# Engineering

# Level 3 Principal Learning

# Specification (2760-03)

# Assessment 2013 onwards

This Principal Learning specification should be read in conjunction with:

- Specimen assessment materials and mark schemes for Principal Learning
- Teacher guidance materials for Principal Learning
- Examiners' Reports for Principal Learning

This specification will be published annually on our website www.cityandguilds.com. We will notify centres in writing of any changes to this specification. We will also publish changes on our website. The version of the specification on our website will always be the most up-to-date version, although it may be different from printed versions.

# Contents

# 1 Introduction

## 1.1 Why choose City & Guilds?

City & Guilds is a household name for vocational qualifications. City & Guilds offers over 500 awards across a range of industries. With over 8500 centres in over 100 countries, City & Guilds is recognised by employers worldwide. It works closely with employers and industry bodies to ensure that its qualifications provide the benchmark standard for workplace skills and knowledge.

Principal Learning is a blend of academic and vocational skills and that is why City & Guilds is the ideal choice for any school, college or consortium looking to offer them.

**Why is City & Guilds so popular?**

**Specifications**

These are designed to the highest standards, so that teachers, learners and learners' parents or guardians can be confident that a City & Guilds award provides an accurate measure of achievement. Assessment structures have been designed to achieve a balance between rigour, reliability and demands on learners and teachers.

**Support**

City & Guilds runs the most extensive programme of Principal Learning support meetings available in the UK; these are free of charge in the first years of a new specification and are offered at a very reasonable cost thereafter. These meetings explain the specification and suggest practical teaching strategies and approaches that really work.

**Service**

We are committed to providing an efficient and effective service and we are at the end of a phone when you need information, advice or guidance. We will try to resolve issues the first time you contact us and will work with you to find the solution.

**Ethics**

City & Guilds is a registered charity. We have no shareholders to pay. We exist solely for the good of education. Any surplus income is ploughed back into educational research and our service to you, our customers. We don't profit from education, you do.

If you are an existing customer, we thank you for your support. If you are thinking of adopting City & Guilds for Principal Learning, we look forward to welcoming you.

## 1.2 Why choose the Engineering Principal Learning?

The Engineering Principal Learning introduces learners to the world of engineering. It provides a gateway to the different sectors of engineering and the underlying systems and structures. Learners will acquire an understanding of the contribution engineering makes to modern life and of the career opportunities available.

The Principal Learning will enable learners to progress into further and higher education and future employment.

## 1.3 How do I start using this specification?

You will need to register your centre with us. (See Section 5.2.) This will enable us to ensure that you receive all the material you need to help you to deliver units and to enter your learners for examinations. This is particularly important where examination material is issued before the entry deadline. You can let us know by completing the appropriate registration forms. We will send copies to your exams officer and they are also available on the City & Guilds website: **www.cityandguilds.com**

If your centre is new to City & Guilds, please contact your local City & Guilds Regional Office.

# 2 Specification at a glance

## 2.1 Level 3 Engineering Principal Learning at a glance

All nine units are compulsory.

| **Unit 1 60 GLH** |
| --- |
| **Engineering business and the environment**<br>Internally set and marked |

| **Unit 2 60 GLH** |
| --- |
| **Applications of Computer Aided Designing**<br>Internally set and marked |

| **Unit 3 60 GLH** |
| --- |
| **Selection and application of engineering materials**<br>Internally set and marked |

| **Unit 4 60 GLH** |
| --- |
| **Instrumentation and Control engineering**<br>Internally set and marked |

| **Unit 5 30 GLH** |
| --- |
| **Maintaining engineering systems and products**<br>Internally set and marked |

| **Unit 6 60 GLH** |
| --- |
| **Production and manufacturing**<br>Internally set and marked |

| **Unit 7 60 GLH** |
| --- |
| **Innovative design and enterprise**<br>Internally set and marked |

| **Unit 8 60 GLH** |
| --- |
| **Mathematical techniques and applications for engineers**<br>Externally assessed |

| **Unit 9 90 GLH** |
| --- |
| **Scientific principles and applications for engineers**<br>67% Externally assessed<br>33% Internally set and marked |

# 3 Principal Learning

## 3.1 Personal, Learning and Thinking Skills

The Framework of Personal, Learning and Thinking Skills 11-19 comprises six groups of skills that, together with the Functional Skills of English, mathematics and ICT, are essential to success in learning, life and work. For each group there is a focus statement that identifies the main PLTS in that group. This is followed by a set of outcome statements that are indicative of behaviours and personal qualities associated with each group of skills.

Each group of skills is distinctive and coherent. The groups are also inter-connected. Learners are likely to encounter skills from several groups in any one learning experience.

