Course Support Notes

National 5 Engineering Science Course Support Notes

Please refer to the note of changes at the end of this document for details of changes from previous version (where applicable).

July 2013, version 1.1

Contents

Course Support Notes

Introduction

These support notes are not mandatory. They provide advice and guidance on approaches to delivering and assessing the National 5 Engineering Science Course. They are intended for teachers and lecturers who are delivering the Course and its Units. They should be read in conjunction with the *Course Specification*, the *Course Assessment Specification* and the Unit Specifications for the Units in the Course.

General guidance on the Course

Aims

As stated in the *Course Specification*, the aims of the Course are to enable learners to:

- apply knowledge and understanding of key engineering facts and ideas
- understand the relationships between engineering, mathematics and science
- apply skills in analysis, design, construction and evaluation to a range of engineering problems
- communicate engineering concepts clearly and concisely using appropriate terminology
- develop an understanding of the role and impact of engineering in changing and influencing our environment and society

This Course will also give learners the opportunity to develop thinking skills and skills in numeracy, employability, enterprise and citizenship.

Progression into this Course

Entry to this Course is at the discretion of the centre. However, learners would normally be expected to have attained some relevant skills and knowledge through prior experience.

Skills and knowledge developed through any of the following, while **not mandatory**, are likely to be helpful as a basis for further learning in this Course.

Other SQA qualifications

- National 4 Engineering Science Course

Other experience

Learners may have relevant skills and knowledge gained through other education systems or from their own interests and informal learning.

Skills, knowledge and understanding covered in this Course

This section provides further advice and guidance about skills, knowledge and understanding that could be included in the Course.

Note: teachers and lecturers should refer to the *Course Assessment Specification* for mandatory information about the skills, knowledge and understanding to be covered in this Course.

The mandatory skills may be developed throughout the Course. The table below shows where there are significant opportunities to develop these in the individual Units.

Mandatory skills and knowledge	Engineering Contexts and Challenges	Electronics and Control	Mechanisms and Structures	Course assessment
analysing engineering problems				✓
designing, developing, simulating, building, testing and evaluating solutions to engineering problems in a range of contexts		✓	✓	✓
investigating and evaluating existing and emerging technologies	✓			
communicating engineering concepts clearly and concisely using appropriate terminology	✓	✓	✓	✓
knowledge of the many types of engineering	✓			✓
knowledge of the wide role and impact of engineering on society and the environment	✓			✓
knowledge of the workings of a range of everyday engineered objects	✓			✓
knowledge and understanding of key concepts related to electronic and microcontroller-based systems, and their application		✓		✓
knowledge and understanding of key concepts related to mechanical, structural and pneumatic systems, and their application			✓	✓
knowledge of the relevance of energy, efficiency and sustainability to engineering problems and solutions			✓	✓
applying engineering knowledge and skills in a range of contexts		✓	✓	✓

Progression from this Course

This Course or its components may provide progression to:

- Higher Engineering Science
- National Certificate Group Awards in a range of engineering disciplines
- Skills for Work Courses in Energy and in Engineering Skills
- employment, apprenticeships and/or training in engineering and related fields

and ultimately, for some, to:

- Advanced Higher Engineering Science
- a range of engineering-related Higher National Certificates (HNCs) and Higher National Diplomas (HNDs)
- degrees in Engineering and related disciplines
- careers in engineering

Hierarchies

Hierarchy is the term used to describe Courses and Units which form a structured sequence involving two or more SCQF levels.

It is important that any content in a Course and/or Unit at one particular SCQF level is not repeated (unless required for consolidation) if a learner progresses to the next level of the hierarchy. The skills and knowledge should be able to be applied to new content and contexts to enrich the learning experience. This is for centres to manage.

The Course is designed in hierarchy with the corresponding Courses at SCQF levels 4 and 6 (National 4 and Higher). The Engineering Science Courses at all three levels have the same structure of three Units with corresponding titles.

Each of the three Units — *Engineering Contexts and Challenges*, *Electronics and Control*, and *Mechanisms and Structures* — is in hierarchy with the corresponding Unit at SCQF levels 4 and 6.

The design of the Units means that teachers may be able to design learning activities that are appropriate for a class with learners working at different levels.

Appendix 2 contains a table showing the relationship between the mandatory National 4 and National 5 knowledge and understanding. This table may be useful for:

- designing and planning learning activities for mixed level delivery
- ensuring seamless progression between levels
- identifying important prior learning for learners at National 5

Teachers should also refer to the Outcomes and Assessment Standards for each level when planning delivery.

A similar table in the Higher Engineering Science *Course Support Notes* shows the relationship between the mandatory National 5 and Higher knowledge and understanding, which may be useful for bi-level National 5/Higher classes.

Further advice on delivery to a group including National 4 and National 5 learners is given in the next section of these support notes, with additional detailed guidance in the *Unit Support Notes*.

Approaches to learning and teaching

Engineering Science, like all new and revised National Courses, has been developed to reflect Curriculum for Excellence values, purposes and principles.

The approach to learning and teaching developed by individual centres should reflect these principles. Learners should spend less time passively listening to the teacher; instead learners, often working together, should talk, listen, write, read or reflect on a topic while the teacher acts as a facilitator.

An appropriate balance of teaching methodologies should therefore be used in the delivery of the Course. Whole-class, direct teaching opportunities should be balanced by activity-based learning on practical tasks. An investigatory approach is encouraged, with learners actively involved in developing their skills, knowledge and understanding by investigating a range of real-life and relevant engineering systems, problems and solutions.

The use of a variety of other active learning approaches is encouraged, including peer teaching, individual and group presentations, role-playing and game-based learning with pupil-generated questions.

Learning should be supported by appropriate practical activities, so that skills are developed simultaneously with knowledge and understanding.

Practical activities and investigations lend themselves to group work, and this should be encouraged. Co-operative and collaborative learning approaches support and encourage learners to achieve their full potential. Unlike individual learning, learners engaged in these strategies capitalise on one another's resources and skills — asking one another for information, evaluating one another's ideas and monitoring the group's work. While 'working in a group' is not specifically identified as one of the skills for life, learning and work for this Course, and therefore not assessed, it is a fundamental aspect of working in the engineering industry and so should be encouraged and developed by teachers. Group work approaches can be used within Units and across Courses where it is helpful to simulate real life situations, share tasks and promote team working skills. However, there must be clear evidence for each learner to show that the learner has met the required assessment standards for the Unit or Course.

Problem-Based Learning (PBL) is another strategy which will support a learner's progress through this Course. This method may be best utilised at the end of an Outcome or a topic where additional challenge is required to ensure learners are secure in their knowledge and understanding and to develop the ability to apply knowledge and skills in less familiar contexts. The teacher sets a problem which requires learners to apply their knowledge to solve a problem. For example, learners could be asked to design a machine to transport tyres in a factory. The learners must apply their knowledge of friction, chain drives and motion to devise, then present, a solution. This could be an individual or group task.

Learning through PBL develops a learner's problem solving, decision making, investigative skills, creative thinking, team working and evaluative skills. Throughout the teaching of this Course, the stimulation of learners' interest and curiosity should be a prime objective.

Where possible, locally relevant contexts should be studied, with visits where this is practical. Guest speakers from industry and further and higher education can be used to bring the world of engineering into the classroom. Where this is not possible, online resources, such as STEM-Central, and online news articles, may be valuable alternatives. Computer-based simulations also encourage learning as learners can manipulate and investigate systems without requiring expensive equipment.

Assessment activities, used to support learning, may usefully be blended with learning activities throughout the Course.

For example:

- sharing learning intentions/success criteria
- using assessment information to set learning targets and next steps
- adapting teaching and learning activities based on assessment information
- boosting learner confidence by providing supportive feedback

Self- and peer-assessment techniques should be encouraged wherever appropriate.

Learning about Scotland and Scottish culture will enrich the learners' learning experience and help them to develop the skills for learning, life and work they will need to prepare them for taking their place in a diverse, inclusive and participative Scotland and beyond. Where there are opportunities to contextualise approaches to learning and teaching to Scottish contexts, teachers and lecturers should consider this.

Working towards Units and Course

Learning and teaching activities should be designed to develop both:

- skills and knowledge to the standard required by **each Unit** and to the level defined by the associated Outcomes and Assessment Standards
- ability to apply the breadth of knowledge, understanding and skills listed in the *Course Assessment Specification*, as required to complete the **Course assessment** successfully

Meeting the needs of all learners

Within any class, each learner has individual strengths and weaknesses.

For example, within a National 5 class, there may be learners capable of achieving Higher standards in some aspects of the Course. Where possible, they should be given the opportunity to do so. There may also be learners who are struggling to achieve National 5 level in all aspects of the Course, and may only achieve National 4 in some areas.

Teachers need to consider both the Outcomes and Assessment Standards, and the tables of concepts in the previous section of these notes, to identify the differences between National 4 and National 5.

In some aspects of the Course, the difference between National 4 and National 5 is defined in terms of a higher level of skill. For example, in *Electronics and Control,* Assessment Standard 2.4 requires National 4 learners to be able to test an electronic solution, while National 5 learners require to test **and evaluate** the solution. In other aspects of the Course, the difference between National 4 and National 5 is defined by different or additional knowledge. For example, National 4 learners need to cover belt drive and chain drives, while National 5 learners also need to know about crank and slider, cam and follower and rack and pinion.

When delivering this Course to a group of learners, with some working towards National 4 and others towards National 5, it may be useful for teachers to identify activities covering common knowledge and skills for all learners, and additional activities required for National 5 learners. This is particularly appropriate where the National 5 learners have come directly from the broad general education without previously studying National 4.

However, where National 5 learners have studied National 4 in a previous year, it is important to provide them with new and different contexts for learning to avoid demotivation. For example, in the *Engineering Contexts and Challenges* Unit, it would be better to choose different engineered objects for the National 5 learners to study rather than just asking them to do a more in-depth study of the objects they considered the previous year.

