Scottish Qualifications Authority

SQA Advanced Unit Specification

General information for centres

Unit title: Mathematics for Engineering 3

Unit code: HT1E 48

Unit purpose: This Unit is designed to enable candidates to apply, using a computer algebra, techniques from algebra and calculus to engineering problems.

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

1. Use matrix techniques to solve sets of linear equations.
2. Apply differentiation and integration techniques to engineering problems.
3. Solve differential equations arising from engineering problems.
4. Apply Fourier analysis to create standard waveforms.

Credit value: 2 SQA Credits at SCQF level 8: (16 SCQF credit points at SCQF level 8*)

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

Recommended prior knowledge and skills: Candidates should have a basic knowledge and understanding of mathematical concepts. This may be evidenced by possession of SQA Advanced Certificate Units in Mathematics for Engineering 1: Electronics and Electrical and Mathematics for Engineering 2, Advanced Higher Mathematics, or an equivalent level of experience.

Core Skills: The achievement of this Unit gives automatic certification of Using Number at SCQF level 6.

Context for delivery: This Unit was developed for the SQA Advanced Diploma in Electronics awards. If the Unit is used in another Group Award(s) it is recommended that it should be taught and assessed within the context of the particular Group Award(s) to which it contributes.

Assessment: It is possible to assess candidates either on an Outcome-by-Outcome basis or by combining all Outcomes in this Unit into one assessment paper.

This paper could be taken by candidates at one single assessment event, which should last two and a half hours. The assessment paper could be composed of an appropriate balance of short answer, restricted response and structured questions. Assessment should be carried out under supervised, controlled conditions. A pass mark of 60% is recommended for this paper.

If the assessment is on an Outcome-by-Outcome basis, then there should be four papers lasting thirty minutes for each of Outcomes 1, 2 and 4, and one hour for Outcome 3, each of which should be carried out under supervised, controlled conditions. A pass mark of 60% is recommended for each of these assessments.

SQA Advanced Unit Specification: Statement of standards

Unit title: Mathematics for Engineering 3

Unit code: HT1E 48

The sections of the Unit stating the Outcomes, knowledge and/or skills, and Evidence Requirements are mandatory.

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

Outcome 1

Use matrix techniques to solve sets of linear equations

Knowledge and/or skills

- Perform basic algebra on matrices of dimension up to 3x3
- Solve simultaneous equations containing two unknowns
- Use a computer algebra to solve problems from engineering involving sets of simultaneous equations containing at least three unknowns

Evidence Requirements

Evidence for the knowledge and/or skills in this Outcome will be provided by an examination taken at a single assessment event lasting thirty minutes and carried out under supervised, controlled conditions. The evidence may be presented in responses to specific questions. Each candidate will need to demonstrate that he/she can achieve at least 60% of the marks available in the assessment. In any assessment of this Outcome all of the knowledge and/or skills items should be tested. Candidates should be provided with appropriate formula sheets, should **not** have access to a computer algebra for the first two knowledge and/or skills items, but **must** have access to a computer algebra for the last knowledge and/or skills item in this Outcome.
All computer algebra solutions must be fully documented showing all major steps and inferences.

In order to ensure that candidates will not be able to foresee the exact form of the assessment, a different examination is required each time the Outcome is assessed.

Assessment guidelines

Questions used to elicit candidate evidence may take the form of an appropriate balance of short answer, restricted response and structured questions.

The assessment of this Outcome can be combined with Outcomes 2, 3 and 4 to form a single assessment paper, details of which are given after Outcome 4.

Outcome 2

Apply differentiation and integration techniques to engineering problems

Knowledge and/or skills

- Use a computer algebra to differentiate functions of one variable to solve engineering problems
- Use a computer algebra to differentiate functions of two variables to solve engineering problems
- Use a computer algebra to integrate functions of one variable to solve engineering problems

Evidence Requirements

Evidence for the knowledge and/or skills in this Outcome will be provided by an examination taken at a single assessment event lasting thirty minutes and carried out under supervised, controlled conditions. The evidence may be presented in responses to specific questions. Candidates should be provided with appropriate formula sheets, and **must** have access to a computer algebra for all the knowledge and/or skills item in this Outcome. All computer algebra solutions must be fully documented showing all major steps and inferences. Each candidate will need to demonstrate that he/she can achieve at least 60% of the marks available in the assessment. In any assessment of this Outcome all of the knowledge and/or skills items should be tested.

