Next Generation Higher National Educator Guide

Higher National Diploma in Engineering

Group award code	GV2A 48
Valid from	session 2024 to 2025

Prototype educator guide for use in pilot delivery only (version 0.1) October 2024

This guide provides detailed information about the group award to ensure consistent and transparent assessment year on year.

This guide is for assessors and lecturers and contains all the mandatory information you need to deliver and assess the group award.

This edition: October 2024 (version 0.1)

Contents

Group award overview

Introduction

This guide:

- assists centres to implement, deliver and manage the group award
- provides a guide for new staff involved in offering the group award
- informs course managers, teaching staff, assessors, learners, employers and higher education institutions of the aims and purpose of the group award
- provides details about the range of learners that the group award is suitable for and the progression opportunities

Purpose of the group award

The Higher National Diploma (HND) in Engineering equips learners with the technical knowledge and skills, as well as the professional skills and personal behaviours (meta-skills), that employers expect from individuals entering and working in industries within the Scottish engineering and advanced manufacturing sector at HND level.

Structure

HNDs are designed at SCQF level 8 and consist of 120 SCQF credit points. HNDs must incorporate at least 80 credit points (10 credits) at SCQF level 8.

HNDs contain 15 credits that can be used flexibly to increase opportunities for learners returning to education. Refer to the 'Meta-skills' section of this guide for more information.

In HND Engineering, learners engage in projects, personal reflection and practical tasks. A meta-skills outcome is included in the Professional Practice in Engineering unit. Learners also develop meta-skills in the context of the rest of the unit content.

Framework

The HND is made up of the following mandatory units, mandatory optional units and optional units.

Mandatory units (6 SQA credits)

Unit code	Unit title	SQA credit	SCQF credit points	SCQF level
J7BS 48	Engineering Project Management	2	16	8
J7BR 48	Professional Practice in Engineering	3	24	8
J7GL 47	Engineering Mathematics 2	1	8	7

Mandatory optional units (6 SQA credits required)

Unit code	Unit title	SQA credit	SCQF credit points	SCQF level
J7BY 48	Thermodynamics, Plant Systems and Fluid Mechanics	3	24	8
J7C1 48	Advanced Materials	3	24	8
J7C4 48	Sustainable Design Engineering and Innovation Entrepreneurship	3	24	8
J7BW 48	Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety	3	24	8
J7BT 48	Electrical Transformers, Motors and Machine Systems	3	24	8
J7BV 48	Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves	3	24	8
J7C2 48	Analogue Electronics: Design and Analysis	3	24	8
J7C3 48	Digital Electronics: Digital System Design	3	24	8
J7C5 48	Renewable Energy: Generation, Storage and Transmission	3	24	8
J7BX 48	Dynamic Engineering Systems: Modelling, Simulation and Control	3	24	8

Optional units (3 SQA credits required)

Unit code	Unit title	SQA credit	SCQF credit points	SCQF level
J7BY 48	Thermodynamics, Plant Systems and Fluid Mechanics	3	24	8
J7C1 48	Advanced Materials	3	24	8
J7C4 48	Sustainable Design Engineering and Innovation Entrepreneurship	3	24	8
J7BW 48	Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety	3	24	8
J7BT 48	Electrical Transformers, Motors and Machine Systems	3	24	8
J7BV 48	Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves	3	24	8
J7C2 48	Analogue Electronics: Design and Analysis	3	24	8
J7C3 48	Digital Electronics: Digital System Design	3	24	8
J7C5 48	Renewable Energy: Generation, Storage and Transmission	3	24	8
J7BX 48	Dynamic Engineering Systems: Modelling, Simulation and Control	3	24	8
J6D6 47	Electrical Engineering: Practical Skills	3	24	7
J6DA 47	Engineering Systems: Practical Skills	3	24	7
J6DB 47	Instrumentation and Control: Practical Skills	3	24	7
J6D9 47	Mechanical Engineering: Practical Skills	3	24	7
J750 47	Electronics in Practice: Skills and Techniques	3	24	7
J6CW 47	Electrical Engineering Principles	3	24	7
J6D2 47	Electrical Power and Drive Systems	3	24	7
J752 47	Digital Electronics: Theory and Applications	3	24	7
J751 47	Analogue Electronics: Theory and Applications	3	24	7
J89H 47	Engineering Systems: Validation and Verification	3	24	7
J6D4 47	Engineering Systems Principles	3	24	7
J6D0 47	Instrumentation and Control: Measurement Systems	3	24	7
J6D5 47	Instrumentation and Control: Control Systems	3	24	7
J6CV 47	Manufacturing Engineering Materials and Processes	3	24	7
J6D1 47	Manufacturing Engineering: Simulation and Modelling	3	24	7
J6CX 47	Thermodynamics and Fluid Mechanics	3	24	7
J6D3 47	Engineering Mechanics and Materials	3	24	7

Unit code	Unit title	SQA credit	SCQF credit points	SCQF level
J7L9 47	Engineering Mathematics 3	1	8	8
J7LA 48	Engineering Mathematics 4	1	8	8
J7LB 48	Engineering Mathematics 5	1	8	8
J7GS 46	Engineering Practical Skills	2	16	6
J7GP 47	Application of Programmable Logic Controllers	1	8	7
J7N3 47	Work-based Learning	3	24	7

Aims of the group award

General aims

1. Enhance employment prospects.
2. Further develop meta-skills to support the active development of professional practice and behaviours.
3. Develop self-awareness and understanding to enable learners to use meta-skills to discuss, increase and enhance employability.
4. Support continuing professional development (CPD) and career development.
5. Enable progression within the Scottish Credit and Qualifications Framework (SCQF).
6. Develop the ability to apply advanced analysis and synthesis skills to solve engineering problems.
7. Develop learning and transferable skills (including meta-skills).
8. Develop the ability to accurately apply a range of mathematical and other analytical techniques to solve advanced engineering problems in the relevant engineering discipline.

Specific aims

1. Enable learners to work as engineering technicians or incorporated engineers.
2. Meet the academic requirements for Engineering Technician (EngTech) status, with specific reference to the Engineering Council's five competences:
   - A. Knowledge and understanding
   - B. Design, development and solving engineering problems
   - C. Responsibility, management and leadership
   - D. Communication and interpersonal skills
   - E. Professional commitment
3. Enable progression, with advanced standing, to a degree in Engineering or a related subject.
4. Transfer knowledge and skills gained to other areas of employment.
5. Develop project management skills through an enhanced, project-based approach to solving engineering problems.
6. Raise awareness of sustainability, environmental impact and other related areas in an engineering context.
7. Enhance the ability to develop safe systems of work.
8. Develop commitment to professional engineering values.
9. Carry out substantive advanced project analysis and development across key engineering content through project assignments across units.

10 Allow learners to specialise in one or more of the following engineering disciplines:

- electronics
- electrical engineering
- manufacturing engineering
- mechanical engineering
- instrumentation and control
- engineering systems

Who is this group award for?

This group award is suitable for learners who want to work in industries within the Scottish engineering and advanced manufacturing sector, or progress to a degree in an engineering discipline.

Recommended entry	Progression
Entry to this group award is at the discretion of your centre. Learners would benefit from having attained the skills, knowledge and understanding required by one or more of the following or equivalent qualifications and/or experience: ♦ an HNC or equivalent SQA qualification in Engineering, or a related discipline such as Construction, Science or Computing ♦ a qualification comparable to those listed above from another awarding body It is at your centre's discretion to accept applicants with a different experiential background who could benefit from taking the course or units within the course. This could include adult returners or those with relevant work experience.	♦ other qualifications in Engineering or related areas ♦ further study, employment and/or training, such as a degree in Engineering or a related discipline ♦ create a route towards meeting the academic requirements for the Engineering Council's EngTech status

Recognising prior learning

SQA recognises that learners gain knowledge and skills through formal, non-formal and informal learning contexts.

It is unlikely that a learner would have the appropriate prior learning and experience to meet all the requirements of a full group award. However, we expect that the majority of part-time learners will be employed apprentices attending as part of their apprenticeship, under the supervision of a training officer. During their apprenticeship, they will have gained a valuable and varied range of practical skills.