Sequence of delivery

The sequence of delivery of the Units within the National 5 Engineering Science Course is at the discretion of the centre and the models suggested below simply exemplify possible approaches which may be developed to suit individual circumstances and resources.

The example structures outlined below are similar to those shown in the National 4 *Course Support Notes* so that centres may plan, where applicable, for delivery to mixed level groups. (Further suggestions and specific advice can be found in the *Unit Support Notes*.)

Fitting the Assignment into a Course plan

Note that the delivery of the assignment (Developing an Engineering Solution), and time for preparation for the question paper, has been omitted from the diagrams and Course structures which follow. As the assignment is intended to assess application of knowledge, understanding and skills developed through the other Units, it will normally be delivered at the end of the Course. However, it may be possible to begin work on the assignment at an earlier stage, but only where it is clear that learners have already gained the required skills and knowledge.

Example 1a: Sequential delivery of the Units, beginning with *Engineering Contexts and Challenges*

Engineering Contexts and Challenges → *Electronics and Control* → *Mechanisms and Structures*

In this example, the three Units are delivered sequentially, beginning with *Engineering Contexts and Challenges*, which provides an introduction to some important concepts which underpin the whole Course, including the systems approach and energy.

The other two Units, *Electronics and Control*, and *Mechanisms and Structures*, may then follow, deepening the learners' experience in these more focused areas. These two Units may be delivered in either order or in parallel.

The remainder of the Course time will provide opportunities for:

- re-assessment
- preparation for, and completion of, the assignment
- preparation and revision for the question paper

Although this approach reflects the order in which the Units are listed in the *Course Specification*, it is not mandatory, and other approaches have many benefits for the learner. Several other approaches are described below.

Example 1b: Sequential delivery of the Units, with *Engineering Contexts and Challenges* as the final Unit

Electronics and Control → *Mechanisms and Structures* → *Engineering Contexts and Challenges*

Again, the three Units are delivered sequentially, but with the *Engineering Contexts and Challenges* Unit kept until the end. The *Electronics and Control* Unit is delivered first, followed by *Mechanisms and Structures*.

The teaching approach for the first two Units might include a combination of individual and group investigation tasks, problem solving exercises, and direct instruction, with the focus on acquisition of engineering skills and knowledge. The topics could be taught in the following order:

- digital electronics (including microcontroller systems)
- analogue electronics
- pneumatics
- energy
- structures
- drive systems

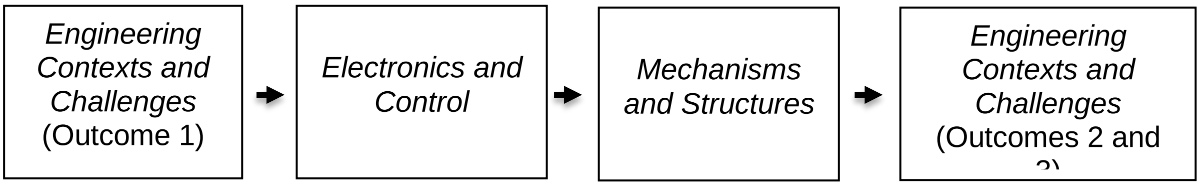
This order will help ensure a gradual increase in conceptual and mathematical demands as the Course progresses.

The final Unit, *Engineering Contexts and Challenges*, provides an opportunity to consolidate and extend the previously taught engineering knowledge. The learning is set within a context of modern engineering practice with the analysis and study of more complex engineered solutions and systems, some of which may integrate aspects from the other Units.

As in Example 1a, the remainder of the Course time will provide opportunities for:

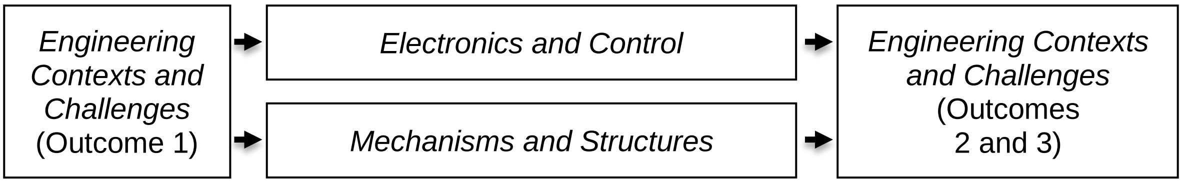
- re-assessment
- preparation for, and completion of, the assignment
- preparation and revision for the question paper

Example 1c: Sequential delivery of the Units, with *Contexts and Challenges* split into two parts



Example 1c is a hybrid. Outcome 1 of the *Engineering Contexts and Challenges* Unit (systems approach, reverse engineering of products, and energy) is used to introduce the Course. Then the *Electronics and Control*, and *Mechanisms and Structures* Units follow (in either order). Finally, Outcomes 2 and 3 of *Contexts and Challenges* are used to consolidate and integrate knowledge and skills in preparation for the assignment and question paper.

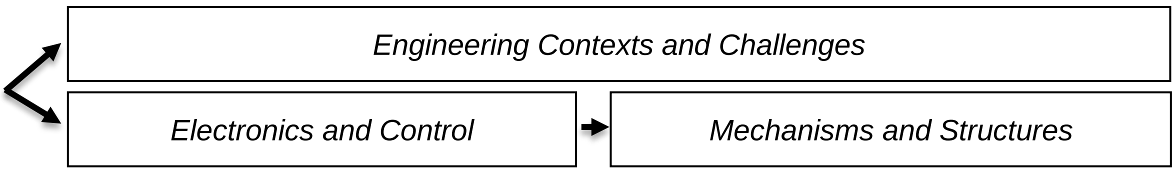
Example 2a: Concurrent delivery of Units



It is possible to deliver the *Electronics and Control* Unit concurrently with the *Mechanisms and Structures* Unit. This may be beneficial in terms of timetabling of teachers and facilities, and also may have educational benefits for some learners. For example, the concepts of electronics and control, or mechanisms, can be developed more gradually as they can be spread over a longer period. Also, this provides better opportunities for integration between topics and Units.

Example 2b: Parallel/integrated delivery of *Engineering: Contexts and Challenges* Unit

Another option is to deliver *Engineering Contexts and Challenges* as a permeating Unit throughout the Course, linking it, as appropriate, to the learning of the other two Units:



This integrated approach is developed in more detail in Example 3:

Example 3: Integrated approach
The integrated approach shown below uses a modular structure to deliver the engineering knowledge and skills. It is organised into three distinct phases:

1. Induction	**2. Skill and knowledge development**	**3. Consolidation**
Induction: systems approach	**Engineered world:** research engineered systems	**Engineering concepts:** further study of engineering theory
Reverse engineering: investigate a range of products	**Role of an engineer:** analyse engineered solutions for the type and role of engineers involved	**Engineering problems:** solve integrated problems
	Engineering principles: develop knowledge and skills in the discrete topics: electronics, pneumatics, energy, drive systems and structures	
	Engineering & society: research into sustainability and environmental issues	
	Meet the engineers: field trips, visits and guest speakers	

In this approach, the induction phase introduces the learner to the systems approach. This might involve the analysis of products and engineered systems. Typically this stage will last a short time, but the systems approach will permeate the Course and so the learner's knowledge and ability to analyse the engineered world will develop throughout the whole Course.

The second phase is where the majority of the engineering knowledge and skills are introduced and then developed. The modules may be taught in any order and covered in a linear or concurrent manner.

In the final phase, the more demanding engineering concepts are covered (velocity ratios, pneumatics calculations, energy efficiency, etc), perhaps through direct teaching and practice questions. The engineering skills are further consolidated through a series of integrated problem solving tasks designed to prepare the learner for the assignment.

As in Example 1a, the remainder of the Course time will provide opportunities for:

- re-assessment
- preparation for, and completion of, the assignment
- preparation and revision for the question paper

This final suggested Course structure has many educational benefits, but will require the teacher to keep a careful record cross-referencing learning activities to the Assessment Standards of the three Units.

Advice on distribution of time
Learners may be expected to contribute their own time in addition to programmed learning time.

The distribution of time between the various Units is a matter for professional judgement and is entirely at the discretion the centre. Each Unit is likely to require an approximately equal time allocation, although this may depend on the learners' prior learning in the different topic areas.

Time should be allocated for preparation for the Course assessment (assignment and question paper). See below for further advice on use of this time.

Resources
Centres may find that existing equipment within either Design and Technology or Physics areas provide all that is required to deliver the Course. This equipment is summarised below:

- internet-enabled computers and a digital projector
- microcontroller ICs, such as PICAXE project boards or the legacy Stamp Controller, and associated flowchart simulation software (PICAXE Programming Editor — free download from Picaxe web site.
- breadboards, discrete electronic components, single core wire, wire stripper/cutter and test equipment
- electronic simulation software such as Crocodile/Yenka Technology, Control Studio 2, or Circuit Wizard, etc
- pneumatic components or pneumatic simulation software such as Airways or Simulator Virtual Pneumatic Trainer
- mechanism modelling kits/simulation software such as fishertechnik, Lego Technik, Crocodile/Yenka Technology or Focus on Mechanism.

A wide range of other suppliers, kits and software may also be available.

Resources for Programmable Control Systems
At each level from National 4 to Advanced Higher, the Engineering Science Courses include aspects of programmable control systems. At National 5, such systems may be used to deliver Outcome 2 of the Electronics and Control Unit, and may be used in the Course Assessment (assignment).

Teachers who have delivered Technological Studies will be familiar with many of the concepts, and have experience of developing control systems using the BASIC Stamp system. This system is adequate for delivering the control aspects of Engineering Science, and may continue to be used successfully. However, the BASIC Stamp hardware in most schools is likely to be reaching the end of its useful life, and more flexible, cheaper alternatives are now available.

PICAXE chips are based on a range of PICs (Peripheral Interface Controllers) which can be programmed in PICBASIC (a language similar to the PBASIC used with STAMP). Various PICAXE kits are available from Revolution Education Limited. Currently, the AXE056 Trainer Starter pack is probably the most suitable as an integrated unit, or the PICAXE 28x2 shield base (AXE401) with additional interfacing shields is a cost effective solution.

