Course Support Notes

Higher 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).

May 2015, version 1.1

Contents

Introduction

These support notes are not mandatory. They provide advice and guidance to support the delivery of the Higher 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 Specification*s 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:

- extend and apply knowledge and understanding of key engineering concepts, principles and practice
- understand the relationships between engineering, mathematics and science
- apply analysis, design, construction and evaluation to a range of problems with some complex features
- communicate engineering concepts clearly and concisely using appropriate terminology
- develop a greater 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 5 Engineering Science
- National 5 Mathematics

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	Contexts and Challenges	Electronics and Control	Mechanisms and Structures	Course assessment
analysing engineering problems with some complex features	✓			✓
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 and understanding of the many types of engineering	✓			✓
knowledge and understanding of the wide role and impact of engineering on society and the environment	✓			✓
knowledge and understanding of the workings of a range of 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 and understanding of the relevance of energy, efficiency and sustainability to engineering problems and solutions			✓	✓
applying engineering knowledge, understanding and skills in a range of contexts		✓	✓	✓

Progression from this Course

This Course or its components may provide progression to:

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

and ultimately, for some, to:

- a range of engineering-related 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 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 Course at SCQF level 5 (National 5). The Engineering Science Courses at both 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 level 5.

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 5 and Higher knowledge and understanding. This table may be useful for:

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

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

Further advice on mixed level delivery 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, particularly at Higher, should take more responsibility for their own learning. Students will therefore, often working together, analyse, investigate, debate and evaluate engineering systems and solutions while the teacher acts increasingly in the role of 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. While 'working in a group' is not specifically identified as one of the skills for learning, life 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. Examples are provided in the Unit Support Notes.

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 learners' 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 Outcomes and associated Assessment Standards
- ability to apply the breadth of knowledge and understanding 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 class, there may be learners capable of achieving a standard beyond Higher in certain aspects of the Course. Where possible, these students should be encouraged and given the opportunity to deepen and broaden their engineering skills and knowledge.

There may also be learners who struggle to achieve the Higher standard in particular aspects of the Course, for example in the nodal analysis of a frame structure. Here teachers may consider the use of peer support, with a more able student taking on a tutor-type role and assisting other learners to develop and reinforce their understanding of a particular engineering topic.

Ultimately, though, it may be that certain learners only achieve National 5 in some of the Unit Outcomes. Teachers need to consider both the Outcomes and Assessment Standards, and the tables of concepts in Appendix 2 of these notes, to identify the differences between standards required for National 5 and Higher.

In some aspects of the Course, the difference between National 5 and Higher is defined in terms of a higher level of skill. For example, in *Engineering Contexts and Challenges*, Outcome 1 requires National 5 learners to ‘Investigate engineering systems, problems and solutions…’ while the equivalent Higher Outcome requires the learner to ‘Research and describe a complex system…’. In other aspects of the Course, the difference between National 5 and Higher is defined by different or additional knowledge. For example, National 5 learners need to describe the logic functions of AND, OR and NOT gates, while Higher students also need to know about NAND, NOR and EOR.

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

Where Higher learners have studied National 5 in a previous year, it is important to provide them with new and different contexts for learning to avoid demotivation.
For example, in Outcome 3 of the *Contexts and Challenges* Unit, it would be better for Higher learners to select a new engineered system to analyse and describe the environmental impact rather than re-using a National 5 topic and presenting this in greater depth.

Advice on distribution of time
Learners, especially at Higher, should 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.

Sequence of delivery
The sequence of delivery of the Units within the Higher 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.

A number of alternative approaches to delivering the Engineering Science Course are described in detail in the National 5 Engineering Science *Course Support Notes*. As the Higher Course has the same structure, any of these approaches may also be applied to Higher.

