design
- Methods and tools used for assisting concept generation (at least two of the six methods/tools listed in the Guidance on the content and context)
- Information required during the process of designing a product

Evidence requirements

Evidence for the knowledge and/or skills for Outcome 1 will be provided on a sample basis. The evidence may be provided in response to specific questions. Each candidate will need to demonstrate that they can answer questions based on a sample of the nine knowledge and/or skills items shown above. In any assessment of this outcome **five** out of **nine** knowledge and/or skill items should be sampled. If knowledge and/or skills item eight is chosen only **one of the six** methods/tools below should be sampled:

- brainstorming
- gallery technique
- problem decomposition
- morphological analysis
- boundary shifting
- function trees

Where sampling takes place, a candidate's response can be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

- Correctly define the basic product design process
- Explain the limitations of a design model
- Explain the importance of the Iteration process
- Describe the five phases of the product — life cycle

- Explain the purpose and rationale of writing of a product design specification (PDS) from customer/product requirements
- Explain an approach of top-down design and bottom-up design
- Explain the concept of traditional/sequential engineering design
- Briefly describe one method and associated tools used for assisting concept generation
- Describe what information is required during the process of designing a product

In order to ensure that the candidates will not be able to foresee what items they will be questioned on, a different sample of **five** out of **nine** knowledge and/or skill items is required each time the outcome is assessed. Candidates must provide a satisfactory response to all five items.
The whole content listed must be taught.

Assessment guidelines

The assessment for Outcomes 1 and 2 of this unit should be integrated into one assessment paper. This paper should be taken by candidates at one single assessment event that should last two hours. The assessment paper should be composed of a suitable balance of short answer, restricted response and structured questions covering the content of Outcomes 1 and 2. This assessment should be closed book and conducted under controlled and supervised conditions.

Outcome 2

Investigate, analyse and evaluate the benefits of utilising concurrent/simultaneous/parallel engineering for a mechatronic design process.

Knowledge and/or skills

- Concurrent/simultaneous/parallel engineering design process in developing a mechatronic product/process/system
- Main design support tools adopted by the concurrent engineering design process
  - Quality function deployment (QFD) for converting customer needs into technical requirements
  - Robust design (Genichi Taguchi)
  - Failure mode effect and criticality analysis (FMECA) and failure mode and effect analysis (FMEA)
  - Design for manufacture and assembly (DFMA)
  - Design for testability, reliability and service

Evidence requirements

Evidence for the knowledge and/or skills in this outcome will be provided on a sample basis. The evidence may be presented in response to specific questions or scenarios. Candidates will need to provide evidence that demonstrates their knowledge and/or skills by showing:

- they can explain and apply the principles of concurrent/simultaneous/parallel engineering and the reasons why design organisations have adopted this method over the traditional/sequential engineering design method with specific regard to mechatronic design
- from a sample of **two out of five** main design support tools explain clearly how to apply the tools in the formulation of a workable design solution

In order to ensure that the candidates will not be able to foresee what items they will be questioned on, a different sample of **two out of five** main design support tools from knowledge and/or skills item two is required each time the outcome is assessed.

Assessment guidelines

The assessment for Outcomes 1 and 2 of this unit should be integrated into one assessment paper. This paper should be taken by candidates at one single assessment event that should last two hours. The assessment paper should be composed of a suitable balance of short answer, restricted response and structured questions covering the content of Outcomes 1 and 2. This assessment should be closed book and conducted under controlled and supervised conditions.

Outcome 3

Develop a partial product design specification (PDS) from customer/user requirements

Knowledge and/or skills

- A partial PDS from market brief/customer specifications
- Customer/User requirements conversion into a formal PDS
- Selection of the most appropriate Partial PDS to your needs
- Role of marketing on the drawing up of a PDS

Evidence requirements

All knowledge and/or skill items should be assessed in this outcome.

Evidence for the knowledge and/or skills in this outcome will be provided by the candidates response in producing a partial product design specification from a given customer's/user's requirements.