Hard-wired shields should be used for National 4 and National 5; the increased scope for Higher can be achieved with a hand wired solution.

Another very real low cost alternative is the Arduino system. The Arduino is a prototyping platform using flexible, easy-to-use open source hardware and software. The supporting community for Arduino is very large and there are very many tutorials, resources and forums freely accessible on the web. Arduino is programmed using C, which may be less familiar to teachers, but is an industry standard language. Pupils pick up the simple C required very quickly. Each successive release of Arduino hardware is compatible with earlier versions, while providing enhanced function, so will not lead to obsolescence. For interfacing, an excellent range of cheap shields are readily available as hard-wired or free form from a number of UK suppliers.

Teaching and learning materials
Support Materials published in August 2005 for Technological Studies cover broadly the same topics as the *Electronics and Control* and the *Mechanisms and Structures* Units, and may be useful. Additional resources have been commissioned to support the *Engineering Contexts and Challenges* Unit and these will be available to download from the Education Scotland website.

Education Scotland's STEM-Central website, although designed mainly for Third level experiences and outcomes, provides a good source of case study material.

Centres may also be able to adapt existing activities and resources to support and consolidate learning.

Developing skills for learning, skills for life and skills for work

Guidance on the development of skills for life, skills for learning and skills for work is to be found in the support notes for each of the Units.

Approaches to assessment

See the *Unit Support Notes* for guidance on approaches to assessment of the Units of the Course.

Added value
Courses from National 4 to Advanced Higher include assessment of added value. At National 5 the added value will be assessed in the Course Assessment.

Information given in the *Course Specification* and the *Course Assessment Specification* about the assessment of added value is mandatory.

Full details of assessment of added value are included in the *Course Assessment Specification.*

The Course assessment (question paper and assignment) will assess the application of skills and knowledge which learners will have developed through the other Units.

Preparation for Course assessment
Each Course has additional time which may be used at the discretion of the teacher or lecturer to enable learners to prepare for Course assessment. This time may be used near the start of the Course and at various points throughout the Course for consolidation and support. It may also be used for preparation for Unit assessment, and towards the end of the Course, for further integration, revision and preparation and/or gathering evidence for Course assessment.

Information given in the *Course Specification* and the *Course Assessment Specification* about the assessment of added value is mandatory.

Within the notional time for the Course assessment, time will be required for:

- preparation for the assignment, which could include considering exemplar assignments and practising the application and integration of skills
- carrying out the stages of the assignment, with teacher guidance and support
- assessing the process and completed solution
- consolidation of learning
- development of problem solving skills
- preparation for the question paper

Combining assessment across Units

If an integrated approach to Course delivery is chosen, then there may be opportunities for combining assessment across Units.

Equality and inclusion

The requirement to develop practical skills involving the use of equipment and tools may present challenges for learners with physical or visual impairment. In such cases, reasonable adjustments may be appropriate, including (for example) the use of adapted equipment or alternative assistive technologies.

It is recognised that centres have their own duties under equality and other legislation and policy initiatives. The guidance given in these *Course Support Notes* is designed to sit alongside these duties but is specific to the delivery and assessment of the Course.

It is important that centres are aware of and understand SQA's assessment arrangements for disabled learners, and those with additional support needs, when making requests for adjustments to published assessment arrangements. Centres will find more guidance on this in the series of publications on Assessment Arrangements on SQA's website: www.sqa.org.uk/sqa//14977.html.

Appendix 1: Reference documents

The following reference documents will provide useful information and background.

- Assessment Arrangements (for disabled learners and/or those with additional support needs) — various publications are available on SQA's website at: www.sqa.org.uk/sqa//14977.html.
- *Building the Curriculum 4: Skills for learning, skills for life and skills for work*
- *Building the Curriculum 5: A framework for assessment*
- Course Specifications
- Design Principles for National Courses
- *Guide to Assessment* (June 2008)
- Overview of Qualification Reports
- Principles and practice papers for curriculum areas
- *SCQF Handbook: User Guide* (published 2009) and
  SCQF level descriptors (to be reviewed during 2011 to 2012):
  www.sqa.org.uk/sqa/4595.html
- *SQA Skills Framework: Skills for Learning, Skills for Life and Skills for Work*
- *Skills for Learning, Skills for Life and Skills for Work: Using the Curriculum Tool*

Appendix 2: Comparison of National 4 and National 5

This table shows the relationship between the mandatory National 4 and National 5 knowledge and understanding. This table may be useful for:

- designing and planning learning activities for mixed level delivery
- ensuring seamless progression between levels
- identifying important prior learning for learners at National 5

Teachers should also refer to the Outcomes and Assessment Standards for each level when planning delivery.

Course themes		
Topic	**National 4**	**National 5**
The systems approach	simple system and sub-system diagrams, showing inputs and outputs systems analysis of an environmental control system. systems analysis of a renewable energy device. working of simple engineered objects	systems and sub-system diagrams function of a system in terms of input — process — output and feedback loops open and closed loop control interaction of sub-systems
Energy and efficiency	the law of conservation of energy energy transfers, losses and transformations in a system, involving kinetic, potential, electrical and heat energy calculations involving efficiency, work done and power, using: $E_w = Fd$ $P = E/t$, Efficiency $\eta = E_{out}/E_{in} = P_{out}/P_{in}$	application of the law of conservation of energy calculations involving forms of energy (kinetic, potential, electrical, heat) energy transfers, losses and transformations in a system energy audits and calculation of overall efficiency applied calculations involving efficiency, work done and power, using: $E_w = Fd$ $P = E/t$, $E_k = ½ mv^2$ $E_p = mgh$ $E_e = VIt$ $E_h = cm\Delta T$ Efficiency $\eta = E_{out}/E_{in} = P_{out}/P_{in}$
Calculations	substituting values into given formulae to obtain answers	manipulating given formulae to obtain answers

Engineering Contexts and Challenges		
Topic	**National 4**	**National 5**
Engineering roles and disciplines	applications of civil, mechanical, electrical and chemical engineering roles of engineers in designing, implementing, testing and controlling systems	examples of applications of environmental, civil, structural, mechanical, chemical, electrical and electronic engineering examples of the contribution of branches of engineering to solve engineering challenges that integrate branches of engineering the varied roles of engineers in designing, implementing, testing and controlling complex systems
Impacts of engineering	social, economic and environmental benefits of engineering impacts of a renewable energy project on the environment and community contribution of engineering to tackling climate change	examples of social and economic impacts (positive and negative) of engineering examples of environmental impacts (positive and negative) of engineering ways in which engineering solutions contribute to tackling climate change

Analogue electronic control systems		
Topic	**National 4**	**National 5**
Circuit diagrams and components	symbols, and simple description of function of: battery; switch; resistor; variable resistor; LDR; thermistor, LED; diode; motor; lamp; ammeter and voltmeter	function and purpose within a circuit of: battery; switch; resistor; variable resistor; LDR; thermistor, LED; diode; motor; lamp; ammeter and voltmeter description of function of a circuit in terms of input, process and output
Voltage, current, and resistance	concept of voltage, current and resistance measurement of resistance, voltage and current using a meter	calculations involving the relationship between voltage, current and resistance (Ohms' Law) calculations involving resistors in series and parallel
Voltage dividers	explanation of the operation of a fixed voltage divider use of a fixed voltage divider to generate a signal	calculations of voltage, current and unknown values in a fixed voltage divider design of a voltage divider to provide an input signal for a

		control circuit Interpretation of information from given tables for an LDR and a thermistor
Transistors and amplifiers	use of resistors in electronic systems for component protection	function of a relay and a protection diode in an electronic circuit explanation of the switching function of a transistor the operation of an electronic control circuit which includes a variable voltage divider, transistor, relay and output transducer

Digital electronic control systems		
Topic	**National 4**	**National 5**
Digital logic	description of AND, OR and NOT gates using truth tables	AND, OR and NOT gates, and combinations with up to three inputs, using truth tables, logic diagrams and Boolean expressions
Microcontroller control systems		examples of the use of microcontrollers in commercial and industrial applications advantages and disadvantages of microcontroller-based control systems compared to a hard-wired electronic equivalent
Flowcharts and programming	use of correct symbols (start, stop, input, output, branch, loop) to construct flowcharts showing solutions to simple control programs	use of correct symbols (start, stop, input, output, branch, loop) to construct flowcharts showing solutions to simple control programs, involving time delays, continuous and fixed loops use of suitable commands, including high, low, for…next, if…then, pause, end (or their equivalents) to construct programs to solve simple control problems, involving time delays, continuous and fixed loops

Mechanisms and Structures		
Context	**National 4**	**National 5**
Drive systems	examples of motion in mechanical systems — rotary, reciprocating, oscillating and	motion in mechanical systems — rotary, linear, reciprocating and oscillating

	linear belt drives and chain drives purpose of a tensioner the use and effects of friction in simple drive systems crank and slider, cam and follower, rack and pinion appropriate British Standard symbols	simple gear train systems, including idler gears (diagrams and conventions for representation) compound gear trains calculation of speed (velocity) ratio of simple and compound gear trains the effects of friction in drive systems appropriate British Standard symbols
Pneumatics	use of fluid (air) to produce linear movement in single and double acting cylinders standard pneumatic symbols, eg mains air, pilot air, exhaust, tee piece, single and double acting cylinders, 3/2 valve, shuttle valve and actuators (push button, roller, roller trip, plunger, lever, solenoid, spring return and pilot) logic control of pneumatic circuits including OR and AND control circuits relationship between force, pressure and area in single acting cylinders	symbols and operation of standard pneumatic components (including restrictor, uni-directional restrictor, reservoir, 5/2 valve and actuators (diaphragm, solenoid) pneumatic time delay circuits calculation of relationships between force, pressure and area in single and double acting cylinders control of speed and force
Structures and forces	effects of a force concurrent forces, equilibrium use of triangle of forces and free body diagrams	examples of effects of a force concurrent forces, equilibrium use of triangle of forces and free body diagrams non-concurrent forces, parallel forces moment of a force calculations involving the principle of moments balance beam, simply supported beam, reaction forces
Materials	compression, tension, shearing and bending properties of materials	selection of appropriate material for given application, with justification calculation of the relationship between direct stress, force and area calculation of strain

Administrative information

Published: July 2013 (version 1.1)

History of changes to Course Support Notes

Course details	Version	Description of change	Authorised by	Date
	1.1	Minor changes to gathering evidence and content tables.	Qualifications Development Manager	July 2013

Note: You are advised to check SQA's website (**www.sqa.org.uk**) to ensure you are using the most up-to-date version.