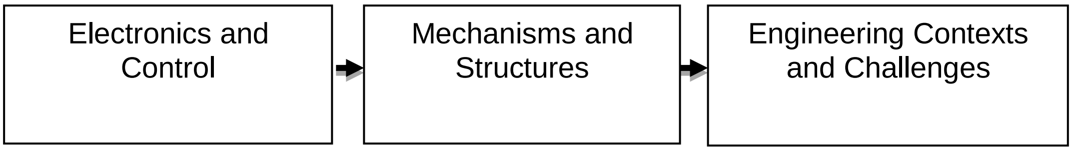
However, at Higher, there are good arguments for delivering the *Engineering Contexts and Challenges* Unit last to allow learning from the other Units to be integrated and consolidated within engineering contexts, and as a preparation for the assignment.

The assignment assesses application of knowledge, understanding and skills developed through the other Units, so 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.

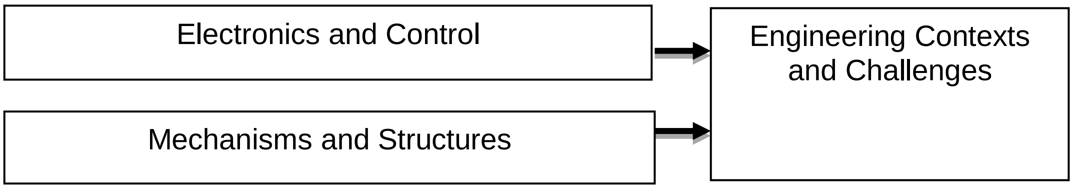
Mechanisms and Structures, and *Electronics and Control*, can be taught in either order, or in parallel. This provides flexibility for centres, regarding access to equipment, as this may need to be shared with a National 5 class.

Taking all of the above into account, the following two example Course structures might be considered.

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



Example 2: Concurrent delivery of Units



In both cases (or any other of the structures suggested in the National 5 *Course Support Notes*) the remainder of the Course time will provide opportunities for:

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

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, legacy Stamp Controllers, or Arduino boards, and associated flowchart simulation software (eg PICAXE Programming Editor — free download from the Picaxe website
- 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. Other software, including freeware and apps, may also be suitable
- 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. Other kits may also be suitable

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 Higher, such systems may be used to deliver Outcomes 2 and 3 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. Learners 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 April 1999 for Higher Technological Studies cover broadly the same topics as the *Electronics and Control* and the *Mechanisms and Structures* Units, and parts of these may be useful.

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

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

Calculations and significant figures
In carrying out calculations and using relationships to solve problems, it is important to encourage learners to give answers to an appropriate number of significant figures.

The simple rule for this is that the final answer can have no more significant figures than the value with least number of significant figures used in the calculation.

For example, if a learner is asked to calculate the kinetic energy of a mass of 103 kg travelling at 23 ms^{-1}, the correct answer should be 27 kJ (rather than 27,243.5 J). As the mass is given to 3 significant figures, and the velocity to 2 significant figures, the answer cannot be calculated to more than 2 significant figures.

If the velocity had been given as 23.0 ms^{-1}, then an answer of 27.2 kJ (3 significant figures) would have been appropriate.

If the velocity had been given as 23.01 ms^{-1}, then an answer of 27.2 kJ (3 significant figures) would still have been appropriate. Although the velocity is given to 4 significant figures, the mass is only to 3 significant figures, and so the answer is limited to 3 significant figures.

Where a calculation requires several stages, the rounding to the correct number of significant figures should always be applied to the final answer only.

In Course and Unit Assessments, some leniency may be applied to inappropriate numbers of significant figures, but learners should be encouraged to apply the guidance given here.

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

Guidance on the development of skills for learning, skills for life 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 Higher, 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 from the Units
- development of skills in applying knowledge and understanding
- 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, alternative assistive technologies or software simulations.