This award contains an options list of 3-credit practical skills units. These are in the areas of:

- electrical
- mechanical
- engineering systems
- electronics

There is also the more general 2-credit Engineering Practical Skills unit. We recommend that part-time learners receive credit for skills gained as part of their apprenticeship if they correspond with any of these practical skills units, or any other unit within the framework. This gives centres an additional opportunity to discuss apprentice learners' progress with training officers. This could reduce their study to 12 credits, with the final 3 credits consisting of recognised prior learning.

Centres should enter dialogue on recognition of prior learning with apprentices and training officers at the start of the programme to match their skills to one of the practical skills units. A complete match is not always possible.

You can find more information and guidance about the recognition of prior learning on SQA's website.

Articulation and/or progression

Learners who complete the HND can progress to an engineering degree with advanced standing or a degree in a related discipline.

Professional recognition

There is no automatic professional recognition on completing this qualification. However, it has been designed to provide a route towards meeting the academic requirements for recognition of EngTech status by the Engineering Council.

Core Skills entry profile

The Core Skills entry profile provides a summary of the assessment activities that demonstrate the SCQF level of this group award. This information can help identify learners that need additional support or those who should take an alternative level or learning programme.

Core Skill	Recommended SCQF entry profile	Associated assessment activities
Communication	SCQF level 6	Learners require good communication skills in written work as part of course assessment, as well as good oral communication skills to take part in discussions and make formal presentations.
Numeracy	SCQF level 6	Good numerical skills are essential for learners taking these qualifications, as they need to apply a wide range of numerical skills. Learners need to be able to apply numerical analysis techniques to solve engineering problems.

Core Skill	Recommended SCQF entry profile	Associated assessment activities
Information and communication technology (ICT)	SCQF level 6	Learners must use a range of applications software (for example, word processing and spreadsheets) in assessment work.
Problem solving	SCQF level 6	Learners require good problem-solving skills to interpret engineering problems, identify factors of a problem and compose a plan to solve the problem, including identifying resources required.
Working with others	SCQF level 6	Teamwork is an essential element in engineering. Desirable co-operative working skills include identifying roles, strengths and weaknesses within a team.

Meta-skills

Meta-skills are higher-order skills that support the development of other skills and promote success in any context. They enable learners to respond to professional challenges and opportunities by reflecting on, developing, applying, and adapting industry skills and sector knowledge.

Our new Higher National Qualifications are developed with meta-skills at their core. Meta-skills complement the industry and sector-specific content of the qualifications. They provide a framework for learners to complete personal development aligned to professional practices.

Throughout the qualifications, learners develop meta-skills while studying industry and sector-specific content. You can integrate meta-skills into contextualised teaching activities and include them in integrated and holistic assessment approaches.

The 21st century skills and meta-skills learning, teaching and assessment model focuses on how we can use skills to respond to societal, economic and industry drivers and change. Meta-skills frameworks vary, but they share an approach that emphasises individualistic, context-based skills development with reflective practice and localised definitions.

Skills Development Scotland developed a model of meta-skills in response to the concept of Industry 4.0 (or the 'fourth industrial revolution'). In this model, they identify 12 meta-skills that help learners adapt to changes to industry, job roles and society expected as a result of technological advances and global trends. Developing these meta-skills supports learners as they prepare for a constantly evolving future.

The 12 meta-skills are grouped into three categories: self-management, social intelligence and innovation.

Self-management	**Social intelligence**	**Innovation**
Focusing	Communicating	Curiosity
Integrity	Feeling	Creativity
Adapting	Collaborating	Sense-making
Initiative	Leading	Critical thinking

Adapted from: Skills 4.0: A skills model to drive Scotland's future, Centre for Work-based Learning in Scotland (2018).

You should:

- make learners aware that meta-skills are generic and transferable across many different contexts
- support learners to focus on the meta-skills that they find most relevant by encouraging an individualised, active learning approach that relates to the industry and sector contexts of the qualification
- help learners to understand key meta-skills for their industry or sector and any other personally important meta-skills, and set development goals for these
- encourage learners to focus on reflective practice

None of the meta-skills are mandatory.

Learning and teaching

You can introduce meta-skills to learners as tools they can use in response to real-world challenges and opportunities. At SCQF level 8, you should use terminology from the Skills 4.0 model, but it is important that you develop a shared understanding with learners about meta-skills and what they mean to them, both individually and in the context of coursework, projects and sectors.

You should embed meta-skills in learning and project tasks as a context for planning, practice and reflection. You should encourage learners to be self-aware, set active goals and monitor their progress.

The process of developing meta-skills is not linear and you should make learners active participants in their learning. At the start of the process, you should introduce meta-skills to learners and explore the concept of self-assessment with them. You should set goals and make development and evaluation plans together. The process should become cyclical, with reflective practice informing new self-awareness, goal setting and review.

Many traditional learning and teaching activities used to develop industry or sector-specific skills, knowledge and understanding also support the development of meta-skills. You can map these in course materials and resources, and during learning.

Meta-skills are central to successfully engaging with and completing assignments and projects. You should encourage learners to plan how they will use and develop meta-skills in their coursework and to reflect on their success and future goals.

For HND Engineering:

- the mandatory unit Professional Practice in Engineering includes a specific outcome on meta-skills in which learners must demonstrate how their meta-skills have developed over the unit
- learners carry out projects, personal reflection and practical tasks throughout the course, which help them develop meta-skills

All units in this award reference meta-skills and how they can be progressed and evidenced throughout delivery.

Learners can focus on any meta-skills appropriate to them and their context. However, learning and teaching should also facilitate individual development. Learners have individual strengths and areas for development and they do not have to reach a particular level in relation to meta-skills. Coursework and projects provide the context for development appropriate to the SCQF level. Within these contexts, the process of development is important. You should create a clear learning plan with each learner to provide evidence of their development.

You can create descriptions of abilities and skills that relate to meta-skills with your learners. These can come from self-profiling, exploring the industry and sector, and discussion with peers and employers. You should consider the meta-skills needed to complete coursework and meet personal goals to set a context for reflection.

Exploring learning and working styles, personality traits and preferences, personal profiling and self-assessment tools can help learners to develop an understanding of their strengths and areas for development.

You can use case studies and scenario-based activities to demonstrate the value of meta-skills and how they can be applied. You can provide opportunities for peer reflection. A group of learners could share experiences and reflections about how to apply meta-skills in the context of their coursework. You could adopt the role of facilitator to draw learners' attention to situations where meta-skills were or could have been applied.

Reflective discussions can focus on how and where meta-skills are being developed. Your discussions with learners could include positive recognition and guidance on future development based on previous performance. As learners progress, you could introduce industry content that requires skills like problem recognition and problem solving, both of which combine multiple meta-skills.

You can deliver the knowledge and skills for practical aspects of projects in sequence. However, learners benefit from learning and teaching that integrates meta-skills with project planning and development. This approach supports learners to engage in reflective practice throughout the project and develops their self-awareness and an appreciation for continuous learning. It also maximises your opportunities to support, coach and mentor learners through their projects.

Learning for Sustainability

Context

The UN 2030 Agenda for Sustainable Development, adopted by the UK in 2015, has shaped the development of internal and national sustainability policy. It sets out the United Nations Sustainable Development Goals (SDGs), which are central to the Scottish Government's National Performance Framework. Learning for Sustainability (LfS) is a commitment to embedding the SDGs in Scottish education.

In line with this, SQA is committed to incorporating the skills, knowledge, understanding and values of LfS within all new and revised qualifications.

LfS combines:

- education for sustainable development (ESD)
- global citizenship
- outdoor learning

ESD is the internationally used term for sustainability education. LfS has a broader remit; however, the terms are largely interchangeable. ESD tends to be used by colleges and universities, while LfS is usually used in schools. Both focus on a broad range of social, economic and environmental themes and approaches across all levels of education. SQA uses LfS as an umbrella term.

LfS is designed to nurture a generation of learners who know the value of the natural world and are committed to the principles of social justice, human rights, global citizenship, democratic participation and living within the ecological limits of the planet. It aims to respond to global challenges by developing learners' skills, knowledge, understanding and values relating to sustainability so they can interact with the world in a socially responsible way.