In order to ensure that candidates will not be able to foresee the exact form of the assessment, a different examination is required each time the Outcome is assessed.

Assessment guidelines

Questions used to elicit candidate evidence may take the form of an appropriate balance of short answer, restricted response and structured questions.

The assessment of this Outcome can be combined with Outcomes 1, 3 and 4 to form a single assessment paper, details of which are given after Outcome 4.

Outcome 3

Solve differential equations arising from engineering problems

Knowledge and/or skills

- Identify different types of first and second order differential equations
- Use a computer algebra to solve first and second order differential equations arising from engineering problems
- Use Laplace transforms and a computer algebra to solve first and second order differential equations arising from engineering problems
- Find an approximate solution to differential equations using numerical methods such as Euler or Runga-Kutta

Evidence Requirements

Evidence for the knowledge and/or skills in this Outcome will be provided by an examination taken at a single assessment event lasting one hour and carried out under supervised, controlled conditions. The evidence may be presented in response to specific questions. Candidates should be provided with appropriate formula sheets, and **must** have access to a computer algebra for all the knowledge and/or skills item in this Outcome. All computer algebra solutions must be fully documented showing all major steps and inferences. Each candidate will need to demonstrate that he/she can achieve at least 60% of the marks available in the assessment. In any assessment of this Outcome all of the knowledge and/or skills items should be tested.

In order to ensure that candidates will not be able to foresee the exact form of the assessment, a different examination is required each time the Outcome is assessed.

Assessment guidelines

Questions used to elicit candidate evidence may take the form of an appropriate balance of short answer, restricted response and structured questions.

The assessment of this Outcome can be combined with Outcomes 1, 2 and 4 to form a single assessment paper, details of which are given after Outcome 4.

Outcome 4

Apply Fourier analysis to create standard waveforms

Knowledge and/or skills

- ♦ Use a computer algebra to find the Fourier series for appropriate functions
- ♦ Use a computer algebra to demonstrate that standard waveforms can be created from the appropriate Fourier series

Evidence Requirements

Evidence for the knowledge and/or skills in this Outcome will be provided by an examination taken at a single assessment event lasting thirty minutes and carried out under supervised, controlled conditions. The evidence may be presented in responses to specific questions. Candidates should be provided with appropriate formula sheets, and **must** have access to a computer algebra for all the knowledge and/or skills item in this Outcome. All computer algebra solutions must be fully documented showing all major steps and inferences. Each candidate will need to demonstrate that he/she can achieve at least 60% of the marks available in the assessment. In any assessment of this Outcome all of the knowledge and/or skills items should be tested.

In order to ensure that candidates will not be able to foresee the exact form of the assessment, a different examination is required each time the Outcome is assessed.

Assessment guidelines

Questions used to elicit candidate evidence may take the form of an appropriate balance of short answer, restricted response and structured questions.

The assessment of this Outcome can be combined with other Outcomes 1, 2 and 3 to form a single assessment paper, details of which are given below.

This paper could be taken by candidates at one single assessment event, which should last two and a half hours. The assessment paper could be composed of an appropriate balance of short answer, restricted response and structured questions. Assessment should be carried out under supervised, controlled conditions. Candidates should be provided with appropriate formula sheets, and **must** have access to a computer algebra for all the knowledge and/or skills items which specify its use. All computer algebra solutions must be fully documented showing all major steps and inferences. A pass mark of 60% is recommended for this paper.

Administrative information

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Unit title:	Mathematics for Engineering 3
Superclass category:	RB
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History of changes:

Version	Description of change	Date

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SQA Advanced Unit Specification: Support notes

Unit title: Mathematics for Engineering 3

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

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 80 hours.

Guidance on the content and context for this Unit

This Unit has been developed as part of a group of Mathematics Units. There are two other Units in the group entitled Mathematics for Engineering 1: Electronics and Electrical and Mathematics for Engineering 2. This Unit is at level 8 and has been incorporated within the second year of the new SQA Advanced Diploma in Electronics award as an optional Unit. This Unit follows on from the Unit Mathematics for Engineering 2. The Mathematics for Engineering 3 Unit has been included in the SQA Advanced Diploma in Electronics award as an option to support those students who wish to progress onto engineering honours degree courses. It is felt that the Mathematics content of the three Mathematics Units is the minimum needed to allow students to progress to the advanced stages of incorporated engineering degree courses.

The three Units mentioned in the previous paragraph have been developed as an integrated suite of Units to meet all the mathematics requirements of the new SQA Advanced Certificate/Diploma in Electronics awards. Mathematics for Engineering 2 and Mathematics for Engineering 3 may also be used in other engineering awards.