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)
- Principles and practice papers for curriculum areas
- *SCQF Handbook: User Guide* (published 2009) and
  SCQF level descriptors (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*

Appendix 2: Comparison of National 5 and Higher

This table shows the relationship between the mandatory National 5 and Higher 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 Higher

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

Course themes		
Topic	**National 5**	**Higher**
The systems approach	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	complex system, sub-system and control diagrams the role of feedback in a system closed loop, automatic, two-state and proportional feedback use of error detection in a closed loop system
Energy and efficiency	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 related to energy audits: inputs, outputs, energy losses and 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	manipulating given formulae to obtain answers	manipulating and combining given formulae to obtain answers using trigonometric functions and substitution in simultaneous equations to solve structural problems

Engineering Contexts and Challenges		
Topic	**National 5**	**Higher**
Engineering roles and disciplines	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	the role of the professional engineer within a project, including communication and team working the skills and specialist knowledge required within projects
Impacts of engineering	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	examples of social and economic impacts (positive and negative) of engineering examples of environmental impacts (positive and negative) of engineering sustainability of engineering solutions emerging technologies and their impact

Analogue electronic control systems		
Topic	**National 5**	**Higher**
Circuit diagrams and components	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	calculations involving the relationship between voltage, current and resistance (Ohm's law) calculations involving resistors in series and parallel	
Voltage dividers	calculations of voltage, current and unknown values in a fixed voltage divider design of a voltage divider to provide an input signal for a	variable resistors, light and temperature sensors in voltage dividers use of input transducer characteristics (from data

	control circuit Interpretation of information from given tables for an LDR and a thermistor.	booklet) to design voltage dividers to meet specification
Transistors and amplifiers	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	function and purpose of BJTs (bipolar junction transistors), 741ICs (building blocks) and op-amps (devices for amplifying voltage signals)function of op-amp configurations: inverting, non-inverting, comparator, difference amplifier, summing amplifier design of BJT circuit as a current amplifier calculation of relationship between input and output voltages for different op-amp configurations calculation of current gain (H_{FE}) of an npn transistor function and purpose of MOSFETs (unipolar junction transistors) using diagrams and characteristic graphs design of MOSFET (n-channel enhancement mode) circuit as a voltage operated switch function calculation of transconductance in a MOSFET comparison of two types of transistor in a given application

Digital electronic control systems		
Topic	**National 5**	**Higher**
Digital logic	AND, OR and NOT gates, and combinations with up to three inputs, using truth tables, logic diagrams and Boolean expressions	logic functions: AND, OR, NOT, NAND, NOR, EOR and combinations conversion to NAND equivalent development of Boolean expressions from truth tables, logic diagrams or circuit specifications

		construction of truth tables and logic diagrams from written specifications
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	controlling a motor using pulse width modulation control routines with up to 4 inputs and 4 outputs, processing analogue inputs
Flowcharts and programming	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	use of infinite and finite loops and time delays use of logic and arithmetic operations to make decisions

Mechanisms and Structures		
Context	**National 5**	**Higher**
Drive systems	motion in mechanical systems — rotary, linear, reciprocating and oscillating 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	selection of appropriate drive systems (including simple and compound gear trains, belt drives and chain drives) in different contexts the purpose of couplings (rigid and flexible — all types), bearings and joints in shafts purpose of friction in brakes and clutches calculation of torque: T = Fr
Pneumatics	symbols and operation of standard pneumatic components (including restrictor, uni-directional restrictor, reservoir, 5/2 valve	sequential control circuits with u to two cylinders electro-pneumatic control circuits

	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	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	resolving triangle/polygon of forces, resultant/equilibrium calculation of reaction forces in simply supported beams where loads are not exclusively horizontal or vertical, with hinge and roller supports, with UDLs (uniformly distributed loads) use of nodal analysis to calculate the size and nature of forces in frames
Materials	selection of appropriate material for given application, with justification calculation of the relationship between direct stress, force and area calculation of strain	properties of materials: brittleness, elasticity, ductility, plasticity calculation of Young's Modulus of elasticity and factor of safety use of strain gauges stress/strain (load/ extention) graphs calculation of strain energy: $E_s = \frac{1}{2} Fx$

Administrative information

Published: May 2015 (version 1.2)

History of changes to Course Support Notes

Version	Description of change	Authorised by	Date
1.1	Addition of guidance on use of significant figures. Clarification of some items in concept tables for consistency with the Course Assessment Specification, including using trigonometric functions and simultaneous equations to solve structural problems.	Qualifications Development Manager	June 2014
1.2	Amendment to some wording in appendix 2 for clarification. Removal of the term 'sheer stress'.	Qualifications Manager	May 15

Unit Support Notes

Unit Support Notes — Engineering Contexts and Challenges (Higher)

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* (Higher) 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 deep understanding of the broad discipline of engineering, and its role and impact on our society and environment. Learners will investigate complex 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 Higher 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 5) 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 Higher Engineering Science Course Support Notes.