LfS is more than the sum of its parts; it is about building learners' capacity to deal with the unpredictable challenges facing our rapidly changing world. It encourages transformational change through learning, by which learners are able to critically analyse, communicate and collaborate on complex social, environmental and economic challenges. This gives learners increased confidence, opportunities to develop a range of meta-skills, and enhanced motivation and readiness to learn.

Learning for Sustainability in Next Generation Higher National Qualifications

Next Generation Higher National (NextGen: HN) qualifications have been developed with sustainability as a core component.

All NextGen: HN learners should exit their qualification with:

- a general understanding of sustainability and the SDGs
- an understanding of subject-specific sustainability issues, how these relate to the SDGs, and potential improvements
- the confidence to apply their knowledge and skills in the next stage of their lives

Central to these aims is a need for familiarity with both the SDGs and the concept of sustainability (which is the need to ensure a balance between economic growth, environmental stewardship and social well-being). Knowledge and understanding of current industry practices and behaviours, and consideration of how these could be made more sustainable and contribute towards the SDGs, are integral in developing young people to be responsible and empowered citizens who are able to contribute to building a socially just, sustainable and equitable society.

With this in mind, sustainability is embedded as an outcome in Professional Practice in Engineering.

By completing this outcome, learners develop skills, including the abilities to:

- assess their own knowledge and understanding of sustainability and the SDGs
- review unit content against the SDGs to identify a sustainability-related issue
- apply knowledge and understanding of sustainability and the SDGs to propose improvements

Any of the SDGs can be covered; there are none that are mandatory.

Sustainability is embedded in the key aims of all levels of professional engineer set by the Engineering Council. Engineers must 'demonstrate appropriate consideration of the principles of sustainability' to gain professional recognition. The Engineering Council lists six principles to guide and motivate professional engineers in their Guidance on Sustainability.

One of the specific aims of this award is to 'raise awareness of sustainability, environmental impact and other related areas in an engineering context'. Specifically, in outcome 1 of the mandatory core unit Professional Practice in Engineering, learners must demonstrate that they have 'examined and summarised the sustainability and environmental impacts of the solutions to the problem' for a given task. Sustainability is also considered in other units within this qualification.

Grading

Please see the Grading Pack for this qualification for more information on grading.

Learners who pass NextGen: HN qualifications receive one of the following grade outcomes for the qualification as a whole:

- Achieved with Distinction
- Achieved with Merit
- Achieved

You assess and judge each learner's performance across the key aspects of the group award to determine their whole qualification grade. You must align judgements with the whole qualification grade descriptors, which are:

Achieved with Distinction

This candidate consistently demonstrates outstanding knowledge, understanding and application of skills. Thinking and working independently to an exceptional standard, they apply excellent judgement and creative problem-solving skills. They achieve or exceed agreed aims by confidently applying an extensive range of meta-skills and working very effectively with colleagues and peers.

Achieved with Merit

This candidate demonstrates an excellent level of knowledge, understanding and application of skills. Thinking and working independently to a high standard, they demonstrate good judgement and effective problem-solving skills. They achieve agreed aims by applying a broad range of meta-skills and working effectively with colleagues and peers.

Achieved

This candidate demonstrates thorough knowledge, understanding and application of skills. They think and work independently and use their judgement to find solutions to problems. They achieve agreed aims by applying a range of meta-skills and working well with colleagues and peers.

Successful learners receive their grade, along with the grade descriptor text, on their commemorative certificate.

In addition, you assess individual units on a pass or fail basis. Each unit has evidence requirements that learners must achieve before you can consider them for whole qualification grading.

You make judgements about learners' quality of assessment evidence using a grading matrix based on important criteria in the qualification.

Grading and meta-skills

Meta-skills are a key part of the NextGen: HN qualifications and learners develop them throughout the group award. Competence in individual meta-skills is not assessed or graded. For example, the qualification does not judge the quality of learners' feeling or creativity, or their specific progress in any given meta-skill. Rather, it is the process of development the learner goes through that contributes to the whole qualification judgement. This means learners should provide evidence of planning, developing and reflecting on their meta-skills. The grading matrix includes criteria on meta-skills, which you should use to support this judgement. See the NextGen: HN Meta-skills, Outcome and Assessment Guidance document for support with assessing meta-skills.

How the group award meets employer needs

This group award is designed in collaboration with employers to meet the sector need. The following tables show how the group award can benefit employers by producing learners with the necessary skill set.

The first table shows how units map to the aims of the group award. The second table shows how the units map to National Occupational Standards and/or trade or professional body requirements. The third table shows the significant opportunities that the group award provides for learners to develop more generic skills and meta-skills. The final table shows the assessment strategy for the group award.

Mapping group award aims to units

General aims

Unit code	Unit title	Aim 1	Aim 2	Aim 3	Aim 4	Aim 5	Aim 6	Aim 7	Aim 8
J7BR 48	Professional Practice in Engineering	X	X	X	X	X	X	X	X
J7BS 48	Engineering Project Management	X	X	X	X	X	X	X	X
J7BY 48	Thermodynamics, Plant Systems and Fluid Mechanics	X	X	X	X	X	X	X	X
J7C1 48	Advanced Materials	X	X	X	X	X	X	X	X
J7C4 48	Sustainable Design Engineering and Innovation Entrepreneurship	X	X	X	X	X	X	X	X
J7BX 48	Dynamic Engineering Systems: Modelling, Simulation and Control	X	X	X	X	X	X	X	X
J7BW 48	Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety	X	X	X	X	X	X	X	X
J7C2 48	Analogue Electronics: Design and Analysis	X	X	X	X	X	X	X	X
J7C3 48	Digital Electronics: Digital System Design	X	X	X	X	X	X	X	X
J7BT 48	Electrical Transformers, Motors and Machine Systems	X	X	X	X	X	X	X	X
J7BV 48	Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves	X	X	X	X	X	X	X	X
J7C5 48	Renewable Energy: Generation, Storage and Transmission	X	X	X	X	X	X	X	X
J7GL 48	Engineering Mathematics 2	X	X	X	X	X	X	X	X

Mapping group award aims to units

Specific aims

Key: Aim is directly relevant to unit (X) Aim is optional in this unit (O)

Unit code	Unit title	Aim 1	Aim 2	Aim 3	Aim 4	Aim 5	Aim 6	Aim 7	Aim 8	Aim 9	Aim 10
J7BR 48	Professional Practice in Engineering	X	X	X	X	X	X	X	X	X	O
J7BS 48	Engineering Project Management	X	X	X	X	X	X	X	X	X	O
J7BY 48	Thermodynamics, Plant Systems and Fluid Mechanics	X	X	X	X	X	X	X	X	X	O
J7C1 48	Advanced Materials	X	X	X	X	X	X	X	X	X	O
J7C4 48	Sustainable Design Engineering and Innovation Entrepreneurship	X	X	X	X	X	X	X	X	X	O
J7BX 48	Dynamic Engineering Systems: Modelling, Simulation and Control	X	X	X	X	X	X	X	X	X	O
J7BW 48	Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety	X	X	X	X	X	X	X	X	X	O
J7C2 48	Analogue Electronics: Design and Analysis	X	X	X	X	X	X	X	X	X	O
J7C3 48	Digital Electronics: Digital System Design	X	X	X	X	X	X	X	X	X	O
J7BT 48	Electrical Transformers, Motors and Machine Systems	X	X	X	X	X	X	X	X	X	O
J7BV 48	Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves	X	X	X	X	X	X	X	X	X	O
J7C5 48	Renewable Energy: Generation, Storage and Transmission	X	X	X	X	X	X	X	X	X	O
J7GL 47	Engineering Mathematics 2	X	X	X	X	X	X	X	X	X	O
J7L9 47	Engineering Mathematics 3	X	X	X	X	X	X	X	X	X	O
J7LA 48	Engineering Mathematics 4	X	X	X	X	X	X	X	X	X	O
J7LB 48	Engineering Mathematics 5	X	X	X	X	X	X	X	X	X	O

Mapping National Occupational Standards (NOS) and/or trade or professional body requirements to units

The Engineering Council key competences for Engineering Technician (EngTech) standard are as follows:

A. Knowledge and understanding

Engineering Technicians should use engineering knowledge and understanding to apply technical and practical skills. This competence is about them having knowledge of the technologies, standards and practices relevant to their work. They should be able to provide evidence of maintaining and applying this knowledge.