Unit Support Notes

Unit Support Notes — Engineering Contexts and Challenges (National 5)

Please refer to the note of changes at the end of this document for details of changes from previous version (where applicable).

Introduction

These support notes are not mandatory. They provide advice and guidance to support the delivery of the *Engineering Contexts and Challenges* (National 5) Unit. They are intended for teachers and lecturers who are delivering this Unit. They should be read in conjunction with:

- the *Unit Specification*
- the *Course Specification*
- the *Course Assessment Specification*
- the *Course Support Notes*
- appropriate assessment support materials

General guidance on the Unit

Aims

The general aim of this Unit, as stated in the *Unit Specification*, is to develop a basic understanding of engineering, and its role and impact on our society and environment. Learners will investigate engineering systems, problems and solutions, involving some existing and emerging technologies, and consider implications relating to the environment, sustainable development, and to economic and social issues.

This Unit will also give learners the opportunity to develop thinking skills and skills in numeracy, employability, enterprise and citizenship.

The Unit can be delivered:

- as a stand-alone Unit
- as part of the National 5 Engineering Science Course

Progression into this Unit

Entry to this Unit is at the discretion of the centre. However, learners would normally be expected to have attained some useful skills and knowledge from prior learning, such as:

- *Engineering Contexts and Challenges* (National 4) Unit

Learners may also have gained relevant skills and knowledge through other education systems or from their own interests and informal learning.

Skills, knowledge and understanding covered in this Unit

Information about skills, knowledge and understanding is given in the National 5 Engineering Science *Course Support Notes*.

If the Unit is being delivered as part of the National 5 Engineering Science Course, the teacher should refer to the 'Further mandatory information on Course coverage' section within the *Course Assessment Specification* for detailed content.

If this Unit is being delivered on a free-standing basis, teachers and lecturers are free to select the skills, knowledge, understanding and contexts which are most appropriate for delivery in their centres.

Progression from this Unit

On successful completion of this Unit, the following Units and Courses provide appropriate progression pathways for learners:

- the Engineering Contexts and Challenges (Higher) Unit
- National Certificate Group Awards in a range of engineering disciplines
- Skills for Work Courses in Energy and in Engineering Skills
- employment, apprenticeships and/or training in engineering and related fields

Approaches to learning, teaching, and assessment

The Unit is designed to provide flexibility and choice for both the learner and the teacher.

Learning and teaching activities should be designed to stimulate learners' interest, and to develop skills and knowledge to the standard required by the Outcomes and to the level defined by the associated Assessment Standards.

Tasks and activities throughout the Unit should be linked to relevant contexts. The *Unit Specifications* and *Course Specifications* define the skills and knowledge required, but leave complete freedom to the teacher and learner to select interesting contexts in which to develop these. This provides scope for personalisation and choice, as relevant and motivating contexts can be used. Aspects of existing engineered solutions to real-world problems should be studied to develop understanding. Possible contexts for study should be made as relevant as possible to the learners, by reflecting local, topical and Scottish issues. Individual, paired or group problem-solving tasks should be related to such contexts.

The *Course Support Notes* provide further broad guidance on approaches to learning and teaching which applies to all the Units of the Course, and should be read before delivering this Unit.

When delivering the Unit as part of the National 5 Engineering Science Course, reference should be made to the appropriate content statements within the 'Further mandatory information on Course coverage' section to ensure the required breadth of knowledge is covered.

Sequence of delivery of Outcomes

The sequence of delivery of the Outcomes is also a matter for professional judgement and is entirely at the discretion of the centre. One possible approach is suggested below, but other possibilities exist.

Outcome 1 should be delivered first, not only in the Unit but also in the Course. Even if it is decided to teach this Unit last, the Outcome on systems will be required as an introduction to the engineering knowledge developed in the other two Units.

The systems approach should be introduced and then reinforced by developing system and then sub-system diagrams for a number of familiar products. Simple everyday products are ideal for the purpose. Learners should be encouraged to identify inputs and outputs. The sub-system diagram should identify the main input devices and output devices. Feedback loops providing closed loop control should also be identified where appropriate.

An introduction to energy can be overtaken using the same products as used for the systems approach. Learners should draw up energy transformation block diagrams showing the energy changes and losses, and carry out simple calculations on the efficiency of the process.

Outcomes 2 and 3 can be delivered together or separately and can be delivered either at the start of the Course, or at the end of the Course (see *Course Support Notes*). If delivered early in the Course, they would act as a broad introduction to engineering. If delivered after the other two Units, they could effectively pull together and consolidate knowledge and skills gained from the other two Units.

For these Outcomes, an engineering project involving the expertise of at least two (but preferably more) different branches of engineering is identified. The choice of project is not specified, allowing scope for personalisation and choice. Within the time available, one detailed project or several less detailed ones covering different aspects could be used.

Learners should then be given the opportunity to model some aspects of a solution to an engineering challenge (preferably related to the project studied) to show how what happens in the classroom relates to the skills and roles of engineers in projects, and to consolidate engineering knowledge and skills.

Outcome 3 could be considered as a permeating aspect of Outcome 2 and the effects of the project/projects considered as the function and engineering roles are being researched. Alternatively, it could be done separately and related to a local or topical project.

Meeting the needs of all learners
When delivering this Unit to a group of learners, with some working towards National 4 and others towards National 5, it may be useful for teachers to identify activities covering common knowledge and skills for all learners, and additional activities required for National 5 learners.

For example, while National 4 learners are working on identifying energy transformations, National 5 learners should be progressing on to energy audits. Similarly, when National 4 learners are considering the benefits of some engineering projects, National 5 learners should be moving on to consider both the benefits and any negative impacts.

Where National 5 learners have studied National 4 in a previous year, it is important to provide them with new and different contexts for learning to avoid demotivation. For example, an approach to Outcome 2 based on different engineering challenges from those used the previous year would allow similar topics to be covered but in a fresh context, thus maintaining motivation.

A similar approach is also appropriate for a mixed National 5 and Higher class, as the Higher Unit is similar in structure to the National 5 Unit.

In line with the underlying principles of Curriculum for Excellence, learners should be encouraged, and expected, to take an active role in their own learning. Where Course activities and materials allow them to progress in an independent manner, this will allow teaching of the two groups to happen most effectively.

Useful resources
Whichever electronic simulation package and programmable control hardware and software are chosen for the *Electronics and Control* Unit can usefully be introduced here if this Unit is delivered in its entirety at the start of the Course.

Possible electronic simulation packages would include:

- YENKA, produced by Crocodile Clips
- Visual Spice, produced by Quasar Electronics
- Circuit Logix student version, produced by Logic Design

A programmable control system which uses PICAXE basic is suitable. Hardware and free software downloads for Windows, MacOS and Linux are available from Revolution Education.

A range of mechanical components can be obtained from Rapid Education or other suppliers.

Construction kits such as those from Lego, fischertechnik and Meccano are ideal though not essential. They provide structures as well as a range of mechanisms, motors and interfaces, but are expensive if not already available, and the same results can be obtained using craft materials.

The *Engineering Daily* website provides a range of resources including an interesting list of what they consider to be the top 10 most impressive engineering projects.

There is good information about canals designed by some of Scotland's most famous engineers, and projects such as the Falkirk wheel, on the Scottish Canals website.

A good source of information on famous Scottish engineers and an excellent range of photographs can be found on the klickthis website.

Approaches to delivering and assessing each Outcome

The learner must demonstrate attainment of **all** of the Outcomes and their associated Assessment Standards. Assessment must be valid, reliable and fit for purpose.

SQA does not specify the methods of assessment to be used; teachers should determine the most appropriate method for their learners. In many cases, evidence (which may be oral or observational) will be gathered during normal classroom activities, rather than through formal assessment instruments.

Centres are expected to maintain a detailed record of evidence, including oral or observational evidence. Evidence in written or presentation format should be retained by the centre for verification.

Authentication of evidence

All evidence should be gathered under supervised conditions.

In order to ensure that the learner's work is their own, the following strategies are recommended:

- personal interviews with learners where teachers can ask additional questions about the completed work
- asking learners to do an oral presentation on their work
- ensuring learners are clear about acknowledging sources
- using checklists to record the authentication activity

Assessment Evidence may be produced in a variety of formats including presentations, web pages, digital photographs, digital video, podcasts and blogs, and these can be stored by the learner (or teacher) within a proprietary e-portfolio, or simply by storing them in a secure folder. It should be noted that centres should verify that this evidence is indeed that of the learner and ensure that no credit is given for archive information without further analysis or comment by the student.

Outcome 1
The learner will:

1 Investigate engineered objects by:

1.1 Describing, using the systems approach, how some engineered objects work.
1.2 Identifying sub-systems and describing the function of each and how they interact.
1.3 Producing system diagrams to show sub-systems.
1.4 Carrying out energy audits.

Notes on delivery of Outcome 1
The key word for this Outcome is ‘investigate’. Teachers should avoid a didactic approach, and use active learning approaches, such as pairs reverse-engineering simple products and presenting their findings with photos in PowerPoint to highlight and explain the working of the sub-systems. Learners need to develop an understanding that all products can be described in terms of the universal system of input, process and output. Learners should be given the chance to identify inputs and outputs and complete system diagrams for a range of familiar products.