If the Unit is being delivered as part of the Higher 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:

- related Units in Advanced 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

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, reflecting a variety of engineering disciplines. The Unit and Course Specifications define the skills and knowledge required, but leaves 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 and analysed, mathematically where possible, 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 these contexts.

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

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

Sequence of delivery of Outcomes
It is strongly recommended that, if this Unit is being delivered as part of the Higher Engineering Science Course, it should be delivered last. This would allow learning from the other Units to be integrated and consolidated within engineering contexts. If being delivered as a stand-alone Unit, then every opportunity should be taken to allow learners to apply and integrate technological knowledge and skills from previous learning.

The sequence of delivery of the Outcomes is a matter for professional judgement and is entirely at the discretion of the centre.

Outcome 1 provides an opportunity to develop skills and knowledge in analysis and the systems approach in more complex systems than studied at National 5. Outcomes 2 and 3 can then be delivered together or in sequence.

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

For example, all learners could study the same engineering project or projects. While National 5 learners are working on closed loop systems, Higher learners should be progressing by considering whether these are proportional or two-state and producing more detailed control system diagrams. Similarly, when National 5 learners are considering engineering roles, Higher learners can be progressing on to more detailed research into the professional roles and knowledge required and how engineers from different disciplines work together to produce integrated solutions.

Where Higher learners have studied National 5 in a previous year, it is important to provide them with new and different contexts for learning to avoid demotivation. For example, the engineering project or projects should be different from those used the previous year. This would allow similar concepts to be explored but in a fresh context, thus maintaining motivation. A similar approach may also be appropriate for a mixed Higher and Advanced Higher class.

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
The electronic simulation package and programmable control hardware and software chosen for the *Electronics and Control* Unit can usefully be introduced here if this Unit is delivered it 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. Arduino systems provide an alternative basis for developing electronic control systems.

Prototype boards and a range of components such as BJTs, MOSFETS, operational amplifiers 7400 and/or 4000, family logic chips, diodes, switches, relays, light and temperature sensors, all available from suppliers such as TEP, Technology Supplies, Rapid, CPC and many others.

A range of mechanical components can be obtained from Rapid Education or other similar 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 resource *DET Technological Studies Integrated Assignments Higher 8663* provides some idea of the type of integrated sub-systems which might be suitable. It is available from the Education Scotland website.

A number of useful textbooks have been developed for the Edexcel Engineering Diploma (published by Pearson), which contain relevant material. Free downloadable activity sheets and videos are also available from the publisher's website (FE and vocational section).

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 Research and describe a complex engineering system by:

1.1 Analysing the needs being met by the system
1.2 Identifying sub-systems, and describing the function of each and how they interact
1.3 Producing system and sub-system diagrams
1.4 Explaining the role of feedback in the system
1.5 Carrying out an energy audit of the system

The system researched should include both mechanical and electronic aspects.

Notes on delivery of Outcome 1

The key word for this Outcome is 'research'. Teachers should avoid didactic teaching, and use active learning approaches.

Initially, the teacher may guide the whole class through the analysis of a chosen engineering system, developing a broad overview of the need it fulfils, the type of technologies and the engineering disciplines involved. The system should be more complex (involving multiple disciplines and several interacting sub-systems) than those studied at National 5. Information can be found using videos, printed information and online resources. Learners can then carry out further research focusing on aspects of particular interest to them. Energy audit techniques (introduced at National 5) can be applied to this more complex system. The aim is to build up skills and knowledge so that learners can then undertake their own research project, into a system of their own choice.