Listed below are the PLTS that are integrated within the assessment criteria in each unit. A copy of the PLTS framework should be given to each learner. Following these descriptors is a table showing the PLTS in the nine units of the Level 3 Engineering Principal Learning.

| **Independent enquirers** |
|---|
| Focus:<br>Young people process and evaluate information in their investigations, planning what to do and how to go about it. They take informed and well-reasoned decisions, recognising that others have different beliefs and attitudes. |
| Young people:<br>IE1 identify questions to answer and problems to resolve<br>IE2 plan and carry out research, appreciating the consequences of decisions<br>IE3 explore issues, events or problems from different perspectives<br>IE4 analyse and evaluate information, judging its relevance and value<br>IE5 consider the influence of circumstances, beliefs and feelings on decisions and events<br>IE6 support conclusions, using reasoned arguments and evidence |

| **Creative thinkers** |
|---|
| Focus:<br>Young people think creatively by generating and exploring ideas, making original connections. They try different ways to tackle a problem, working with others to find imaginative solutions and outcomes that are of value. |
| Young people:<br>CT1 generate ideas and explore possibilities<br>CT2 ask questions to extend their thinking<br>CT3 connect own and others' ideas and experiences in inventive ways<br>CT4 question own and others' assumptions<br>CT5 try out alternatives or new solutions and follow ideas through<br>CT6 adapt ideas as circumstances change |

| **Reflective learners** |
| --- |
| Focus:<br>Young people evaluate their strengths and limitations, setting themselves realistic goals with criteria for success. They monitor their own performance and progress, inviting feedback from others and making changes to further their learning. |
| Young people:<br>RL1 assess themselves and others, identifying opportunities and achievements<br>RL2 set goals with success criteria for their development and work<br>RL3 review progress, acting on the outcomes<br>RL4 invite feedback and deal positively with praise, setbacks and criticism<br>RL5 evaluate experiences and learning to inform future progress<br>RL6 communicate their learning in relevant ways for different audiences |

| **Team workers** |
| --- |
| Focus:<br>Young people work confidently with others, adapting to different contexts and taking responsibility for their own part. They listen to and take account of different views. They form trusting relationships, resolving issues to reach agreed outcomes. |
| Young people:<br>TW1 co-operate with others to work towards common goals<br>TW2 reach agreements, managing discussions to achieve results<br>TW3 adapt behaviour to suit different roles and situations<br>TW4 show fairness and consideration to others<br>TW5 take responsibility, showing confidence in themselves and their contribution<br>TW6 provide constructive support and feedback to others |

| **Self-managers** |
| --- |
| Focus:<br>Young people organise themselves, showing personal responsibility, initiative, creativity and enterprise with a commitment to learning and self-improvement. They actively embrace change, responding positively to new priorities, coping with challenges and looking for opportunities. |
| Young people:<br>SM1 seek out challenges or new responsibilities and show flexibility when priorities change<br>SM2 work towards goals, showing initiative, commitment and perseverance<br>SM3 organise time and resources, prioritising actions<br>SM4 anticipate, take and manage risks<br>SM5 deal with competing pressures, including personal and work-related demands<br>SM6 respond positively to change, seeking advice and support when needed |

| **Effective participators** |
|---|
| Focus:<br>Young people actively engage with issues that affect them and those around them. They play a full part in the life of their school, college, workplace or wider community by taking responsible action to bring improvements for others as well as themselves. |
| Young people:<br>EP1 discuss issues of concern, seeking resolution where needed<br>EP2 present a persuasive case for action<br>EP3 propose practical ways forward, breaking these down into manageable steps<br>EP4 identify improvements that would benefit others as well as themselves<br>EP5 try to influence others, negotiating and balancing diverse views to reach workable solutions<br>EP6 act as an advocate for views and beliefs that may differ from their own |

This table shows the coverage of PLTS in the nine units of the Level 3 Engineering Principal Learning.

**Level 3 Engineering Principal Learning**

| PLTS | IE | CT | RL | TW | SM | EP |
|---|---|---|---|---|---|---|
| Unit 1 | * | | | * | | |
| Unit 2 | * | * | * | | | |
| Unit 3 | * | * | | | * | |
| Unit 4 | * | * | * | | | |
| Unit 5 | * | | * | | * | |
| Unit 6 | * | | | | * | * |
| Unit 7 | * | * | | | | * |
| Unit 8 | * | * | | | | |
| Unit 9 | * | * | * | | * | |

## 3.2 Functional Skills signposting

The units may use and/or contribute towards the underpinning skills and knowledge of the Functional. Skills in the following areas, depending on the precise nature of the work done in the Principal Learning.