Learners should identify sub-systems and draw diagrams to show the relationship between these within the overall system. Through a number of tasks of increasing complexity, learners should learn to distinguish between open and closed loop control and describe the difference between manual and automatic closed loop control.

For some of the products analysed, learners might identify the energy inputs and outputs and consider the energy transformation function of the transducers. Learners could draw up block diagrams which show the energy transformations in a product. For example, the diagrams could show the inputs of light, heat and/or kinetic energy going into their respective input, electrical energy feeding the output transducers to produce light, sound, heat and/or kinetic energy as appropriate. The main energy losses should also be shown.

Learners should be given input and output energy values for a few example energy transformation systems and asked to calculate the losses. They should also be able to identify the form these ‘lost’ energies would take. Learners should put these values into a block diagram showing the type and amount of each of the input and output energies. Using these values a simple energy audit would be carried out and the overall efficiency of the system determined.

Notes on assessment of Outcome 1
Suitable systems are likely to be familiar to the learner, such as common household machinery, and in which sub-systems and input, process and outputs can be easily identified.

It is anticipated that learners will investigate a number of systems as part of their learning, until able to demonstrate the required competencies reliably.

- Energy audits could relate to kinetic, potential, electrical and heat energy.
- Evidence of Assessment Standards 1.1, 1.2 and 1.4 may be oral or written.
- Evidence of Assessment Standard 1.3 may be hand-drawn or electronic.

Outcome 2
The learner will:

2 Investigate engineering challenges and relate these to key engineering concepts by:

2.1 Identifying and describing how several different branches of engineering contribute to solving an engineering challenge
2.2 Describing examples of the varied roles of engineers in designing, implementing, testing and controlling complex systems
2.3 Modelling some aspect (related to one branch of engineering) of a solution to an engineering challenge
2.4 Explaining how emerging technologies may provide improved solutions to engineering challenges

Notes on delivery of Outcome 2
Learners will be developing their understanding of the main branches of engineering (civil, mechanical, electrical and chemical) and some other sub-branches. They may also discover that many hybrid types of engineering roles have developed in recent years. This can be achieved by involving learners in guided research and case studies.

Once a basic understanding has been developed, learners could be given the opportunity to study current and preferably local projects involving engineers from a number of the different branches. At least one project which involves the use of a renewable energy source in order to improve sustainability could be studied (this would also contribute to Outcome 3).

The systems approach should be applied to the project and its main component parts. The roles of engineers within parts of the project can be considered, as well as the contribution of different branches of engineering.

It is likely that as learners research a number of these projects, they will develop a broad understanding of the varied roles of engineers. There should be some discussion of how emerging technology could be used in the project to improve it in some way. Current online news items might be a useful resource for this area of study.

It is important that learners see the relevance of any design, simulation and modelling that they do. So activities should be chosen which replicate, albeit in a simplified way, the function of a sub-system of the project. Groups within the class could be given different aspects of the same engineering project to model or simulate. This could be done using simulation packages such as YENKA, or by building electronic control systems using modular boards such as E&L or Alpha, or mechanical aspects using Lego, fischertechnik or craft materials.

The way these design and modelling activities is carried out will depend on whether this Unit is being delivered first or whether Outcomes 2 and 3 are being delivered after the other Units of the Course. If it is being delivered first, learners (especially those who have come directly into National 5 without first studying National 4) will require some considerable explanation of the components involved. However, if these Outcomes are being done towards the end of Course, there is a possibility of using this activity as a consolidation of learning from the other two Units.

Notes on assessment of Outcome 2
Following study of a series of suitable 'engineering challenges', learners should have developed an understanding of the broad range of applications of various branches of engineering and the diverse roles of engineers within these, and should then be able to demonstrate Assessment Standards 2.1, 2.2 and 2.4. This could be by oral or written responses to questions, or by contributing to group presentations.

Assessment Standard 2.3 could be modelling using a kit, simple materials or by simulation.

Outcome 3
The learner will:

3 Describe some aspects of the impact of engineering by:

3.1 Describing examples of social and economic impacts of engineering.
3.2 Describing some examples of environmental impacts of engineering.
3.3 Describing some ways in which engineering solutions contribute to tackling climate change.

Notes on delivery of Outcome 3
This Outcome might be better delivered towards the end of the Course, following study of mechanism, structures, electronics and control, as a useful way of drawing together many strands of the Course.

The use of class discussion, group research and presentation could be used to develop an awareness of the pervasive impact of engineering, bringing advantages and disadvantages to society as a whole, as well as to local communities. Learners should be able to describe these advantages and disadvantages under the broad headings of society, the economy and the environment. The projects considered for Outcome 2 could be used.

Notes on assessment of Outcome 3
Evidence may be written, or in the form of a presentation (or presentations) on a particular engineering application (or applications).

Developing skills for learning, skills for life and skills for work

Learners are expected to develop broad generic skills as an integral part of their learning experience. The *Unit Specification* lists the skills for learning, skills for life and skills for work that learners should develop through this Course. These are based on SQA's *Skills Framework: Skills for Learning, Skills for Life and Skills for Work* and must be built into the Unit where there are appropriate opportunities. The level of these skills will be appropriate to the level of the Unit.

The table below highlights opportunities to develop these skills during this Unit.

2 Numeracy	
2.3 Information handling	Drawing and interpreting system and sub-system diagrams Interpreting online and other data sources

4 Employability, enterprise and citizenship	
4.2 Information and communication technology (ICT)	Researching engineering applications using on-line resources

5 Thinking skills	
5.2 Understanding	Describing how some engineered objects work Describing some examples of environmental impacts of engineering Describing how engineering solutions contribute to tackling climate change
5.3 Applying	Producing system diagrams to show sub-systems Modelling aspects of a solution to an engineering challenge Explaining how emerging technologies may provide improved solutions to engineering challenges

The Unit may also provide opportunities to develop or consolidate other skills for life, learning and work, including:

- reading and writing
- number processes
- working with others
- enterprise and citizenship
- applying and evaluating

Combining assessment within Units

It may be possible to develop learning/assessment activities which provide evidence that learners have achieved the standards for more than one Outcome within the Unit, thereby reducing the assessment burden on learners. Combining assessment of Outcomes (or parts of Outcomes) in this way is perfectly acceptable, but needs to be carefully managed to ensure that all assessment standards and Outcomes for the Unit are covered.

Equality and inclusion

The requirement to develop practical skills involving the use of equipment and tools may present challenges for learners with physical or visual impairment. In such cases, reasonable adjustments may be appropriate, including (for example) the use of adapted equipment or alternative assistive technologies.

It is recognised that centres have their own duties under equality and other legislation and policy initiatives. The guidance given in these Unit Support Notes is designed to sit alongside these duties but is specific to the delivery and assessment of the Unit.

Alternative approaches to Unit assessment to take account of the specific needs of learners can be used. However, the centre must be satisfied that the integrity of the assessment is maintained and that the alternative approach to assessment will, in fact, generate the necessary evidence of achievement.

Appendix 1: Reference documents

The following reference documents will provide useful information and background.

- Assessment Arrangements (for disabled learners and/or those with additional support needs) — various publications on SQA's website: http://www.sqa.org.uk/sqa/14976.html
- *Building the Curriculum 4: Skills for learning, skills for life and skills for work*
- *Building the Curriculum 5: A framework for assessment*
- Course Specifications
- Design Principles for National Courses
- *Guide to Assessment* (June 2008)
- Overview of Qualification Reports
- *Principles and practice papers for curriculum areas*
- *Research Report 4 — Less is More: Good Practice in Reducing Assessment Time*
- *Coursework Authenticity — a Guide for Teachers and Lecturers*
- *SCQF Handbook: User Guide (published 2009)* and SCQF level descriptors (to be reviewed during 2011 to 2012): www.sqa.org.uk/sqa/4595.html
- *SQA Skills Framework: Skills for Learning, Skills for Life and Skills for Work*
- *Skills for Learning, Skills for Life and Skills for Work: Using the Curriculum Tool*
- SQA Guidelines on e-assessment for Schools
- SQA Guidelines on Online Assessment for Further Education
- SQA e-assessment web page: www.sqa.org.uk/sqa/5606.html

Administrative information

Published: July 2013 (version 1.1)