Notes on assessment of Outcome 1

- a clear understanding of the function of the main parts of the system should be demonstrated
- evidence of Assessment Standards 1.1, 1.2 and 1.3 should be system and sub-system diagrams with accompanying explanations
- evidence of Assessment Standard 1.4 may be in the form of diagrams which show the feedback sensor, error detection, desired and actual outputs and explain the control device being used
- energy audits would relate to kinetic, potential, electrical and heat energy
- evidence of Assessment Standard 1.5 would require the learner to have calculated energy values and used these to determine losses and efficiency

Outcome 2

The learner will:

2 Model aspects of a complex engineered solution by:

2.1 Constructing or simulating a model of its control system
2.2 Constructing or simulating a model of a mechanical or structural aspect of the solution

Notes on delivery of Outcome 2

The purpose of this Outcome, when delivered as part of the Higher Engineering Science Course, is to relate learning from the *Electronics and Control* and *Mechanisms and Structures* Units to real-world engineered solutions. Where possible, learners should use information obtained from Outcome 1 to identify a control sub-system, and a mechanical or structural aspect of the system they have researched, and develop a model of this. The models may be constructed or simulated.

There is scope within this Outcome for more able learners to develop complex models, using calculated values, thus consolidating learning from the other Units. For example, sensor voltage dividers could be designed by looking up the resistance of a light or temperature sensor, and then calculating the value of a fixed or variable resistor to produce the desired output signal. If signal conditioning is required, suitable inverting and non-inverting operational amplifier resistor values can be calculated. If comparators or difference amplifiers are being used to provide two-state or proportional control respectively, again the requisite resistor value should be calculated.

Investigations and calculations could be carried out to determine suitable designs of mechanical or structural elements. This may involve determining a suitable material for a particular application and calculating the required section. Once the need for power transmission, motion conversion and/or mechanical advantage has been identified, suitable mechanisms can then be selected and designed.

Notes on assessment of Outcome 2
Evidence may be photographic, supplemented by information on how the models relate to the engineering system studied.

Outcome 3
The learner will:

3 Present a critical analysis of an engineered solution to a contemporary problem by:

3.1 Describing clearly the nature of the problem
3.2 Describing some social and economic impacts of the solution
3.3 Describing clearly some environmental impacts of the solution
3.4 Identifying and describing emerging technologies which may impact future developments

Notes on delivery of Outcome 3
The engineering systems and solutions considered for Outcomes 1 and 2 could be used as a basis for this Outcome. Where possible, a local or topical context should be chosen.

Notes on assessment of Outcome 3
Evidence may be written, or in the form of a presentation on a particular engineering problem and its solution.

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 and using these in the design of sub-systems. Calculating values to produce devices with particular characteristics.

4 Employability, enterprise and citizenship	
4.2 Information and communication technology (ICT)	Researching engineering applications using online resources. Preparing, delivering and reflecting on a presentation of research findings.

5 Thinking skills	
5.2 Understanding	Describing the function of one or more complex engineering systems. Describing the role of engineers within a project. Describing some social, economic and environmental impacts of engineering. Describing how engineering solutions contribute to tackling climate change.
5.3 Applying	Using knowledge gained from previous learning to design sub-systems which will function in a predetermined way. Testing, reflecting on and modifying sub-systems to perform in the desired way.

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

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

Combining assessment within Units

It may be possible to develop learning/assessment activities which provide evidence that learners have achieved the Assessment 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, alternative assistive technologies or the use of simulation software to ‘build’ models.

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: 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)
- *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 (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*
- 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: May 2015 (version 1.1)

History of changes to Unit Support Notes

Version	Description of change	Authorised by	Date
1.1	'An LDR or thermistor' replaced with 'light or temperature sensor' in the 'Approaches to learning, teaching, and assessment' section.	Qualifications Manger	May 15

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 (Higher)

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* (Higher) 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 Higher 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 5) 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 Higher Engineering Science Course Support Notes.

If the Unit is being delivered as part of the Higher 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:

- related Units in Advanced 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

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, mathematically where possible, to aid understanding. Suitable examples would include 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 write a program to control the braking system for a sports car or build an electronic circuit to control an air conditioning system.