The applicant must demonstrate that they can:

1 review and select appropriate techniques, procedures and methods to undertake tasks

2 use appropriate scientific, technical or engineering principles

B. Design, development and solving engineering problems

Engineering Technicians should contribute to the design, development, manufacture, construction, commissioning, decommissioning, operation or maintenance of products, equipment, processes, systems or services. This competence is about the ability to apply engineering knowledge effectively and efficiently to the tasks required in their role.

The applicant must demonstrate that they can:

1 identify problems and apply appropriate methods to identify causes and achieve satisfactory solutions

2 identify, organise and use resources effectively to complete tasks, with consideration for cost, quality, safety, security and environmental impact

C. Responsibility, management and leadership

Engineering Technicians should accept and exercise personal responsibility. This competence is about their ability to plan and manage their own work effectively and efficiently. It also covers the ability to consider and identify improvements to maintain quality in their work.

The applicant must demonstrate that they can:

1 work reliably and effectively without close supervision, to the appropriate codes of practice

2 accept responsibility for the work of themselves or others

3 accept, allocate and supervise technical and other tasks

D. Communication and interpersonal skills

Engineering Technicians should use effective communication and interpersonal skills. This includes the ability to work with others constructively, explain ideas and proposals clearly, and discuss issues objectively and constructively.

The applicant must demonstrate that they can:

1. communicate effectively with others, at all levels, in English
2. work effectively with colleagues, clients, suppliers or the public
3. demonstrate personal and social skills, and awareness of diversity and inclusion issues

E. Professional commitment

Engineering Technicians should demonstrate commitment to an appropriate code of professional conduct, recognising obligations to society, the profession and the environment. This competence is about ensuring that the applicant is acting in a professional manner in their work and in their dealings with others. An Engineering Technician should set a standard and example to others in their professionalism.

The applicant must demonstrate that they can:

1. understand and comply with relevant codes of conduct
2. understand the safety implications of their role and apply safe systems of work
3. understand the principles of sustainable development and apply them in their work
4. carry out and record the CPD necessary to maintain and enhance competence in their own area of practice
5. understand the ethical issues that may arise in their role and carry out their responsibilities in an ethical manner

Key: Aim is directly relevant to unit (X) Aim is optional in this unit (O)

Unit code	Unit title	A1	A2	B1	B2	C1	C2	C3	D1	D2	D3	E1	E2	E3	E4	E5
J7BR 48	Professional Practice in Engineering	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7BS 48	Engineering Project Management	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7GL 47	Engineering Mathematics 2	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O
J7BY 48	Thermodynamics, Plant Systems and Fluid Mechanics	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7C1 48	Advanced Materials	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7C4 48	Sustainable Design Engineering and Innovation Entrepreneurship	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7BW 48	Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7BX 48	Dynamic Engineering Systems: Modelling, Simulation and Control	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7C2 48	Analogue Electronics: Design and Analysis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7C3 48	Digital Electronics: Digital System Design	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7C5 48	Renewable Energy: Generation, Storage and Transmission	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7BT 48	Electrical Transformers, Motors and Machine Systems	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
J7BV 48	Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Mapping opportunities to develop meta-skills across the group award

Self-management

Unit code	Unit title	Meta-skills
J7BR 48	Professional Practice in Engineering	Integrity
J7BS 48	Engineering Project Management	Integrity
J7GL 47	Engineering Mathematics 2	Focusing Adapting Initiative
J7BT 48	Electrical Transformers, Motors and Machine Systems	Integrity Adapting Initiative
J7BV 48	Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves	Integrity Adapting Initiative
J7BW 48	Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety	Integrity Adapting Initiative
J7BX 48	Dynamic Engineering Systems: Modelling, Simulation and Control	Integrity Adapting Initiative
J7BY 48	Thermodynamics, Plant Systems and Fluid Mechanics	Focusing Adapting Initiative
J7C1 48	Advanced Materials	Adapting Initiative
J7C2 48	Analogue Electronics: Design and Analysis	Adapting
J7C3 48	Digital Electronics: Digital System Design	Initiative
J7C4 48	Sustainable Design Engineering and Innovation Entrepreneurship	Integrity Adapting Initiative
J7C5 48	Renewable Energy: Generation, Storage and Transmission	Integrity Adapting Initiative
J7N3 47	Work-based Learning	Focusing Integrity Adapting Initiative
J7L9 47	Engineering Mathematics 3	Focusing Adapting Initiative

Unit code	Unit title	Meta-skills
J7LA 48	Engineering Mathematics 4	Focusing Adapting Initiative
J7LB 48	Engineering Mathematics 5	Focusing Adapting Initiative

Social intelligence

Unit code	Unit title	Meta-skills
J7BR 48	Professional Practice in Engineering	Collaborating
J7BS 48	Engineering Project Management	Collaborating
J7GL 47	Engineering Mathematics 2	Communication
J7BT 48	Electrical Transformers, Motors and Machine Systems	Communication Collaborating
J7BV 48	Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves	Communication Collaborating
J7BW 48	Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety	Communication Collaborating
J7BX 48	Dynamic Engineering Systems: Modelling, Simulation and Control	Communication Collaborating
J7BY 48	Thermodynamics, Plant Systems and Fluid Mechanics	Communication
J7C1 48	Advanced Materials	Communication Collaborating
J7C2 48	Analogue Electronics: Design and Analysis	Communication Collaborating
J7C3 48	Digital Electronics: Digital System Design	Communication Collaborating
J7C4 48	Sustainable Design Engineering and Innovation Entrepreneurship	Communication Collaborating
J7C5 48	Renewable Energy: Generation, Storage and Transmission	Communication Feeling
J7N3 47	Work-based Learning	Communication Feeling Collaborating Leading
J7L9 47	Engineering Mathematics 3	Communication
J7LA 48	Engineering Mathematics 4	Communication
J7LB 48	Engineering Mathematics 5	Communication

Innovation

Unit code	Unit title	Meta-skills
J7BR 48	Professional Practice in Engineering	Sense-making
J7BS 48	Engineering Project Management	Sense-making
J7GL 47	Engineering Mathematics 2	Curiosity Sense-making Critical thinking
J7BT 48	Electrical Transformers, Motors and Machine Systems	Curiosity Sense-making Critical thinking
J7BV 48	Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves	Curiosity Sense-making Critical thinking
J7BW 48	Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety	Curiosity Sense-making Critical thinking
J7BX 48	Dynamic Engineering Systems: Modelling, Simulation and Control	Curiosity Creativity Sense-making Critical thinking
J7BY 48	Thermodynamics, Plant Systems and Fluid Mechanics	Curiosity Sense-making
J7C1 48	Advanced Materials	Curiosity Sense-making Critical thinking
J7C2 48	Analogue Electronics: Design and Analysis	Sense-making
J7C3 48	Digital Electronics: Digital System Design	Creativity
J7C4 48	Sustainable Design Engineering and Innovation Entrepreneurship	Curiosity Creativity Sense-making Critical thinking
J7C5 48	Renewable Energy: Generation, Storage and Transmission	Curiosity Critical thinking
J7N3 47	Work-based Learning	Curiosity Creativity Sense-making Critical thinking
J7L9 47	Engineering Mathematics 3	Curiosity Sense-making Critical thinking
J7LA 48	Engineering Mathematics 4	Curiosity Sense-making Critical thinking

Unit code	Unit title	Meta-skills
J7LB 48	Engineering Mathematics 5	Curiosity Sense-making Critical thinking