Superclass: XA

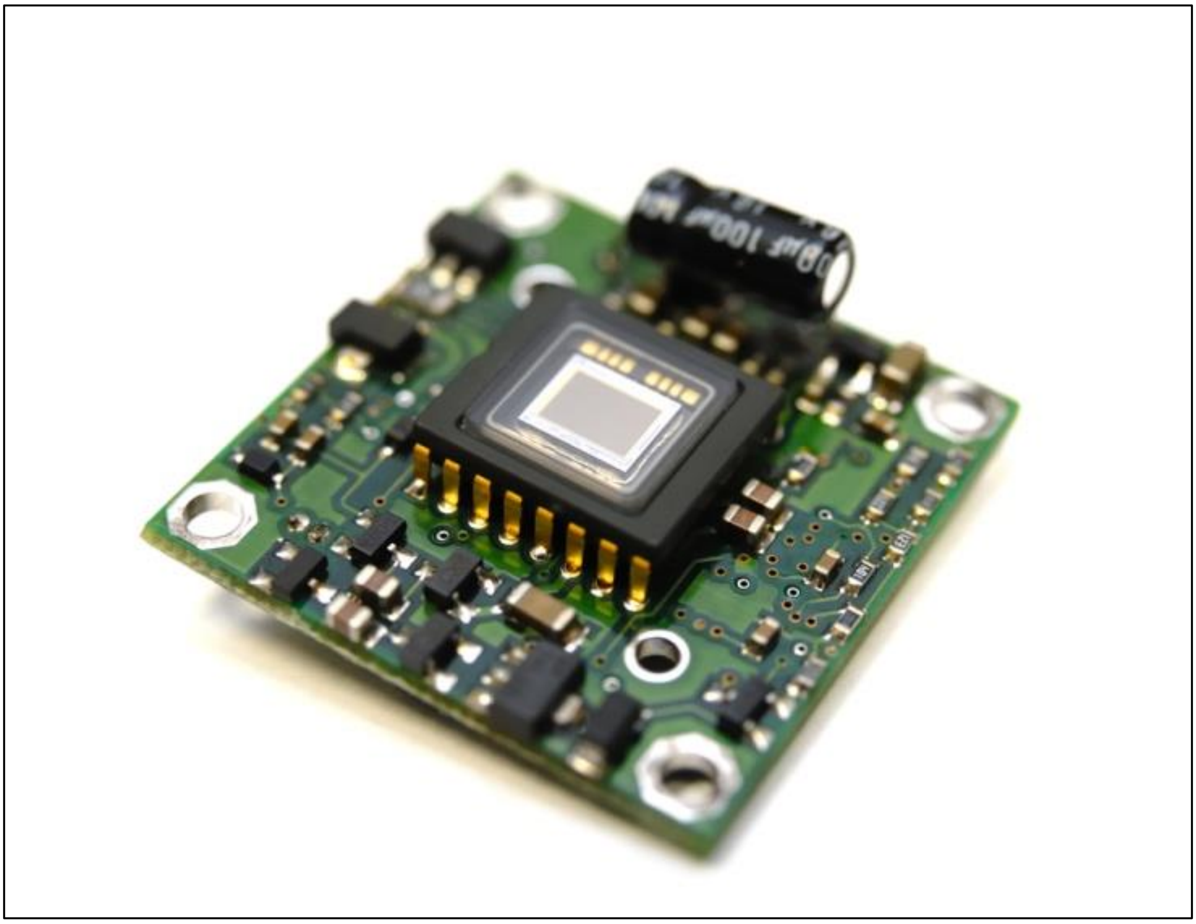
History of changes to Unit Support Notes

Unit details	Version	Description of change	Authorised by	Date
	1.1	Minor changes to gathering evidence and content tables.	Qualifications Development Manager	July 2013

Note: You are advised to check SQA's website (**www.sqa.org.uk**) to ensure you are using the most up-to-date version.

Unit Support Notes

Unit Support Notes — Electronics and Control (National 5)



Please refer to the note of changes at the end of this document for details of changes from previous version (where applicable).

Introduction

These support notes are not mandatory. They provide advice and guidance to support the delivery of the Electronics and Control (National 5) Unit. They are intended for teachers and lecturers who are delivering this Unit. They should be read in conjunction with:

- the *Unit Specification*
- the *Course Specification*
- the *Course Assessment Specification*
- the *Course Support Notes*
- appropriate assessment support materials

General guidance on the Unit

Aims

The general aim of this Unit, as stated in the *Unit Specification*, is to develop an understanding of electronic control systems. Learners will investigate and explore engineering problems and design, simulate, construct, test and evaluate solutions.

This Unit will also give learners the opportunity to develop thinking skills and skills in numeracy, employability, enterprise and citizenship.

The Unit can be delivered:

- as a stand-alone Unit
- as part of the National 5 Engineering Science Course

Progression into this Unit

Entry to this Unit is at the discretion of the centre. However, learners would normally be expected to have attained some useful skills and knowledge from prior learning, such as:

- *Electronics and Control* (National 4) Unit

Learners may also have gained relevant skills and knowledge through other education systems or from their own interests and informal learning.

Skills, knowledge and understanding covered in this Unit

Information about skills, knowledge and understanding is given in the National 5 Engineering Science *Course Support Notes.*

If the Unit is being delivered as part of the National 5 Engineering Science Course, the teacher should refer to the 'Further mandatory information on Course coverage' section within the *Course Assessment Specification* for detailed content.

If this Unit is being delivered on a free-standing basis, teachers and lecturers are free to select the skills, knowledge, understanding and contexts which are most appropriate for delivery in their centres.

Progression from this Unit

On successful completion of this Unit, the following Units and Courses provide appropriate progression pathways for learners:

- *Electronics and Control* (Higher) Unit
- National Certificate Group Awards in a range of engineering disciplines
- Skills for Work Courses in Energy and in Engineering Skills
- employment, apprenticeships and/or training in engineering and related fields

Approaches to learning, teaching, and assessment

The Unit is designed to provide flexibility and choice for both the learner and the teacher.

Learning and teaching activities should be designed to stimulate learners' interest, and to develop skills and knowledge to the standard required by the three Outcomes and to the level defined by the associated Assessment Standards.

Tasks and activities throughout the Unit should be linked to relevant contexts such as manufacturing, consumer electronics, security systems, health/medicine, scientific research, transportation and construction. Aspects of existing engineered solutions to real-world problems can be analysed in simple terms to aid understanding: for example, security alarm systems, electrical kitchen utensils, manufacturing assembly lines, mobile phones, motorsport, scientific research, astronomical observation, medical instrumentation or consumer electronics.

Individual, paired or group problem-solving tasks should be related to authentic contexts. For example, learners could be asked to produce a working circuit that will simulate the operation of the motor in an electric vehicle (battery, variable resistor, switch and motor).

The National 5 Engineering Science *Course Support Notes* provide further broad guidance on approaches to learning and teaching which apply to all of the component Units of the course, and should be read before delivering this Unit.

When delivering the Unit as part of the National 5 Engineering Science Course, reference should be made to the appropriate content statements within the 'Further mandatory information on Course coverage' section to ensure the required breadth of knowledge is covered.

Sequence of delivery of Outcomes

The sequence of delivery of the Outcomes is a matter for professional judgement and is entirely at the discretion of the centre. Two main approaches are suggested, but other possibilities exist.

Delivering Outcomes 1 and 2 sequentially

The obvious approach is to start with Outcome 1 and then progress to Outcome 2. However, learners may find Outcome 2 to be an easier entry point, and this is an equally valid approach.

Within each Outcome, a possible sequence of topics could be:

Outcome 1

- Investigation of the function and purpose of input, process, and output sub-systems in an electronic circuit
- Calculations of voltage, current and resistance in series and parallel circuits
- Voltage divider circuits — investigation and calculation involving LDRs and thermistors
- Transistor driver circuits, including the use of diodes for component protection, and relays
- Problem solving activities based around relevant content and contexts

Outcome 2

- AND/OR/NOT combination logic and Boolean expressions
- Introduction to microcontroller-based systems
- Programming with flow charts
- Control programming
- Problem solving activities based around relevant content and contexts

Note: Centres may decide to teach flowcharts and control programming concurrently.

Delivering the Unit within the Engineering Science Course

When delivering this Unit as part of the National 5 Engineering Science Course, it is advisable to deliver Outcome 1 (the systems approach) of the *Engineering Contexts and Challenges* Unit **before** this Unit.

Meeting the needs of all learners

When delivering this Unit to a group of learners, with some working towards National 4 and others towards National 5, it may be useful for teachers to identify activities covering common knowledge and skills for all learners, and additional activities required for National 5 learners.

For example, while National 4 learners are using circuit building and testing equipment to investigate series circuits, National 5 learners could be doing extension work building transistor-based circuits with light or temperature sensors. Similarly, when National 4 learners are developing flowcharts using simulation software, those capable of National 5 should be moving on into control programming.

Where National 5 learners have studied National 4 in a previous year, it is important to provide them with new and different contexts for learning to avoid demotivation. For example, different digital control problems should be studied, so that the learners do not feel that they are simply doing the same work over again, albeit at a deeper level.

Where resources are limited it may be advantageous for centres to co-ordinate material so that each group is studying a different area at any time. For example, if access to computers is limited, National 4 learners could be set to work on simulated flowchart programming of control systems while National 5 learners are building and testing analogue electronic circuits.

A similar approach is also appropriate for a bi-level National 5 and Higher class, as the Higher Unit is similar in structure to the National 5 Unit.

In line with the underlying principles of Curriculum for Excellence, learners should be encouraged, and expected, to take an active role in their own learning. Where Course activities and materials allow them to progress in an independent manner, this will allow teaching of the two groups to happen most effectively.

Useful resources
Where possible, centres should source or produce modelled systems to enhance learners' ability to contextualise the Unit material. This may take the form of pre-built models that the pupils can use directly or connect to the programmed systems or circuits they create.

- Yenka (from Crocodile Clips), or Electronics Workbench, offer electronic circuit simulation and measurement in analogue and digital circuits. Yenka also provides suitable flowchart simulations that can be linked to microcontroller based circuits within the package. These flowcharts can be downloaded directly to many commercially available microcontroller-based kits without the requirement for pupils to learn any other programming language skills. The Logic-Lab is useful logic simulation software available free from the neuroproductions web site.
- A number of other commercially available products are available.
- Programs can be downloaded to various commercially available products such as those from PICAXE Microsystems, Lego Mindstorm or STAMP controllers. It should be noted that learners should become familiar with standard flowchart symbols and conventions even if particular hardware does not use them.
- There are a number of different high-level programming languages available that may be suitable for the delivery of this Unit, including PBASIC among others. There is no particular language specified for this Course, and the Course assessment will not assume knowledge of any specific language. However, the language used must be able to deliver the constructs listed in the *Course Assessment Specification*, namely: start, stop, input, output, branch, loop.
- Modular electronic systems produced, by manufacturers such as Unilab or E&L, can provide a suitable method of developing some of the required concepts. Control Studio by New Wave Concepts offers similar functions in a simulated environment.

Centres wishing to build circuits will need a stock of components, including resistors, motors, breadboards (prototype board) and so on, from one of the many commercial suppliers. Multimeters and logic probes will also be required for measurement exercises and fault finding.

Approaches to delivering and assessing each Outcome
The learner must demonstrate attainment of **all** of the Outcomes and their associated Assessment Standards. Assessment must be valid, reliable and fit for purpose.

SQA does not specify the methods of assessment to be used; teachers should determine the most appropriate method for their learners. In many cases, evidence (which may be oral or observational) will be gathered during normal classroom activities, rather than through formal assessment instruments.