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

Sequence of delivery of Outcomes
The sequence of delivery and distribution of time between the various Outcomes is a matter for professional judgement and is entirely at the discretion of the centre. However, it is likely that Outcome 1 will require the greatest time allocation. Two main approaches are suggested, but other possibilities exist.

Delivering Outcomes 1, 2, and 3 sequentially
The obvious approach is to start with Outcome 1 and then progress to Outcome 2 then 3. However, depending on their prior learning, learners may find Outcome 3 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

- Investigate the use of light sensors, temperature sensors, and variable resistors in voltage dividers as input sensors. Access information on transducer characteristics (from data booklet) to aid in the design of voltage dividers to meet given specification.
- Investigate the function and purpose of bipolar junction transistors in their capacity as current amplifiers. Perform calculations of current gain.
- Investigate the function and purpose of operational amplifiers configurations. Perform calculations of gain, input voltage and output voltage for inverting, non-inverting, comparator, difference, and summing configurations.

- Investigate the function of MOSFETs (n-channel enhancement mode) in their capacity as voltage-operated switches.
- Design and construct circuits using the above technologies from given specification.

Outcome 2
- AND, OR, NOT, NAND, NOR, and EOR logic functions in combinational logic circuits.
- Simplification of logic circuits by conversion to NAND equivalents.
- Development of Boolean expressions from truth tables and logic diagrams.
- Construction of truth tables and logic diagrams from written specifications.
- Designing and constructing logic circuits to meet given specification.

Outcome 3
- Investigate the use of logic and arithmetic operations in decision making.
- Use of pulse width modulation to control the speed of a DC motor.
- Develop high-level control programs to monitor up to four digital inputs and initiate up to four digital output devices.

Within the time allocated for the Unit, it is important to give scope for problem solving activities, requiring learners to apply the skills and knowledge that they have gained.

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

For example, while National 5 learners are using circuit building and testing equipment to investigate voltage dividers and transistor switching circuits, Higher learners could be doing extension work investigating the current gain in a transistor driver circuit. Similarly, when National 5 learners are developing programs for control systems, those capable of Higher could be working on more advanced systems integrating speed control and arithmetical operations.

Where Higher learners have studied National 5 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 appropriate links are established with outside agencies or bodies, or where members of staff have particular expertise, Course material could be contextualised in different ways at the different levels.

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 5 learners could be set to work on programming control systems while Higher learners are building and testing analogue electronic circuits.

A similar approach may also be possible for a mixed group of Higher and Advanced Higher learners.

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 learners 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. This can be used to trial designs before construction.

PICAXE, STAMP and Arduino hardware are all suitable platforms for developing electronic control systems.

There are a number of different high-level programming languages available that may be suitable for the delivery of this Unit, including PBASIC. 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.

Centres will need a stock of components, including resistors, motors, breadboards (prototype board), 7400 family integrated circuits, 741 op-amps, and so on, from one of the many commercial suppliers. Multimeters and logic probes will also be required for measurement 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 Designing and constructing circuits using sensor inputs and BJT drivers
1.2 Designing and constructing circuits using sensor inputs and MOSFET drivers
1.3 Designing and constructing operational amplifier circuits
1.4 Testing and evaluating analogue electronic solutions against a specification

Notes on delivery of Outcome 1
Learners should be encouraged to investigate electronic circuits using the systems approach.

Voltage dividers should be considered in their capacity of providing input signals for a control system. This will involve the use of light and temperature sensors, and both fixed and variable resistors. Learners should also gain experience of interpreting information on light and temperature sensors 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.

Bipolar junction transistors should be considered in their capacity as current amplifiers. Learners should gain experience in calculating gain based on input and output currents and should design and construct circuits involving input sensors, transistor driver circuits and output devices such as lamps, motors, buzzers and relays. The use of diodes for circuit protection should also be highlighted.