Assessment strategy for the group award

Unit code	Unit title	Assessment method
J7BS 48	Engineering Project Management	Open-book, project-based
J7BR 48	Professional Practice in Engineering	Open-book, project-based
J7GL 47	Engineering Mathematics 2	Closed-book
J7BY 48	Thermodynamics, Plant Systems and Fluid Mechanics	Open-book, project-based
J7C1 48	Advanced Materials	Open-book, project-based
J7C4 48	Sustainable Design Engineering and Innovation Entrepreneurship	Open-book, project-based
J7BW 48	Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety	Open-book, project-based
J7BT 48	Electrical Transformers, Motors and Machine Systems	Open-book, project-based
J7BV 48	Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves	Open-book, project-based
J7C2 48	Analogue Electronics: Design and Analysis	Open-book, project-based
J7C3 48	Digital Electronics: Digital System Design	Open-book, project-based
J7C5 48	Renewable Energy: Generation, Storage and Transmission	Open-book, project-based
J7BX 48	Dynamic Engineering Systems: Modelling, Simulation and Control	Open-book, project-based
J6D6 47	Electrical Engineering: Practical Skills	Open-book, project-based
J6DA 47	Engineering Systems: Practical Skills	Open-book, project-based
J6DB 47	Instrumentation and Control: Practical Skills	Open-book, project-based
J6D9 47	Mechanical Engineering: Practical Skills	Open-book, project-based
J750 47	Electronics in Practice: Skills and Techniques	Open-book, project-based
J6CW 47	Electrical Engineering Principles	Open-book, project-based
J6D2 47	Electrical Power and Drive Systems	Open-book, project-based
J752 47	Digital Electronics: Theory and Applications	Open-book, project-based
J751 47	Analogue Electronics: Theory and Applications	Open-book, project-based
J89H 47	Engineering Systems: Validation and Verification	Open-book, project-based
J6D4 47	Engineering Systems Principles	Open-book, project-based
J6D0 47	Instrumentation and Control: Measurement Systems	Open-book, project-based

Unit code	Unit title	Assessment method
J6D5 47	Instrumentation and Control: Control Systems	Open-book, project-based
J6CV 47	Manufacturing Engineering Materials and Process	Open-book, project-based
J6D1 47	Manufacturing Engineering: Simulation and Modelling	Open-book, project-based
J6CX 47	Thermodynamics and Fluid Mechanics	Open-book, project-based
J6D3 47	Engineering Mechanics and Materials	Open-book, project-based
J7L9 47	Engineering Mathematics 3	Closed-book
J7LA 48	Engineering Mathematics 4	Closed-book
J7LB 48	Engineering Mathematics 5	Closed-book
J7GS 46	Engineering Practical Skills	Open-book, project-based
J7GP 47	Application of Programmable Logic Controllers	Open-book, project-based
J7N3 47	Work-based Learning	Open-book, project-based

Approaches to delivery and assessment

Delivering centres should sequence and integrate assessment across units to reflect the needs of their group of learners and the resources available. Typical sequences of units for engineering systems, mechanical and electrical routes are given below:

Sequencing or integrating units

Delivery of Engineering Systems, Mechanical and Electrical pathways

Engineering Systems

Semester 1 (18 weeks)	Semester 2 (18 weeks)
♦ Engineering Mathematics 2 (1 credit) — 2 hours per week ♦ Engineering Project Management (part) (2 credits) — 2 hours per week ♦ Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety (3 credits) — 6 hours per week ♦ Dynamic Engineering Systems: Modelling, Simulation and Control (3 credits) — 6 hours per week ♦ Grading and meta-skills support (1 credit) — 1 hour per week	♦ Professional Practice in Engineering (3 credits) — 6 hours per week ♦ Engineering Project Management (part) (2 credits) — 2 hours per week ♦ Sustainable Design Engineering and Innovation Entrepreneurship (3 credits) — 6 hours per week ♦ Grading and meta-skills support (1 credit) — 1 hour per week
Total hours per week: 17	Total hours per week: 15

Mechanical

Semester 1 (18 weeks)	Semester 2 (18 weeks)
♦ Engineering Mathematics 2 (1 credit) — 2 hours per week ♦ Engineering Project Management (part) (2 credits) — 2 hours per week ♦ Thermodynamics, Plant Systems and Fluid Mechanics (3 credits) — 6 hours per week ♦ Advanced Materials (3 credits) — 6 hours per week ♦ Grading and meta-skills support (1 credit) — 1 hour per week	♦ Professional Practice in Engineering (3 credits) — 6 hours per week ♦ Engineering Project Management (part) (2 credits) — 2 hours per week ♦ Sustainable Design Engineering and Innovation Entrepreneurship (3 credits) — 6 hours per week ♦ Grading and meta-skills support (1 credit) — 1 hour per week
Total hours per week: 17	Total hours per week: 15

Electrical

Semester 1 (18 weeks)	Semester 2 (18 weeks)
♦ Engineering Mathematics 2 (1 credit) — 2 hours per week ♦ Engineering Project Management (part) (2 credit) — 2 hours per week ♦ Electrical Transformers, Motors and Machine Systems (3 credits) — 6 hours per week ♦ Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves (3 credits) — 6 hours per week ♦ Grading and meta-skills support (1 credit) — 1 hour per week	♦ Professional Practice in Engineering (3 credits) — 6 hours per week ♦ Engineering Project Management (part) (2 credits) — 2 hours per week ♦ Renewable Energy: Generation, Storage and Transmission (3 credits) — 6 hours per week ♦ Grading and meta-skills support (1 credit) — 1 hour per week
Total hours per week: 17	Total hours per week: 15

Outcome delivery

Engineering Systems — Semester 1 (18 weeks)

Engineering Mathematics 2 (1 credit, 2 hours per week)

1 Solve trigonometric and hyperbolic function problems.
2 Use differentiation techniques to solve engineering problems.
3 Use integration techniques to solve engineering problems.

Instrumentation and Control: Transducers, Transmitting Signals and Functional Safety (3 credits, 6 hours per week)

1 Design systems to measure strain, position and vibration in industrial applications.
2 Analyse elements of pneumatic transmission systems.
3 Analyse elements of instrument electrical transmission systems.
4 Analyse modulation system components.
5 Explain elements of digital transmission systems.
6 Apply safety-instrumented systems (SISs), risk reduction and logic solvers.
7 Analyse safety integrity levels (SIL) and safety in field instruments.

Dynamic Engineering Systems: Modelling, Simulation and Control (3 credits, 6 hours per week)

1 Identify dynamic engineering systems and control systems.
2 Identify mathematical models of dynamic engineering systems.
3 Model mechanical engineering systems.
4 Model electrical, electronic and electromechanical engineering systems.
5 Analyse the response and stability of dynamic engineering systems.
6 Analyse control systems.
7 Identify digital control systems.

Engineering Project Management (part) (2 credits, 2 hours per week)

1 Analyse project management concepts, tools and standards, and demonstrate a knowledge of total quality management (TQM) as applied to an engineering or engineering service industry.
2 Analyse and apply risk management techniques in project management, including an analysis of security risks and effective mitigation methods, and budget risk and control.

Total hours = 16

Engineering Systems — Semester 2 (18 weeks)

Professional Practice in Engineering (3 credits, 6 hours per week)

1 Define an engineering project.
2 Plan an engineering project.
3 Implement an engineering project.
4 Develop meta-skills in a vocational or academic context.
5 Work to engineering codes of practice.

Engineering Project Management (part) (2 credits, 2 hours per week)

1 Analyse stakeholder needs and translate them into success criteria, while managing project stakeholders and maintaining effective project communications.
2 Evaluate, report and close a project using recognised project management methods and tools as applied to an engineering or engineering service industry.

Sustainable Design Engineering and Innovation Entrepreneurship (3 credits, 6 hours per week)

1 Evaluate opportunities for innovation and entrepreneurship.
2 Evaluate ways to create engineering products.
3 Elaborate new product design specifications.
4 Create the best alternative new product concept.
5 Generate engineering requirements for new product concepts.
6 Evaluate new product prototype performance.

Total hours = 14

Mechanical — Semester 1 (18 weeks)

Engineering Mathematics 2 (1 credit, 2 hours per week)

1 Solve trigonometric and hyperbolic function problems.
2 Use differentiation techniques to solve engineering problems.
3 Use integration techniques to solve engineering problems.

Thermodynamics, Plant Systems and Fluid Mechanics (3 credits, 6 hours per week)

1 Apply the fundamental properties of thermodynamics to a process.
2 Evaluate the performance of internal combustion engines.
3 Explain the uses of common types of pumps and fans.
4 Explain the function of compressed air systems.
5 Explain the function of air-conditioning systems.
6 Explain the function of steam generation and distribution systems.
7 Explain the function of refrigeration systems.
8 Produce an installation and commissioning plan for an industrial system unit.
9 Analyse fluid flow patterns.
10 Solve flow measurements problems.
11 Solve problems involving incompressible flow in pipe systems.