Each candidate will need to demonstrate that they can correctly produce a partial product design specification from a given product/process/system. In producing the specification, the candidate must:

- evaluate alternative ways of writing a PDS and being able to choose the one most appropriate to the needs of the given product/process/system
- the specification will have to be written in such a manner that highlights and minimises the opportunities for errors and ambiguities to occur
- highlight the role marketing has on the drawing up and production of a PDS

The 20 primary elements required to complete a partial PDS are listed below:

- Size
- Shipping
- Company constraints
- Disposal
- Manufacturing facility
- Politics
- Weight
- Maintenance
- Shelf life storage
- Environment
- Safety
- Legal
- Documentation
- Materials
- Ergonomics
- Aesthetics

- Installation
- Life in service
- Performance
- Product cost

The customer/users requirements given to the candidate could be come from a variety of sources including:

- customer/users requirements produced by the centre/college
- an actual product from which the candidate could develop a specification
- a specification from the candidate's employer or other organisation
  (Note: The assessor must first agree the specification prior to proceeding with the partial PDS)

Assessment guidelines

The assessment for Outcome 3 of this unit should take the form of a partial product design specification assignment in which the candidate is given user/customer requirements of a final product/process/system. This assignment draws together the design concepts and methodologies developed in Outcomes 1 and 2 and should be developed during the delivery of the unit's content. The partial PDS will be an open book exercise with access to student's notes, learning resource facilities, manufacturer's data books and charts, and the internet to carry out research. This assessment should be completed in the candidate's own time.

Centres should make every reasonable effort to ensure the assignment is the candidate's own work. Where copying or plagiarism is suspected candidates may be interviewed to check their knowledge and understanding of the subject matter. A checklist could be used to record evidence of the candidate's knowledge and understanding of a product design specification and the reasons for its conception.

Administrative information

Unit code: HV5A 48

Unit title: Engineering Design Process: Mechatronics

Superclass category: VF

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SQA acknowledges the valuable contribution that Scotland's colleges have made to the development of SQA Advanced Qualifications.

For further information, please call SQA's Customer Contact Centre on 44 (0) 141 500 5030 or 0345 279 1000. Alternatively, complete our Centre Feedback Form.

SQA Advanced Unit Specification: support notes

Unit title: Engineering Design Process: Mechatronics

This part of the unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this unit

The purpose of this unit is to provide candidates with an opportunity to acquire knowledge and understanding of the design process, the design tools used in conjunction with the design process and the design organisations and structures. These principles, concepts and methodologies are commonly used in modern engineering industries involved in the complex business of design.

Allocated delivery times are for guidance purposes only.

Outcome 1 (10 hours) — the aim of this outcome is to introduce the candidates to the engineering design process and give them an understanding of the essence of the design process. Understanding and knowledge of the limitations of this process and the need for iteration should also be covered to ensure that the candidate has a full and comprehensive knowledge of this process. In today's environmentally friendly world it is of paramount importance that the end of a product should be considered at the design stage. When the product finally fails or is superseded by an updated version, consideration should be given to its disposal or recycling. It is important to touch on the fact that the ethos of design has developed to include the design of products for total life recycling eg there are a number of current engineering companies that invest a lot of time and money on this important part of the design process. The basic reasons for producing a PDS should also be looked at in this outcome in order to give the candidate's some underpinning knowledge and understanding for them to build upon in order to attempt Outcome 3.

Understand the limitations of modern design process models and appreciate the importance of iteration during the design process. Identify the five phases of the product life cycle including disposal/recycling where applicable. Understand the purpose and rationale for writing a PDS from customer/product requirements. Understand the different approaches of top-down design vs. bottom-up design. Some of the methods and tools used for assisting concept generation should be understood. Some of the methods/tools that can be utilised to aid the creative activities that form a part of the product design process could include the following: brainstorming, gallery technique, problem decomposition, morphological analysis, boundary shifting and function trees. The need for information during the process of designing a product should be understood and recognised. They should have a general overview of the technical aspects of the product design process from requirements analysis through design, test, manufacture, customer use and finally disposal or recycling. The concept of systems and subsystems using the systems approach to design should also be understood by the candidates.

Time constraints will make it impossible to cover all six, although there might be opportunities to give the student a brief overview of the other four if time permits, this is optional. Therefore when teaching this part of the unit it is only necessary to cover **two** of the methods/tools that could be used for generating design concepts.

Outcome 2 (12 hours) — the aim of this outcome is to introduce the candidate to the processes and design tools that are involved in the design of mechatronic products/processes/systems. The objectives of concurrent engineering have a close association with the requirements of mechatronics; therefore consideration should be given to their introduction and adoption as part of the mechatronic design process. Traditional engineering will have been studied in Outcome 1 hence a natural progression in this outcome is to study the role concurrent engineering plays in the design of mechatronic products. Although there are a number of design tools currently used to support the concurrent engineering design process we will look at the five main tools commonly adopted by design teams. It should be apparent at this stage that the design of a mechatronic product/process/system may well require the use of a number of overlapping descriptive and other models (not covered in this unit) in order to provide an effective basis for the design process. This should be intimated to the students, but because this unit does not cover the complete spectrum of design models it should not be assessed.