Learners should gain experience of designing and constructing operational amplifiers in inverting, non-inverting, comparator, difference, and summing configurations. To do this effectively, learners must gain experience of calculating gain, and input and output voltages. Reference values should generally be set using fixed voltage dividers or potentiometers. Input voltages should be generated from sensing circuits. Circuits should be monitored using voltmeters or oscilloscopes or connected to appropriate output devices or models.

MOSFETs in n-channel enhancement mode should be investigated in their capacity as voltage-operated switching devices and their operating characteristics contrasted with bipolar transistors.

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 standards may be addressed using a series of separate activities or by combining two or three where an appropriate specification is given.

- Evidence of the designing element of Assessment Standards 1.1, 1.2 and 1.3 may be in the form of hand-drawn or electronically produced circuit diagrams.
- Evidence of the constructing element of Assessment Standards 1.1, 1.2 and 1.3 may be photographic.
- Evidence of Assessment Standard 1.4 may be written or oral.

Outcome 2
The learner will:

2 Develop digital electronic control systems by:

2.1 Designing and constructing complex combinational logic circuits
2.2 Describing logic functions using Boolean operators
2.3 Simplifying logic circuits using NAND equivalents
2.4 Testing and evaluating combinational logic circuits against a specification

Notes on delivery of Outcome 2
Learners should develop their understanding of combinational logic circuits using AND, OR, NOT, NAND, NOR and EOR gates with up to three inputs. They should have both an understanding and experience of developing NAND equivalent circuits and the relative advantage over circuits containing a number of different logic gates. Logic diagrams and truth tables should be designed or developed from written specifications. Boolean expressions should be developed from written specifications and truth tables. Learners should construct logic circuits using 7400 family integrated circuits with digital input devices.

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 Assessment Standards may be addressed by a series of separate activities or by combining two or three where an appropriate specification is given.

- Evidence of Assessment Standard 2.1 may be graphical or a photograph of a constructed circuit.
- Evidence of Assessment Standard 2.2 may be written or oral
- Evidence of Assessment Standard 2.3 may be written or a photograph of a constructed circuit.
- Evidence of Assessment Standard 2.4 may be written or oral.

Outcome 3
The learner will:

3 Develop programmable control systems for mechatronic systems by:

3.1 Designing and simulating high-level programs to monitor inputs and initiate digital outputs
3.2 Designing and simulating high-level programs to make decisions using arithmetic and logic functions
3.3 Testing and evaluating programs against a specification

Notes on delivery of Outcome 3
Learners should develop their use of high-level programming to control systems requiring up to four inputs and outputs. Learners should develop their experience from using standard commands (such as those to switch output devices, create time delays, test conditions, and generate fixed and continuous loops) to incorporate both logic and arithmetic operations in decision making processes. Pulse width modulation may be investigated as a method for controlling the speed of a DC motor and incorporated in problem solving activities.

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 3
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 series of separate activities or by combining two or three where an appropriate specification is given.

- Evidence of the designing element of Assessment Standards 3.1 and 3.2 may be written, a printed output, or an appropriate electronic format.
- Evidence of the simulation element of Assessment Standards 3.1 and 3.2 may be printed output or in an appropriate electronic format.
- Evidence of Assessment Standard 3.3 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 meters to measure voltage, current and resistance. Problem solving questions applying Ohm's law to calculate values of resistance, current and voltage. Using variables in arithmetic processes as part of control programming.
2.3 Information handling	Use of Boolean algebra in analysing and designing logic circuits. Interpreting information on operating characteristics of electronic components from logarithmic graphs. 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. Programming of microcontroller systems. Storing evidence (notes, reports, diagrams) in digital format.