Advanced Materials (3 credits, 6 hours per week)

1 Understand the relationship between atomic structures and material properties, and the relationship between molecular structures and material properties.
2 Determine material properties specifications for applications, and select materials using property charts, data sheets and process compatibility charts.
3 Understand how altering material structures can enhance or degrade material properties.
4 Analyse and calculate material strength and stress factors in engineering applications.
5 Understand the causes of material failure in service, and how they may be mitigated.

Engineering Project Management (part) (2 credits, 2 hours per week)

1 Analyse project management concepts, tools and standards, and demonstrate a knowledge of total quality management (TQM) as applied to an engineering or engineering service industry.
2 Analyse and apply risk management techniques in project management, including an analysis of security risks and effective mitigation methods, and budget risk and control.

Total hours = 16

Mechanical — Semester 2 (18 weeks)

Professional Practice in Engineering (3 credits, 6 hours per week)

1 Define an engineering project.
2 Plan an engineering project.
3 Implement an engineering project.
4 Develop meta-skills in a vocational or academic context.
5 Work to engineering codes of practice.

Engineering Project Management (part) (2 credits, 2 hours per week)

3 Analyse stakeholder needs and translate them into success criteria, while managing project stakeholders and maintaining effective project communications.
4 Evaluate, report and close a project using recognised project management methods and tools as applied to an engineering or engineering service industry.

Sustainable Design Engineering and Innovation Entrepreneurship (3 credits, 6 hours per week)

1 Evaluate opportunities for innovation and entrepreneurship.
2 Evaluate ways to create engineering products.
3 Elaborate new product design specifications.
4 Create the best alternative new product concept.
5 Generate engineering requirements for new product concepts.
6 Evaluate new product prototype performance.

Total hours = 14

Electrical — Semester 1 (18 weeks)

Engineering Mathematics 2 (1 credit, 2 hours per week)

1 Solve trigonometric and hyperbolic function problems.
2 Use differentiation techniques to solve engineering problems.
3 Use integration techniques to solve engineering problems.

Electrical Transformers, Motors and Machine Systems (3 credits, 6 hours per week)

1 Analyse the construction and operations of single-phase and three-phase transformers.
2 Analyse the applications of induction and synchronous motors.
3 Analyse the functions and applications of transducers and actuators, including power electronics.
4 Analyse the operations of direct current (DC) and alternating current (AC) drives in industrial applications.
5 Analyse motor characteristics for industrial loads.
6 Analyse protection arrangements for motors and ancillary equipment.

Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves (3 credits, 6 hours per week)

1 Understand sources and construction of electrical power generation and distribution systems.
2 Understand interconnections of power systems and their protection.
3 Calculate phasor voltages and currents at two points.
4 Understand the physical arrangements of an overhead transmission line.
5 Understand power systems and alternative energy sources.
6 Discuss new and emerging methods to optimise energy usage.

Engineering Project Management (part) (2 credits, 2 hours per week)

1 Analyse project management concepts, tools and standards, and demonstrate a knowledge of total quality management (TQM) as applied to an engineering or engineering service industry.
2 Analyse and apply risk management techniques in project management, including an analysis of security risks and effective mitigation methods, and budget risk and control.

Total hours = 16

Electrical — Semester 2 (18 weeks)

Professional Practice in Engineering (3 credits, 6 hours per week)

1 Define an engineering project.
2 Plan an engineering project.
3 Implement an engineering project.
4 Develop meta-skills in a vocational or academic context.
5 Work to engineering codes of practice.

Engineering Project Management (part) (2 credits, 2 hours per week)

3 Analyse stakeholder needs and translate them into success criteria, while managing project stakeholders and maintaining effective project communications.
4 Evaluate, report and close a project using recognised project management methods and tools as applied to an engineering or engineering service industry.

Renewable Energy: Generation, Storage and Transmission (3 credits, 6 hours per week)

1 Outline a holistic overview of the global energy supply situation.
2 Analyse a range of renewable energy generation methods.
3 Describe, with the aid of diagrams, a range of electrical and hydrogen generators.
4 Describe, with the aid of block diagrams, energy transmission and storage methods.

Total hours = 14

Additional guidance on integrated or holistic assessment

Holistic or integrated assessment focuses on assessing a number of outcomes in a unit together, or in some cases the whole unit rather than specific outcomes. When assessing a unit of competence holistically, the assessment activities integrate a number of aspects of the competence. Holistic or integrated assessment can reduce the time spent on assessment and can promote greater equity in the assessment process.

When developing or revising a Higher National Qualification, SQA works with a development team to devise an appropriate assessment strategy that accommodates holistic or integrated assessment. However, the practice of integrating units for the purposes of learning and teaching is a centre-led activity.

Units are designed to facilitate holistic or integrated assessment approaches that prevent large, unwieldy instruments of assessment.

Sometimes more than one piece of evidence is needed for a unit. For example, if a unit is about building a wall, a learner would need to produce evidence of performance (following the correct procedures and processes when building the wall) and product (a completed wall).

Evidence requirements must do what they say: specify requirements for evidence of learner competence in the unit(s). The evidence must be of sufficient quality for an assessor or verifier to judge that the learner has achieved the unit(s).

This award uses a project-based approach to gathering evidence both within and across units. This is aided by centres developing engineering-specific case studies to enable learners to submit project-based evidence. Three examples of case studies are given in the following sections.

3D printing case study

The term ‘3D printing’ covers a wide range of processes and technologies that involve the production of parts and products in different materials. This form of manufacturing has been available for the past 35 years, but it is only in recent years that the main technologies have reduced to a cost that allows small companies and individuals to get involved.

What makes 3D printing different from traditional manufacturing processes can be summed up in two ways:

1. The printed parts are built layer-by-layer, allowing for complex shapes to be constructed, many of which could not have been made by conventional means.
2. Material is added rather than subtracted, moulded or cast, making the process less wasteful, and more efficient and cost-effective.

3D printing utilises a variety of concepts and techniques across many engineering disciplines. This range of topics includes:

- systems elements — for example, amplifiers, stepper motors, belt drives, control devices
- transducers — applications, principles of operation, standard output signals and their uses
- actuators — applications and principles of operation
- properties of materials used in the specification and design of related systems
- calculations of basic engineering quantities — for example, velocity, acceleration, force, energy, power
- system power sources — hydraulic, pneumatic and electrical
- sub-systems specifically related to 3D printing
- control principles
- open-loop, closed-loop, use of controllers
- control system responses — under-, over- and critically damped
- effects of proportional plus integral plus derivative control

Questions to help direct your studies

As you carry out your research, the following questions will help point you in the right direction:

- Systems can be electrically, pneumatically or hydraulically operated. What are the principles of each, and what are the advantages and disadvantages of each?
- Transducers convert a non-electrical quantity into an electrical signal. List the transducers described in the core units. What are typical applications of each?
- Before constructing a system, a great deal of thought must go into deciding which materials to use. Are they rigid, flexible, light, ductile, good conductors, good insulators, good in compression, good in tension, etc? The characteristics of materials in manufacturing processes and during their service life are also major factors in choice of materials. Produce a list of materials identifying their properties and characteristics.
- Amplifiers are used to allow a small force or signal to drive or operate a large load. How is amplification achieved electrically, pneumatically and hydraulically?

- What is meant by open-loop control and closed-loop control? How can the responses of a system be modified to compensate for a change in input?
- Describe linear and angular movement and positioning through Cartesian and polar co-ordinate systems.

Wind turbine case study

As we become more aware of the adverse environmental effects of burning fossil fuels, there is an increasing trend towards developing less harmful methods of power generation. This trend is also driven by the realisation that the resources of coal and oil that we have become dependent on are finite, and eventually will no longer be available to meet our demands.

As an alternative means of generating power, renewable sources of energy are being utilised to produce power to meet our increasing demands. Renewable energy originates from sunlight, wind, tidal, geothermal and other natural sources, and is classed as ‘renewable’ since it may be either naturally replenished or sustained by actions such as replanting trees.