In designing this Unit, the Unit writers have identified the range of subjects they would expect to be covered by lecturers. The range of topics is traditional, but the approach is not, in that it makes considerable use of a computer algebra. The proportion of time devoted to mathematics in the engineering SQA Advanced Diplomas for which this and the other Units Mathematics for Engineering 1: Electronics and Electrical and Mathematics for Engineering 2 have been written is less than in the past, and so students cannot be expected to have the facility in algebraic techniques of earlier years. The computer algebra is to be used to overtake this deficiency and provide a means of solving engineering problems, often of a more computationally complex nature than was feasible in the past, both accurately and rapidly. The graphical facilities of the computer algebra should also be used, where appropriate, to verify and/or investigate solutions to problems. However, computer algebra solutions must be fully documented showing all major steps, graphs, etc and inferences.

The writers have also given recommendations as to how much time should be spent on each Outcome, and these include an allowance for familiarisation with the computer algebra. This has been done to help lecturers decide what depth of treatment should be given to topics attached to each of the Outcomes. While it is not mandatory for centres to use this list of topics, it is strongly recommended that they do so in order to ensure continuity of teaching and learning across the mathematics Units, and because the assessment exemplar pack for this Unit is based on the knowledge/and or skills and list of topics for each of the Outcomes.

A list of topics is given below. Lecturers are advised to study this list of topics in conjunction with the assessment exemplar pack, so that they can get a clear indication of the standard of achievement expected of candidates for this Unit.

Outcome 1

Use matrix techniques to solve sets of linear equations. (15 hours).

The use of a matrix to encode information. Perform basic algebra using 'hand' calculations (addition, subtraction, multiplication by a scalar, matrix multiplication) of matrices of dimension up to 3x3. Calculation of the inverse of matrices of dimension up to 2x2, with an indication of the method for matrices of dimension 3x3. Solve simultaneous equations containing two unknowns. Calculations of any greater complexity should be carried out using a computer algebra. Solve problems from engineering involving sets of simultaneous equations containing at least three unknowns using a computer algebra.

Outcome 2

Apply differentiation and integration techniques to engineering problems (15 hours).

Since both differentiation and integration techniques for simple functions should be familiar from the Unit Mathematics for Engineering 2, this Outcome should concentrate on engineering problems that would traditionally require additional algebraic skills, but instead use a computer algebra to obviate the need for these skills. For example, functions whose differentiation requires the use of the product, quotient or chain rule, or for which the finding of stationary points necessitates the solution of an equation more complex than a quadratic, are suitable for inclusion. Similarly, functions whose integration requires the use of substitution, the method of parts, or approximate methods, are also suitable for inclusion.

Engineering problems whose solution requires the differentiation of functions of one variable could include rates of change, maxima and minima.

Engineering problems whose solution requires the differentiation of functions of two variables could include stationary points and small error problems.

Engineering problems whose solution requires the integration of functions of one variable could include areas, volumes of revolution, root mean square values, first & second moments of area, centroids, radius of gyration, arc lengths, etc.

Where appropriate, students should be encouraged to use the computer algebra to plot graphs of the functions and/or solutions to ascertain whether their solution is likely to be correct.

Outcome 3

Solve differential equations arising from engineering problems. (30 hours).

Since differential equations that can be solved by direct integration, together with the ideas of initial and boundary conditions, should have been encountered in the Unit Mathematics for Engineering 2, part of this Outcome should concentrate on engineering problems that would traditionally require additional algebraic skills, but instead use a computer algebra to obviate the need for these skills.

Candidates should, however, be able to identify different types of first and second order differential equations, such as separable and linear, so that their solution can be achieved efficiently by use of the appropriate computer algebra routine, rather than use a 'catch-all' routine.

Where appropriate, students should be encouraged to use the computer algebra to plot graphs of the solutions to ascertain their behaviour, such as whether their solution is stable or not.

The use of Laplace transforms and the tables of them should be taught in the traditional way. However, a computer algebra should then be used to solve the resulting algebraic equation, before the inverse tables are used to finally solve first and second order differential equations arising from engineering problems.

Since numerical methods in the form of the Newton-Raphson and Simpson's methods should be familiar from the Unit Mathematics for Engineering 2, the last part of the Outcome should extend these ideas to finding an approximate solution to differential equations using numerical methods such as Euler or Runga-Kutta. These should involve the use of a calculator rather than a computer algebra.