Outcome 3 (14 hours) — the production of a partial product design specification for a given product/process/system. The outcome is concerned with the means by which requirements are drawn together into a document known as the PDS. Since it is recognised that, particularly in an SQA Advanced course, full comprehensive coverage can rarely be achieved with design, you will develop a partial PDS appropriate to the design problem or specification. The PDS is probably the most influential document in describing the requirements of the final product and hence it is important that a great deal of attention is given to its compilation. The PDS should be looked upon as a dynamic document rather than a static document. If, during the design of a product there is good reason for changing the PDS, then it should be changed accordingly. Ergonomics is concerned with the relationship between people and the equipment and environments. Anthropometrics concerns the measurement of the physical characteristics of humans and in particular the determination of their physical dimensions, although other data on, for example, how far people can reach, how much space they need and how much force they can exert is also determined. If for example you are faced with the problem of providing uniforms and boots for millions of people, then clearly you have a desperate need for guidelines.

Consideration should be given to product liability and consumer protection, legislation and practice. The need for all relevant patent laws, product standards and codes of practice where and when applicable are also worthy of consideration.

Guidance on the delivery and assessment of this unit

The delivery of this unit should be candidate centred with the emphasis placed on the requirements of the assignment report in Outcome 3. The candidates should be given the assessment for Outcome 3 as early as possible to allow individual research and investigation however the formal assessment should take place at the end of the unit.

Candidates will be required to understand the terminology used in the design process and the reasons and rationale behind the design concepts and tools being delivered. This requires the candidates to gain and command a high level of familiarity of the content of this unit.

The assessment of this unit should provide the candidate with opportunities to develop their knowledge and understanding of the design process from the initial concept through to the realisation of the product/process/system.

The content of this unit can be delivered flexibly to reflect particular interests and approaches adopted by specific centres.

The unit can be delivered through lecturers, tutorials, group work and practical assignments/scenarios. Speakers from industry could be used to reinforce the design ethos giving students an insight into how design methodologies, tools and processes are adopted in a real world design project. This approach could also encourage the candidates to produce work that is of good practice, showing inspirational design and perhaps even some lateral thinking and creativity.

A full PDS consists of 32 elements. Due to the nature of this outcome, it is realistic to assume that only a partial PDS, consisting of the 20 primary elements, could be completed in the available time. The 20 primary elements required to complete a partial PDS are listed below:

- Size
- Shipping
- Company constraints
- Disposal
- Manufacturing facility
- Politics
- Weight
- Maintenance
- Shelf life storage
- Environment
- Safety
- Legal
- Documentation
- Materials
- Ergonomics
- Aesthetics
- Installation
- Life in service
- Performance
- Product cost

If the lecturer feels that all the elements are achievable in the given time, then there is scope for this to occur. For assessment purposes and for clarity the 20 primary elements from the 32 only need to be available for assessment. If more appropriate elements are deemed suitable then there is no valid reason why alternative elements could not be chosen. The 12 remaining elements that would need to be consulted when developing a full PDS are listed below:

- Time scale
- Customer
- Processes
- Market constraints
- Competition
- Packing
- Quality reliability
- Patents
- Testing
- Quantity
- Product life span
- Standards specifications

Opportunities for developing core skills

Candidates will, as they produce a partial product design specification to a given brief, analyse and seek solutions to a range of theoretical and practical problems and issues. As they identify and consider all the variables, including company constraints, manufacturing facilities, installation and budget, they will routinely assess the relative significance of each before identifying and justifying an appropriate aesthetic approach which meets legal and safety requirements. The practical assignment will provide natural opportunities to develop elements of planning, critical thinking and general problem solving skills to an advanced level. Candidates could be supported in the identification of appropriate evaluative criteria with which to measure the success of their design work.

Although communication skills are not formally assessed candidates should be expected to research, produce and present a design specification to meet customer needs at a standard acceptable in industry. They should collate and express essential ideas and information, including graphics, accurately and coherently without errors or ambiguities. The format used should be appropriate to the needs of the users and the product, process and/ or system.