The development and installation of renewable power-generating systems may depend on a number of factors, such as the amount of power required, the geographical location or the local weather conditions. The length of Scotland’s coastline is 7332 miles, which creates the opportunity for tidal and wave generation of power. Coastline, inshore waters, and hilly or mountainous regions are also inherently windy, making many areas of Scotland suitable for siting wind turbines.

Wind turbines are becoming a familiar sight and can be found in cities, offshore and in rural areas. They may be installed as single units or in large numbers to form a wind farm, depending on the user’s power requirements.

Turbines come in a wide variety of designs and power-generating capacities for use as supplementary domestic power sources; for small-scale power generation for farms, factories and community projects; and for large-scale commercial supply to the National Grid.

A wind turbine is an engineering system comprising mechanical, electrical and electromechanical sub-systems. The concepts of these systems relate to those introduced in the core units of HND Engineering, and involve applying the basic concepts and techniques to the branch of engineering you are studying. Specifically:

<Insert units or outcomes covered by this case study>

You need to access the internet to help you prepare. The main sources of information for this case study will be websites providing information on a range of topics as suggested below.

<Insert specific elements covered by this case study, such as:>

- system elements — amplifiers, rectifiers, generators, control devices, etc
- transducers — applications, principles of operation, standard output signals and their uses
- actuators — applications, principles of operation
- properties of materials used in the specification and design of wind turbines

- calculations and descriptions of basic engineering quantities — velocity, acceleration, force, energy, power, power consumption, etc
- system power sources — hydraulic, electrical, wind, etc
- sub-systems related specifically to power generation systems
- control principles
- block diagrams and sketching of engineering systems and components
- open-loop, closed-loop, use of controllers
- control system response
- under-, over- and critical damping
- effects of three-term system control

Questions to help direct your studies
As you carry out your research, the following questions will help point you in the right direction:

- What are the principles of operation of a wind-powered generation system, and what are the engineering quantities relating to such a system, along with the units of those quantities?
- Transducers convert a non-electrical quantity into an electrical signal. List the transducers described in the core units. What are typical applications of each in relation to wind turbines?
- Before constructing a system, a great deal of thought must go into deciding which materials to use. Are they rigid, flexible, heavy, light, ductile, good conductors, good insulators, good in compression, good in tension, etc? The characteristics of materials in manufacturing processes and during their service life are also major factors in choice of materials. Produce a list of materials identifying their properties and characteristics that would be relevant to wind turbine component construction.
- What is meant by open-loop control and closed-loop control? How can the response of a system be modified to compensate for a change of input?

Hydroelectric power case study
The generation of electrical power from hydro sources is an indirect source of solar power. Solar radiation evaporates water from the seas and land. This heated water vapour rises, and as it rises, it cools and expands, eventually condensing to form clouds. When the resulting rain from the clouds falls on higher ground, it has gained potential energy as a result of the sun's input. Hydroelectric power is created by extracting some of this energy as the water flows back to the sea.

The resource of electricity is measured in kilowatt hours (kWh) for usage at a local level. Globally, it is expressed in terawatt hours (TWh) per year.

Around 25% of the 1.5 billion TWh of solar energy that hits Earth is consumed in the evaporation of water. Therefore, the water vapour in our atmosphere gives a very large store of renewable energy. However, most of this energy is not available to us, because as the water vapour condenses, most of the energy is released as heat in the atmosphere and radiates back into space. A very small percentage (0.06%) is retained by the precipitation that falls on mountains and hills.

The worldwide available resource of energy as water flows toward the sea has been estimated at 40 000 TWh per year. This is approximately 15 times the output of hydropower globally. The technical potential of hydropower that could be captured globally has been estimated at 15 000 TWh.

To harness some of this power, hydroelectric schemes must have two essential properties:

- an effective head (the height, H, through which the water falls)
- the flow rate (the number of cubic metres of water per second, Q)

The power carried by the water is roughly 10 times the product of these two quantities:

$$P(kWh) = 10 \times Q \times H$$

The electric power output is, of course, much less than this input.

Stored potential energy
When water is held at height it represents a stored energy, and can be considered as gravitational potential energy. Roughly 9.81 joules of energy input are needed to lift one kilogram vertically through one metre against the gravitational pull of the Earth. If M kilograms are raised through H metres, the stored potential energy in joules is represented as:

Potential energy = MgH (equation 1)

g is the acceleration due to gravity, and is given a value of 9.81 ms².

The above equation allows engineers to calculate the energy store represented by water held at a given height, providing they know the stored mass and the height (the available head).

Power, head and flow rate
To estimate the resource, the power available at any time is vitally important. The power, P, is the rate at which the energy is delivered (the number of joules per second). This obviously depends on the flow rate of the falling water (the number of cubic metres per second, Q). The mass of a cubic metre of fresh water is 1000 kg, so the mass falling per second will be $1000 \times Q$. It then follows from equation 1 that:

$$P = 1000 \times Q \times g \times H$$

When estimating hydroelectric resources, engineers must take into account energy losses. In a real-life hydroelectric system, the water will lose some energy due to friction. Therefore, the effective head is less than the actual head. Sometimes the effective head is no more than 75% of the actual height difference. Sometimes it is as much as 95%.

There are also energy losses in the operating plant itself. At optimum conditions a hydroelectric turbo-generator is a very efficient machine. It converts 95% to 97% of the input power into electrical output. However, the efficiency — the ratio of output power to input power — is always less than 100%.

Types of hydroelectric plant

Hydroelectric plants can range in capacity from 500 watts up to 10 000 megawatts. They can be classified in different ways, including:

- the effective head of water
- the rated power output
- the type of turbine used
- the location and type of dam, reservoir, etc

These factors are not independent of each other. The available head and output determine the type of plant.

Low, medium and high heads

A high head is usually recognised as an effective head of more than 100 metres and a low head less than 10 metres.

The low head dam, or barrage, maintains the head of water and also houses the plant. It sometimes has a lock for ships or a ladder run for salmon. These usually have low storage capacity and are dependent on the flow rate at the time of the year, or the prevailing weather. The large volume flow means the plant and associated civil engineering is large, leading to high construction costs.

The medium head is usually associated with large hydroelectric installations with a dam at a narrow point in the river valley. The large reservoir behind the dam is capable of supplying power, except in very prolonged dry conditions. The civil engineering costs are also very high.

The high head reservoir lies well above the outflow level and the penstock carrying the water may be cut through a mountain to reach the turbine. With a high head, the flow needed for a given power is much smaller than for a low-headed plant, so the turbines and generators are more compact. However, the long penstock adds to the cost, and the structure must be able to withstand the high pressures below the large depth of water.

The rated power output is dependent on flow rates and their variability. When calculating power, the local rainfall of the catchment area is taken into account. However, allowances must be made for evaporation, take-up by vegetation and leakage into the ground. Sometimes these factors can account for 75% of the original total. The preferred technique for estimating the power involves establishing the relationships between flow rate and either water depth or water speed at chosen points along the route.

As previously stated, the transfer of energy carried by the water into electrical energy is carried out by the turbo-generator.

A turbo-generator is a rotating turbine driven by the water and is connected by a common shaft to the rotor of a generator.

Turbines come in many shapes and forms, and vary in size, with blades ranging from under 1 metre to 20 metres.

Francis turbines are the most common type used in medium- to large-scale plants. They can be used where the head is as low as 2 metres to as high as 300 metres. Francis turbines are radial flow turbines. The water flow is inwards, towards the centre. The turbine is submerged and can run with its axis horizontal or vertical. In medium- or high-headed turbines, the water flow is channelled through a scroll case. This is a curved tube that reduces in size like a snail shell. Guide vanes inside the scroll direct the water in towards the runner. The shape of the guide vanes is important in producing the smooth flow that leads to high efficiency. Francis turbines run most efficiently when the blade speed is only slightly less than the speed of the water on the blades.

Maintaining the correct speed and direction of the incoming water relative to the runner blades is important too, and this can sometimes lead to problems. If demand falls, the output power can be reduced by reducing the water flow. In a Francis turbine, this is done by turning the guide vanes. This requires a large torque force, which changes the angle at which the water hits the blades and reduces the efficiency.