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

The Unit may also provide opportunities to develop or consolidate other skills for learning, life 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 Assessment 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: 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)
- *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 (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*
- 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: May 2015 (version 2.0)

History of changes to Unit Support Notes

Version	Description of change	Authorised by	Date
2.0	‘An LDR or thermistor’ replaced with ‘light or temperature sensor’ in the ‘Approaches to learning, teaching, and assessment’ section. Assessment Standard 3.1 — ‘digital input’ changed to ‘input’.	Qualifications Manager	May 15

Unit
Support
Notes

Unit Support Notes — Mechanisms and Structures (Higher)

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* (Higher) 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 deep understanding of mechanisms and structures. Learners will analyse and explore mechanical and structural 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 Higher 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 5) 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 Higher Engineering Science *Course Support Notes.*

If the Unit is being delivered as part of the Higher Engineering Science Course, the teacher should refer to the 'Further mandatory information on Course coverage' section of 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:

- related Units in Advanced Higher Engineering Science
- National Certificate Group Awards in a range of engineering disciplines
- related National Progression Awards (NPA)
- 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 leaves 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.

In order to develop the skills of analysis and evaluation, centres may find it beneficial to plan learning using a problem-based or experiential learning approach. Alternatively, where knowledge and understanding is to be developed, an outcome-focused or co-operative learning approach may benefit learners' progress.

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

Sequence of delivery of Outcomes

The sequence of delivery and distribution of time between 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 wind turbine and renewable energy:

- couplings can be the basis for exploring drive systems and debate and discussion can take place surrounding bearings and friction
- the calculation of torque on the propeller shaft
- Young’s modulus and factor of safety can be related to the structure design
- energy and efficiency can be calculated for the wind turbine
- energy conversion can be studied through the discussion and investigation of the wind calculations of energy transfers and calculations of work done and power

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

Meeting the needs of all learners

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

For example, when National 5 learners are consolidating their understanding of pressure decay systems, those capable of Higher should be moving on into studies of sequential control and electro-pneumatic systems.

Where Higher learners have studied National 5 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 5 learners could be set to work on structures while Higher learners are exploring pneumatics. Similarly, when National 5 learners are consolidating their understanding of pressure decay systems, those capable of Higher should be moving on into studies of sequential control and electro-pneumatic systems.

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 website
- West Point Bridge Design Contest website
- 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.

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 complex mechanisms and structures by:

1.1 Using the systems approach to analyse mechanisms and structures
1.2 Describing or producing diagrams of a range of complex structures
1.3 Describing or producing diagrams of a range of complex mechanisms
1.4 Investigating the properties of a range of materials used in mechanisms and structures

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), 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 structural solutions to solve complex problems by:

2.1 Identifying key aspects of the problem
2.2 Applying knowledge and understanding of structures, materials and/or mechanisms
2.3 Carrying out calculations to assist the selection of materials or component sizes
2.4 Designing structures and/or mechanisms
2.5 Simulating or building mechanisms and/or structures
2.6 Testing and evaluating solutions

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 mechanisms or structures (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 tidal farm to supply renewable energy to a remote community and the national grid. This will require an understanding of and an ability to apply knowledge of factor of safety and use of Young's modulus of elasticity when designing. The learners will also be expected to carry out calculations of energy generation from the tidal turbines.
- An alternative challenge could be to design a temporary structure to host a concert at a festival. This will require a basic knowledge of structural design and material properties.

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 problem solving task or by a series of separate activities.

- Evidence of Assessment Standard 2.1 may be written or oral.
- Evidence of Assessment Standards 2.2, 2.3 and 2.4 may be 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 2.5 may be photographic (constructed solution) or electronic (simulation).
- Evidence of Assessment Standard 2.6 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 torque. Calculating efficiency, work done and power. Calculating forces in frames and reaction forces. Calculating Young's Modulus and factor of safety. Applying correct units to results.

2.3 Information handling	Studying diagrams of mechanisms (couplings and bearings). Building pneumatic systems from diagrams. Drawing diagrams of structures, mechanisms and pneumatic systems. Drawing stress/strain graphs for different materials.

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. Using calculated results during the design of systems.
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 learning, life and work, including:

- reading and writing
- 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 Assessment 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

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: 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)
- *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 (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*
- 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: May 2015 (version 1.1)

History of changes to Unit Support Notes

Version	Description of change	Authorised by	Date
1.1	'An LDR or thermistor' replaced with 'light or temperature sensor' in the 'Approaches to learning, teaching, and assessment' section. Removal of the term 'sheer stress'.	Qualifications Manager	May 2015