Centres are expected to maintain a detailed record of evidence, including oral or observational evidence. Evidence in written or presentation format should be retained by the centre.

Authentication of evidence
All evidence should be gathered under supervised conditions.

In order to ensure that the learner's work is their own, the following strategies are recommended:

- personal interviews with learners where teachers can ask additional questions about the completed work
- asking learners to do an oral presentation on their work
- ensuring learners are clear about acknowledging sources
- using checklists to record the authentication activity

Assessment Evidence may be produced in a variety of formats including presentations, web pages, digital photographs, digital video, podcasts and blogs, and these can be stored by the learner (or teacher) within a proprietary e-portfolio, or simply by storing them in a secure folder. It should be noted that centres should verify that this evidence is indeed that of the learner and ensure that no credit is given for archive information without further analysis or comment by the student.

Outcome 1
The learner will:

1 Develop analogue electronic control systems by:

1.1 Describing a range of analogue components and their functions and purpose within a circuit.
1.2 Producing circuit diagrams of analogue electronic circuits.
1.3 Using simple formulae to calculate appropriate component values.
1.4 Simulating or constructing analogue electronic control systems.
1.5 Testing and evaluating analogue electronic solutions against a specification.

Notes on delivery of Outcome 1
Learners should be introduced to the requirement for input, process and output sub-systems in an electronic circuit and the function of each. This may involve studying existing systems and identifying, where possible, the components that may be required.

Using Ohm's law, learners should gain experience of calculating voltage, current, and resistances in both series and parallel circuits. This can be introduced by, or consolidated with, practical experience and simulation software.

Voltage dividers should be considered in their capacity as both fixed voltage dividers and as providing input signals for a control system. This will involve the use of LDRs, thermistors, and both fixed and variable resistors. Learners should also gain experience of interpreting information on LDRs and thermistors from given tables. Incorporating their understanding of Ohm's law, learners should perform calculations to work out output voltages from voltage dividers under different input conditions.

Transistors should be considered in their capacity as switching devices. Learners should gain experience of connecting them to output devices such as lamps, motors, buzzers and relays. The use of diodes for circuit protection should also be covered.

Notes on assessment of Outcome 1
It is expected that learners will develop a number of control systems as part of their learning, but evidence is only required of one successful example for each Assessment Standard.

All Assessment Standards may be addressed using a single problem solving task or by a series of separate activities.

- Evidence of Assessment Standard 1.1 may be written or oral. The range of components is listed in the *Course Assessment Specification.*
- Evidence of Assessment Standard 1.2 may be in a hand-drawn or electronic format. Standard symbols should be used.
- Evidence of Assessment Standard 1.3 should be written or oral responses to questions.
- Evidence of Assessment Standard 1.4 should demonstrate the use of individual components and should not be produced using 'block' processes. It may be photographic or a printout of a simulation.
- Evidence of Assessment Standard 1.5 may be written or oral.

Outcome 2
The learner will:

2 Develop digital electronic control systems by:

2.1 Describing a range of digital components and their functions
2.2 Producing flowcharts and programs for digital control systems
2.3 Simulating or constructing digital control systems
2.4 Testing and evaluating digital electronic solutions against a specification

Notes on delivery of Outcome 2
Learners should investigate logic circuits using AND, OR and NOT gates with up to three inputs. Systems should be analysed and described using truth tables and Boolean expressions.

Microcontrollers should be investigated with respect to their use in commercial and industrial applications. This could be an investigative group task, followed by a presentation to the class. Learners should consider their advantage over hard-wired electronic equivalent circuits.

Learners should develop their use of flowchart programming to control systems requiring time delays, fixed and continuous loops, and up to three inputs and outputs. High-level programming of microcontroller systems should progress from the use of flowcharts. Learners should gain experience of using standard commands such as those to switch output devices, create time delays, test conditions, and generate fixed and continuous loops. Learners will be expected to generate a flowchart from a given problem specification and a program from a given flowchart.

Where the Unit is being taught as part of the Course in a more integrated fashion, problem solving activities provide excellent opportunities to make links between Units. For example, electronic solutions can be used to control mechanical systems (either using pre-built models or allowing learners the opportunity to construct for themselves). The resulting models could then be analysed with respect to their implications on energy use and the environment.

Notes on assessment of Outcome 2
It is expected that learners will develop a number of control systems as part of their learning, but evidence is only required of one successful example for each Assessment Standard.

All standards may be addressed using a single problem solving activity or by a series of separate activities.

- Evidence of Assessment Standard 2.1 may be written or oral.
- Evidence of Assessment Standard 2.2 may be in a graphical or electronically produced format.
- Evidence of Assessment Standard 2.3 may be photographic or a printout from a simulated system.
- Evidence of Assessment Standard 2.4 may be observational, with written or oral record of test results

Developing skills for learning, skills for life and skills for work

Learners are expected to develop broad generic skills as an integral part of their learning experience. The *Unit Specification* lists the skills for learning, skills for life and skills for work that learners should develop through this Course. These are based on SQA's *Skills Framework: Skills for Learning, Skills for Life and Skills for Work* and must be built into the Unit where there are appropriate opportunities. The level of these skills will be appropriate to the level of the Unit.

The table below highlights opportunities to develop these skills during this Unit.

2 Numeracy	
2.1 Number processes	Applying Ohm's Law Using meters to measure voltage, current and resistance Applying correct units to results Problem solving questions applying Ohms' Law to calculate values of resistance, current and voltage
2.3 Information handling	Constructing electronic circuits by interpreting circuit and layout diagrams Producing circuit diagrams Producing flowcharts and control programs Producing and interpreting truth tables
4 Employability, enterprise and citizenship	
4.2 Information and communication technology (ICT)	Using circuit simulation software Using flowcharting software Researching the commercial uses of microcontrollers Storing evidence (notes, reports, diagrams) in digital format

5	Thinking skills
5.3 Applying	Practical problem solving in designing analogue and digital control systems Applying electronic control concepts to real-life example and situations
5.4 Analysing and evaluating	Testing and evaluating analogue and digital control systems

The Unit may also provide opportunities to develop or consolidate other skills for life, learning and work, including:

- Reading and writing
- Number processes
- Working with others
- Enterprise and citizenship
- Remembering and understanding

Combining assessment within Units

It may be possible to develop learning/assessment activities which provide evidence that learners have achieved the standards for both Outcomes within the Unit, thereby reducing the assessment burden on learners. Combining assessment of Outcomes (or parts of Outcomes) in this way is perfectly acceptable, but needs to be carefully managed to ensure that all assessment standards and Outcomes for the Unit are covered.

Equality and inclusion

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Appendix 1: Reference documents

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- SQA Guidelines on e-assessment for Schools
- SQA Guidelines on Online Assessment for Further Education
- SQA e-assessment web page: www.sqa.org.uk/sqa/5606.html

Administrative information

Published: July 2013 (version 1.1)

Superclass: XL

History of changes to Unit Support Notes

Unit details	Version	Description of change	Authorised by	Date
	1.1	Minor changes to gathering evidence and content tables.	Qualifications Development Manager	July 2013

Note: You are advised to check SQA's website (**www.sqa.org.uk**) to ensure you are using the most up-to-date version.

Unit Support Notes

Unit Support Notes — Mechanisms and Structures (National 5)

Please refer to the note of changes at the end of this document for details of changes from previous version (where applicable).

Introduction

These support notes are not mandatory. They provide advice and guidance to support the delivery of the *Mechanisms and Structures* (National 5) Unit. They are intended for teachers and lecturers who are delivering this Unit. They should be read in conjunction with:

- the *Unit Specification*
- the *Course Specification*
- the *Course Assessment Specification*
- the *Course Support Notes*
- appropriate assessment support materials

General guidance on the Unit

Aims

The general aim of this Unit, as stated in the *Unit Specification*, is to develop an understanding of mechanisms and structures. Learners will explore a range of mechanical and pneumatic systems and design, simulate, construct, test and evaluate mechanical or pneumatic solutions to solve problems.

This Unit will also give learners the opportunity to develop thinking skills and skills in numeracy, employability, enterprise and citizenship.

The Unit can be delivered:

- ♦ as a stand-alone Unit
- ♦ as part of the National 5 Engineering Science Course

Progression into this Unit

Entry to this Unit is at the discretion of the centre. However, learners would normally be expected to have attained some useful skills and knowledge from prior learning, such as:

- ♦ *Mechanisms and Structures* (National 4) Unit

Learners may also have gained relevant skills and knowledge through other education systems or from their own interests and informal learning.

Skills, knowledge and understanding covered in this Unit

Information about skills, knowledge and understanding is given in the National 5 Engineering Science *Course Support Notes.*

If the Unit is being delivered as part of the National 5 Engineering Science Course, the teacher should refer to the 'Further mandatory information on Course coverage' section within the *Course Assessment Specification* for detailed content.

If this Unit is being delivered on a free-standing basis, teachers and lecturers are free to select the skills, knowledge, understanding and contexts which are most appropriate for delivery in their centres.

Progression from this Unit

On successful completion of this Unit, the following Units and Courses provide appropriate progression pathways for learners:

- the *Mechanisms and Structures* (Higher) Unit
- National Certificate Group Awards in a range of engineering disciplines
- Skills for Work Courses in Energy and in Engineering Skills
- employment, apprenticeships and/or training in engineering and related fields

Approaches to learning, teaching, and assessment

The Unit is designed to provide flexibility and choice for both the learner and the teacher.

Learning and teaching activities should be designed to stimulate learners' interest, and to develop skills and knowledge to the standard required by the three Outcomes and to the level defined by the associated Assessment Standards.

Tasks and activities throughout the Unit should be linked to relevant contexts. The Unit and Course Specifications define the skills and knowledge required, but leave complete freedom to the teacher and learner to select interesting contexts in which to develop these. This provides scope for personalisation and choice, as relevant and motivating contexts can be used. Aspects of existing engineered solutions to real-world problems can be analysed to aid understanding. Examples of possible contexts for study could include bicycle design, automotive design, wind turbine design, bridge design, etc. Individual, paired or group problem-solving tasks should be related to such contexts.