Outcome 4

Apply Fourier analysis to create standard waveforms. (15 hours).

Candidates should 'build up' Fourier series using a computer algebra via the construction of the Fourier integrals and hence the Fourier coefficients. Students should thus be able to demonstrate graphically that standard waveforms can be created from the appropriate Fourier series. They should also investigate graphically the effect of adding further terms to their truncated series and compare it with the Fourier series generated by the direct process supplied by the computer algebra.

Guidance on the delivery and assessment of this Unit

As this Unit provides mathematical principles which underpin further studies in engineering awards at degree level, it is recommended that the Unit be delivered during the second year of study for the SQA Advanced Diploma award, after satisfactory completion of the Units Mathematics for Engineering 1: Electronics and Electrical and Mathematics for Engineering 2.

This Unit has been designed to incorporate sufficient time to allow lecturers to teach the core mathematics contained within this Unit. Additionally, the Unit has been designed to allow time for lecturers to teach the use of a computer algebra, since the use of one is mandatory for most of the assessment. The Unit has also been written such that sufficient time has been allowed for candidates to practice what they have learned using appropriate formative assessment exercises, involving hand calculations in the simpler exercises, and a computer algebra in all exercises that would otherwise require algebraic skills that students are not assumed to possess.

Details on approaches to assessment are given under Evidence Requirements and Assessment Guidelines under each Outcome in the SQA Advanced Unit specification: statement of standards section. It is recommended that these sections be read through carefully before proceeding with assessment of candidates.

The content of the Unit is such that it is recommended that if the Unit is assessed by one holistic assessment instrument then assessment takes place at the end of the Unit delivery time.

Open learning

This Unit could be delivered by distance learning, which may incorporate some degree of on-line support. It would be essential that the candidate have adequate access to a computer algebra. However, with regard to assessment, planning would be required by the centre concerned to ensure the sufficiency and authenticity of candidate evidence. Arrangement would be required to be put in place to ensure that assessment whether done at a single or at multiple events was conducted under controlled, supervised conditions.

To keep administrative arrangements to a minimum, it is recommended that a single assessment paper (taken by candidates at a single assessment event) be used for distance learning candidates.

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

Equality and inclusion

This Unit specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence. Further advice can be found on our website www.sqa.org.uk/assessmentarrangements.

General information for candidates

Unit title: Mathematics for Engineering 3

This Unit has been designed to allow you to develop your knowledge, understanding and skills in the mathematics which underpin so much of more advanced studies in mathematics for engineering students. If you have studied some (or all) of these subjects before, the early parts of this Unit will provide you with an opportunity to revise the techniques you have learned in previous courses.

By the end of this Unit you will be expected to apply a computer algebra to solve many different problems which are found in various branches of engineering. The use of a computer algebra is a mandatory part of this Unit, and will be used extensively, so you must have access to one. Your lecturer will be able to give you further details.

In **Outcome 1** you will use matrix algebra to solve systems of simultaneous equations, which are found in all branches of engineering, to underpin the opportunity for further studies in engineering.

In **Outcome 2** you will study the application of differentiation and integration techniques to engineering problems. These techniques will be an extension of the techniques used in Mathematics for Engineering 2, with the use of a computer algebra, to more complex engineering applications.

In **Outcome 3** you will study the solution of differential equations, which are the equations that describe the behaviour of many dynamic and static systems found in engineering. You will also extend the numerical techniques that you met in Mathematics for Engineering 2 to solving differential equations.

In **Outcome 4** you will study Fourier series, which are used in particular to generate approximations to the peculiar periodic waveforms, such as saw-tooth waves, which are much used in electronic devices.

The precise form the assessment will take depends upon the centre at which you are taking this Unit. It is possible for this Unit to be assessed completely at one assessment event or in parts at four separate assessment events. Please ask your lecturer what precise form this assessment will take. If this Unit is assessed at one assessment event, such an assessment will take place at the end of the Unit, and will comprise of one assessment paper lasting 2 hour 30 minutes. This will take place under supervised, controlled conditions. The assessment will be under closed-book conditions in which you will not be allowed to bring any text books, handouts or notes into the assessment. Candidates will be permitted to use scientific calculators during the assessment(s), and a computer algebra is mandatory for many parts of the assessment, but all solutions must be fully documented showing all major steps and inferences. Students will be issued with a formula book for their assessment(s) and will be issued with their own formula book for use in the classroom.