Candidates may benefit from awareness raising on approaches to marketing and team working as an essential aspect of the design process. There are practical opportunities to foster skills in group co-operative working and oral communication as candidates discuss proposed solutions and:

- analyse the task and its component elements
- negotiate the nature and scope of goals, roles and responsibilities taking account of all resources including strengths and weaknesses of individuals
- negotiate rules for effective management of the group and task
- demonstrate the use of working methods consistent with available resources
- demonstrate and explain methodology to others
- review and evaluate their own performance in communicating and working with others

Open learning

This unit could be delivered by distance learning, which may incorporate some degree of online support. However, with regards to assessment, planning would be required by the centre concerned to ensure the sufficiency and authenticity of candidate evidence. Arrangements would be required to be put in place to ensure that assessment, whether done at a single or multiple events, was conducted under controlled, supervised conditions.

For information on normal open learning arrangements, please refer to the SQA guide *Assessment and Quality of Open and Distance Learning* (SQA 2000).

Equality and inclusion

This unit specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence.

Further advice can be found on our website www.sqa.org.uk/assessmentarrangements.

General information for candidates

Unit title: Engineering Design Process: Mechatronics

The aims of this unit are to present an overview of the design process and design methodology. The unit has been developed to enable you to develop a thorough understanding of engineering and mechatronic design and apply that understanding to the design of products, processes or systems at an overall or detail level.

On completion of the unit you should be able to:

1 define the stages in the design, development and production of a new product/process/system
2 investigate, analyse and evaluate the benefits of utilising concurrent/simultaneous/parallel engineering
3 develop a partial product design specification (PDS) from customer/user requirements

The aim of Outcome 1 is to introduce you to the engineering design process and give you an understanding of the essence of the design process. Outcome 2 is designed to introduce you to the processes and design tools that are involved in the design of mechatronic products/processes/systems and Outcome 3 allows you to develop and produce a partial product design specification for a given product/process/system. This unit may be of particular interest to candidates who are interested in pursuing a career in engineering/mechatronic design or who wish to go on and study for a degree in engineering/mechatronic design.

The unit takes you from an inventor's perspective to a more formal model called 'total design'. Although the total design model has been adopted for this unit, other models have been developed, models which have not been included in this unit. This means that the content of this unit is in no way, shape or form a comprehensive study of the design process. If the candidate wants to review other models then the candidate is recommended to review the models proposed by Pahl and Beitz (1996), March (1976) and Cross (2000).

The product design process is a process of activities complicated by the presence of repeated iterations in the quest for the ideal solution to a design problem. The requirement to consider the influence of numerous factors makes a holistic approach to design necessary. With regard to the PDP Outcome 1 is concerned specifically with engineering design, while Outcome 2 introduces some of the concepts utilised in the design of mechatronic products. Mechatronic design differs from engineering design in that it may well require the use of a number of overlapping disciplines and design models in order to provide a good base from which the design process can be initiated and taken forward. In order to be fully effective, concurrent engineering should be adopted as the approach in the designing and developing of a mechatronic product/process/system. Design itself is an activity, not a subject.

The unit has been developed to allow you to develop knowledge and understanding of the design process, culminating in the realisation of a product design specification for a given product/process/system. The unit has been written in the hope that it will take the candidate through the design process in a systematic and logical manner with the appropriate support tools, structures and methods introduced accordingly.

Wherever we are in the design and development stage, the PDS is the basic reference. By designing in a particular design/process/system area, we are, or should be, attempting to meet the specification. The PDS must be considered as an evolutionary and comprehensively written document, which upon completion of the design activity, has itself evolved to match the characteristics of the final document. The PDS is an essential document in all fields of design activity and therefore must be concise, comprehensive and unambiguous. The PDS if carried out correctly should become the specification of the product itself, rather than the specification for its design. There are no alternatives to a meticulous and thorough approach to PDS. In fact there is a great deal of evidence to the effect that a poor PDS is a very common cause of unsuccessful designs.

The assessment of this unit is made up in two parts. Outcome 1 and 2 are combined together into one assessment where you will answer a number of questions relating to the stages in the design, development and production of a new product/process/system and the benefits of utilising concurrent/simultaneous/parallel engineering for a Mechatronics design process. This assessment should last two hours and will be in a controlled examination environment.

Outcome 3 is a design assignment which will be assessed by giving you a customer's/user's requirements from which you have to produce a partial product design specification. This is normally completed while you are undertaking the unit. However it will usually be near the end so that you have gained the appropriate knowledge and skills to achieve the task. This assessment usually requires you to research your notes, external text and the internet to complete the partial design specification.