The National 5 Engineering Science *Course Support Notes* provide further broad guidance on approaches to learning and teaching which applies to all of the component Units of the Course, and should be read before delivering this Unit.

When delivering the Unit as part of the National 5 Engineering Science Course, reference should be made to the appropriate content statements within the 'Further mandatory information on Course coverage' section to ensure the required breadth of knowledge is covered.

Sequence of delivery of Outcomes
The sequence of delivery of the Outcomes is a matter for professional judgement and is entirely at the discretion of the centre. Two main approaches are suggested, but other possibilities exist.

Delivering Outcomes 1 and 2 sequentially
The obvious approach is to start with Outcome 1 and then progress to Outcome 2. Following this approach, the learner explores a range of mechanical systems, pneumatic systems and structures, to gain an understanding of their key features. In Outcome 2, this knowledge is applied to design, construct and/or simulate and test solutions to practical problems.

This approach, however, may be less motivating for learners than a more integrated approach.

Integrated approach to Outcomes 1 and 2
The second approach combines Outcomes 1 and 2 and bases the development of knowledge and skills through one or more contexts. For example, much of the Unit could be delivered through the context of cycling and bike design:

- Chain drives can be the basis for exploring drive systems, and debate and discussion can take place surrounding belt drives (studied at National 4) as an alternative.

- Motion can be delivered easily in this context, as well as calculating speed.
- A real bicycle can be used to demonstrate velocity ratios and the changes in motion which take place during cycling.
- Frame design relates to structures, including shape and properties of materials.
- Forces and moments can be taught through the operation of the brake lever.
- Energy can be studied through the discussion and investigation of cyclists in and during the Tour de France, by looking at forms of energy, energy transfer and transformations during the contest, and calculations of work done.

Other contexts (or combinations of contexts), such as automotive design, alternative energy devices or bridge-building, could equally well be used as a theme.

Delivering the Unit within the Engineering Science Course
When delivering this Unit as part of the National 5 Engineering Science Course, it is advisable to deliver Outcome 1 (the systems approach) of the *Contexts and Challenges* Unit before this Unit.

Meeting the needs of all learners
When delivering this Unit to a group of learners, with some working towards National 4 and others towards National 5, it may be useful for teachers to identify activities covering common knowledge and skills for all learners, and additional activities required for National 5 learners.

For example, while National 4 learners are completing work on basic rotary and linear motion, belt drive and chain drives, National 5 learners could be doing extension work related to gears, cranks, and so on. Similarly, when National 4 learners are consolidating their understanding of free body diagrams, those capable of National 5 should be moving on to studies of moments.

Where National 5 learners have studied National 4 in a previous year, it is important to provide them with new and different contexts for learning to avoid demotivation. For example, if a contextual approach based on bicycles was used the previous year, an approach based on a different context, such as wind turbines, would allow similar topics to be covered but in a fresh context, thus maintaining motivation.

Where resources are limited, it may be advantageous for centres to co-ordinate material so that each group is studying a different area at any time. For example, if access to pneumatic equipment or software is limited, National 4 learners could be set to work on structures while National 5 learners are exploring pneumatics.

A similar approach is also appropriate for a mixed National 5 and Higher class, as the Higher Unit is similar in structure to the National 5 Unit.

In line with the underlying principles of Curriculum for Excellence, learners should be encouraged, and expected, to take an active role in their own learning. Where Course activities and materials allow them to progress in an independent manner, this will allow teaching of the two groups to happen most effectively.

Useful resources
Although not a definitive list, the following resources may support the delivery of Mechanisms and Structures:

- online videos (YouTube etc)
- Technology Enhancement Programme web site
- West Point Bridge Design Contest web site
- STEM-Central website
- various energy/pneumatic/mechanism kits available from Technology Supplies, TEP, Rapid Electronics, Economatics, etc
- Economatics — Airways simulation software

Approaches to delivering and assessing each Outcome
The learner must demonstrate attainment of all of the Outcomes and their associated Assessment Standards. Assessment must be valid, reliable and fit for purpose.

SQA does not specify the methods of assessment to be used; teachers should determine the most appropriate method for their learners. In many cases, evidence (which may be oral or observational) will be gathered during normal classroom activities, rather than through formal assessment instruments.

Centres are expected to maintain a detailed record of evidence, including oral or observational evidence. Evidence in written or presentation format should be retained by the centre for verification.

Authentication of evidence
All evidence should be gathered under supervised conditions.

In order to ensure that the learner’s work is their own, the following strategies are recommended:

- personal interviews with learners where teachers can ask additional questions about the completed work
- asking learners to do an oral presentation on their work
- ensuring learners are clear about acknowledging sources
- using checklists to record the authentication activity

Assessment Evidence may be produced in a variety of formats including presentations, web pages, digital photographs, digital video, podcasts and blogs, and these can be stored by the learner (or teacher) within a proprietary e-portfolio, or simply by storing them in a secure folder. It should be noted that centres should verify that this evidence is indeed that of the learner and ensure that no credit is given for archive information without further analysis or comment by the student.

Outcome 1
The learner will:

1 Investigate a range of mechanical and pneumatic systems by:

1.1 Describing, or producing diagrams of, a range of structures
1.2 Describing, or producing diagrams of, a range of pneumatic systems
1.3 Describing, or producing diagrams of, a range of mechanical drive systems

1.4 Carrying out calculations involving energy, work, power and efficiency, using given formulae

Notes on delivery of Outcome 1

The key word for this Outcome is 'investigate'. Structures, pneumatic systems and mechanical drive systems may be covered in sequence, or a thematic approach may be used (as described earlier in this document). The range of systems is undefined, allowing personalisation and choice. These can be explored in a variety of ways, including:

- reverse engineering of real devices
- studying diagrams of existing systems
- using simulation software
- building small models from kits

As each system is explored, learners can produce diagrams, drawings and reports (oral or written) explaining how these systems work. This will produce naturally-occurring evidence which may be used formatively or as summative evidence for Unit assessment.

Relevant calculations involving energy, work, power and efficiency could be applied to the systems.

Notes on assessment of Outcome 1

Learners should build up a portfolio of naturally-occurring evidence covering the four Assessment Standards.

- Evidence of Assessment Standards 1.1, 1.2 and 1.3 may be hand-drawn or electronic diagrams, and/or written or oral descriptions. The range of structures, pneumatic systems and drive systems should sample those listed in the *Course Assessment Specification*. Standard symbols should be used where appropriate.

- Evidence of Assessment Standard 1.4 could include examples of problem-solving questions, based on the formulae listed in the *Course Assessment Specification*.

Outcome 2

The learner will:

2 Develop mechanical or pneumatic solutions to solve problems by:

2.1 Identifying key aspects of a problem
2.2 Applying knowledge and understanding of structures, pneumatics and/or mechanical drive systems
2.3 Designing, and simulating or building, mechanical or pneumatic systems
2.4 Testing and evaluating solutions against a specification

Notes on delivery of Outcome 2

Outcome 2 may be best achieved through a problem solving challenge or a series of challenges, building on the knowledge developed through Outcome 1. Note that the Outcome can be demonstrated through either mechanical or pneumatic systems (not necessarily both), and the system can be constructed or simulated. A series of increasingly complex systems could be developed, building learners' skills and understanding.

Two possible examples challenges are described below:

- A challenge to design and model/simulate a system to collect fresh farm produce directly from a field and package it. The learner can decide whether to use pneumatics and/or mechanisms. This will require a knowledge of belt and chain drives in order to choose the most suitable, and application of knowledge of rotary and linear motion in a conveyor system. Calculations of speed reductions will also be required.
- An alternative challenge may be to design and build a system for a cheese press in a factory situation. This will require a basic knowledge of pressure and logic control in pneumatics.

This Outcome will also help develop skills in simple analysis, design, testing and evaluation, which will be useful preparation for the Course assessment assignment.

Notes on assessment of Outcome 2
All Assessment Standards may be addressed using a single extended problem solving task or by a series of separate activities.

- Evidence of Assessment Standard 2.1 may be written or oral.
- Evidence of Assessment Standard 2.2 may be observational, inferred from the decisions made during the task; learners could be asked to keep a diary or electronic log, or to give oral explanations to the teacher
- Evidence of Assessment Standard 2.3 may be photographic (constructed solution) or electronic (simulation). At least two working systems should be simulated or constructed.
- Evidence of Assessment Standard 2.4 may be written or oral

Developing skills for learning, skills for life and skills for work

Learners are expected to develop broad generic skills as an integral part of their learning experience. The *Unit Specification* lists the skills for learning, skills for life and skills for work that learners should develop through this Course. These are based on SQA's *Skills Framework: Skills for Learning, Skills for Life and Skills for Work* and must be built into the Unit where there are appropriate opportunities. The level of these skills will be appropriate to the level of the Unit.

The table below highlights opportunities to develop these skills during this Unit.

2 Numeracy	
2.1 Number processes	Using formulae involving energy, power, work done and efficiency Calculating efficiency (%) Applying correct units to results Using calculated results during the design of systems
2.3 Information handling	Studying diagrams of mechanisms Building pneumatic systems from diagrams Drawing diagrams of structures, mechanisms and pneumatic systems

4	Employability, enterprise and citizenship	
4.2	Information and communication technology (ICT)	Using simulation packages Researching mechanisms using online resources

5	Thinking skills	
5.3	Applying	Applying knowledge of structures, pneumatics and drive systems to solve practical problems
5.4	Analysing and evaluating	Identifying key aspects of a problem Evaluating mechanical and pneumatic solutions against a specification Choosing mechanical or pneumatic devices to solve a problem

The Unit may also provide opportunities to develop or consolidate other skills for life, learning and work, including:

- reading and writing
- working with others
- enterprise and citizenship
- remembering and understanding

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Administrative information

Published: July 2013 (version 1.1)

Superclass: XH

History of changes to Unit Support Notes

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