The Francis turbine does have its limits. If the head is low, a large volume flow is needed for a given power. However, a low head also means low water speed, and these two factors mean a larger input area is required. This led to engineers looking at and developing propeller-type turbines such as the Kaplan turbine. In the propeller turbine, the area in which the water enters is as large as possible. It covers the entire area swept by the blades. They are therefore suitable for very large volume flows and are used where the head is only a few metres. The advantage over radial-type turbines is that it is easier to improve its efficiency by varying the angle of the blades when the power demand changes. An important feature is that the optimum blade speed is greater than the water speed. This allows a rapid rate of rotation even with low water speeds.

For sites with heads above 250 metres, the Pelton wheel is the preferred turbine. It is essentially a wheel with a set of buckets around the rim. A high-speed jet of water, formed because of the high head hitting the edge between the buckets in turn, and under optimum conditions, gives up almost all its kinetic energy. The power is varied by adjusting the jet size or deflecting the jet away from the wheel.

The Turgo or crossflow turbine is a variation on the Pelton wheel. The double cups of the Pelton wheel are replaced by shallower ones, with the water entering on one side and leaving on the other. Its ability to handle a larger volume of water than a Pelton wheel of similar diameter gives it an advantage for generation at medium heads.

Control systems and instrumentation
It is vitally important in modern generating stations to be able to control not just the large head of water but also the generating equipment. Speeds, temperature, vibration and pressures within the turbine and generating sets must be constantly monitored by various sensors. Maintenance and calibration procedures of this equipment are rigorously controlled.

Because of the large water pressures, the sluice gates are operated hydraulically. The main hydraulic pressure and the open or closed positions of the gate are monitored by electrical pressure switches.

In modern generating stations, the use of these transducers has made the practice of running pressure lines over long distances to the control room unnecessary. It is extremely important at the station to measure the water level. Differential pressure transducers can be sited locally, and by using a 4-20mA control loop, the level can be monitored and controlled accurately. Some equipment, however, still uses voltage sensors, and these signals have to be signal-conditioned between the sensor and the control room.

As the turbine and generator run at high speeds, two of the most important control systems in a hydroelectric station are the speed of the generator, and the vibration and temperature analysis of the generator bearings. Removing either the turbine or generator to replace the bearings or rework the bearing housings is a large, time-consuming job that has an effect on the National Grid's capability and security. Other work done at this time would involve checking the integrity of the materials that the generator and the turbine are constructed from, and the various seals that protect the equipment from water entry.

To reduce downtime and prevent equipment failure, the speed of the generator is governed by a controller that takes into account the speed and torque from the head of water to proportionally control the electrical output.

The bearings are monitored constantly for vibration, adequate lubrication and, most importantly, temperature by sensors located in the bearing housings.

Assessing project units

All candidates carry out a group or individual project as part of Professional Practice in Engineering, which also includes a meta-skills outcome. The project used for this unit can be formed from the mini projects used for other units.

Opportunities for e-assessment

Assessment that is supported by ICT, such as e-testing or the use of e-portfolios or social software, may be appropriate for some assessments in this qualification.

If you want to use e-assessment, you must ensure that you apply the national standard to all evidence and that the learner meets the conditions of assessment (as specified in the evidence requirements), regardless of the mode of gathering evidence.

Remediation and re-assessment in Next Generation Higher National Qualifications

Remediation

Remediation allows an assessor to clarify learners' responses, either by requiring a written amendment or by oral questioning, where there is a minor shortfall or omission in evidence requirements. In either case, the assessor must formally note such instances, in writing or as a recording, and make them available to the internal and external verifier.

Remediation is not permitted for closed-book assessments.

The size and structure of the larger NextGen: HN units should mean that the assessor or lecturer is close enough to ongoing assessment activity in project-based units to identify the requirement for remediation as it occurs.

Re-assessment

We must give learners who fail the unit a re-assessment opportunity or, in exceptional circumstances, two re-assessment opportunities. Where we have introduced larger units to the framework, we expect instances of re-assessment to be minimal, due to the approach to assessment and remediation. Where re-assessment is required in a project-based unit, a substantially different project must be used.

Resource requirements

Each centre must offer at least one subject-specific engineering discipline and should be equipped to deliver the specific engineering content. Centres already offering HND Engineering have suitable resources to deliver this award.

Information for centres

Equality and inclusion

The units in this group award are designed to be as fair and as accessible as possible, with no unnecessary barriers to learning or assessment.

You should take into account the needs of individual learners when planning learning experiences, selecting assessment methods, or considering alternative evidence.

Guidance on assessment arrangements for disabled learners and/or those with additional support needs is available on the assessment arrangements web page.

Internal and external verification

All instruments of assessment used in HND Engineering should be internally verified according to your centre's policies and SQA's guidelines.

SQA carries out external verification to ensure that internal assessment meets the national guidelines for HND Engineering.

Further information on internal and external verification is available in SQA's Guide to Assessment.

Glossary

SQA credit value: the credit value allocated to a unit gives an indication of the contribution the unit makes to an SQA group award. An SQA credit value of 1 represents approximately 40 hours of programmed learning, teaching and assessment.

SCQF: the Scottish Credit and Qualifications Framework (SCQF) provides the national common framework for describing programmes of learning and qualifications in Scotland. SCQF terminology is used throughout this guide to refer to credits and levels. For further information on the SCQF, visit the SCQF website.

SCQF credit points: SCQF credit points provide a way of describing and comparing the amount of learning required to complete a qualification at a given level of the framework. 1 National Unit credit is equivalent to 6 SCQF credit points. 1 National Unit credit at Advanced Higher and 1 SQA Advanced unit credit (irrespective of level) is equivalent to 8 SCQF credit points.

SCQF levels: the level a qualification is assigned in the framework is an indication of how hard it is to achieve. The SCQF covers 12 levels of learning. SQA Advanced Certificates and SQA Advanced Diplomas are available at SCQF levels 7 and 8, respectively. SQA Advanced units are usually at levels 6 to 9 and graded units at level 7 and 8. National Qualification Group Awards are available at SCQF levels 2 to 6 and are usually made up of National Units, which are available from SCQF levels 2 to 7.

Information for learners

HND Engineering

This information explains:

- what the qualification is about
- what you should know or be able to do before you start
- what you will need to do during the qualification
- opportunities for further learning and employment

Group award information

The Higher National Diploma (HND) in Engineering equips you with the technical knowledge and skills, as well as the professional skills and personal behaviours (meta-skills), that employers expect from individuals entering and working in industries within the Scottish engineering and advanced manufacturing sector. You complete 6 credits common to all engineering disciplines and 9 credits reflecting a specific engineering discipline. The content mirrors the Engineering Council's five competences that you need to become an Engineering Technician (EngTech).

Although there is no set entry route to this qualification, we recommend you have achieved one or more of the following:

- an SCQF level 6 National Certificate or equivalent qualification in a related subject
- two Highers, one involving numeracy, such as Mathematics, Physics or Computing; and another involving communication, such as Modern Studies or English

HND Engineering is project-based. You must provide evidence that meets the requirements of each unit you take by completing projects and tasks that reflect the knowledge, skills and technology of your chosen specific engineering discipline. Your lecturer will give you engineering-specific case studies to base your projects on. The number of projects or tasks you need to complete depends on the resources available at your centre.

When you complete the award, you will receive a grade of Achieved, Achieved with Merit, or Achieved with Distinction. This is based on the evidence you generate in the units. The mandatory and mandatory optional units count towards your overall grade. The 3 optional credits do not contribute to your overall grade, but you still must achieve them to complete the award.

Your centre makes judgements about projects using a detailed criteria matrix based on key competences covering:

- academic knowledge
- sector-specific knowledge
- skills
- professional behaviours

You develop meta-skills throughout the qualification. In the project units, evidence of your meta-skills development contributes to your grade.

HND Engineering enables you to progress to:

- other qualifications in Engineering or related areas
- further study, employment or training, such as a degree in Engineering or a related discipline

Administrative information

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History of changes

Version	Description of change	Date

Note: please check SQA's website to ensure you are using the most up-to-date version of this guide, and check SQA's APS Navigator to ensure you are using the most up-to-date qualification structure.

If a unit is revised:

- no new centres can be approved to offer the previous version of the unit
- centres should only enter learners for the previous version of the unit if they can complete it before its finish date

For further information on SQA's Next Generation Higher National Qualifications please contact nextgen@sqa.org.uk.