| **The Principal** | **Functional Skills** | | |
|---|---|---|---|
| **Unit** | **English** | **Mathematics** | **Information and Communication Technology** |
| **Unit 1** Engineering business and the Environment | • Speaking and listening Level 2<br>• Reading Level 2<br>• Writing Level 2 | • Representing situations using mathematics Level 2<br>• Analysing and processing using mathematics Level 2<br>• Interpreting and presenting results Level 2 | • Use ICT systems Level 2<br>• Find and select information Level 2<br>• Develop, present and communicate information Level 2 |
| **Unit 2** Applications of Computer Aided Designing | • Speaking and listening Level 2<br>• Reading Level 2<br>• Writing Level 2 | • Representing situations using mathematics Level 2<br>• Analysing and processing using mathematics Level 2<br>• Interpreting and presenting results Level 2 | • Use ICT systems Level 2<br>• Find and select information Level 2<br>• Develop, present and communicate information Level 2 |
| **Unit 3** Selection and application of engineering materials | • Speaking and listening Level 2<br>• Reading Level 2<br>• Writing Level 2 | • Representing situations using mathematics Level 2<br>• Analysing and processing using mathematics Level 2<br>• Interpreting and presenting results Level 2 | • Use ICT systems Level 2<br>• Find and select information Level 2<br>• Develop, present and communicate information Level 2 |
| **Unit 4** Instrumentation and control engineering | • Speaking and listening Level 2<br>• Reading Level 2<br>• Writing Level 2 | • Representing situations using mathematics Level 2<br>• Analysing and processing using mathematics Level 2<br>• Interpreting and presenting results Level 2 | • Use ICT systems Level 2<br>• Find and select information Level 2<br>• Develop, present and communicate information Level 2 |
| **Unit 5** Maintaining engineering systems and products | • Speaking and listening Level 2<br>• Reading Level 2<br>• Writing Level 2 | • Representing situations using mathematics Level 2<br>• Analysing and processing using mathematics Level 2<br>• Interpreting and presenting results Level 2 | • Use ICT systems Level 2<br>• Find and select information Level 2<br>• Develop, present and communicate information Level 2 |
| **Unit 6** Production and manufacturing | • Speaking and listening Level 2<br>• Reading Level 2<br>• Writing Level 2 | • Representing situations using mathematics Level 2<br>• Analysing and processing using mathematics Level 2<br>• Interpreting and presenting results Level 2 | • Use ICT systems Level 2<br>• Find and select information Level 2<br>• Develop, present and communicate information Level 2 |

| Unit | English | Mathematics | Information and Communication Technology |
|---|---|---|---|
| **Unit 7** Innovative design and enterprise | • Speaking and listening Level 2<br>• Reading Level 2<br>• Writing Level 2 | • Representing situations using mathematics Level 2<br>• Analysing and processing using mathematics Level 2<br>• Interpreting and presenting results Level 2 | • Use ICT systems Level 2<br>• Find and select information Level 2<br>• Develop, present and communicate information Level 2 |
| **Unit 8** Mathematical techniques and applications for engineers | • Speaking and listening Level 2<br>• Reading Level 2<br>• Writing Level 2 | • Representing situations using mathematics Level 2<br>• Analysing and processing using mathematics Level 2<br>• Interpreting and presenting results Level 2 | • Use ICT systems Level 2<br>• Find and select information Level 2<br>• Develop, present and communicate information Level 2 |
| **Unit 9** Scientific principles and applications for engineers | • Speaking and listening Level 2<br>• Reading Level 2<br>• Writing Level 2 | • Representing situations using mathematics Level 2<br>• Analysing and processing using mathematics Level 2<br>• Interpreting and presenting results Level 2 | • Use ICT systems Level 2<br>• Find and select information Level 2<br>• Develop, present and communicate information Level 2 |

## 3.3 The four themes of the Level 3 Engineering Principal Learning

The principal learning of the Level 3 Engineering Principal Learning is centred around four themes:

**Theme A: The engineered world** enables learners to develop their understanding of careers in engineering and how engineering businesses operate.

**Theme B: Discovering engineering technology** enables learners to understand the importance and breadth of the technologies used in engineering.

**Theme C: Engineering the future** allows learners to understand the relationship between innovative engineering design and business success.

**Theme D: Analytical methods** used for engineering covers the mathematical and scientific principles used by engineers in analysis, design and problem solving.

## 3.4 Level 3 Units

# Level 3 Unit 1: Engineering business and the environment (ENG3U1)

**What is this unit about?**

The purpose of this unit is to provide learners with a broad background knowledge of engineering business and the environmental impact of engineering activities. It is important that learners have a grasp of the basic organisational structures of the Engineering industry. Learners will be able to identify typical companies within the sector and the commercial functions which operate within them.

Learners will become familiar with job roles and career pathways in the engineering business sector. They will learn about the impact of technology, legislation, and Health and Safety issues on employment patterns.

The basic concepts of project management, productivity, budgeting, income generation and profit will be researched and investigated in order to provide an overview of the financial and commercial management of engineering companies. This research will take account of the environmental impact of expanding engineering activities, the effect of diminishing supplies of raw materials, and sustainability and conservation issues.

This unit, alongside the others within the Level 3 Principal Learning in Engineering, has been designed to allow learners the opportunity to develop a range of Personal, Learning and Thinking Skills (PLTS), and to demonstrate these on more than one occasion. This approach will allow them to build towards a full range of PLTS.

**Learning outcomes**

The learner will:

1. understand background information on engineering company profiles
2. know about the role of project management, and the link between risk analysis and the requirements of current legislation
3. understand environmental issues relevant to the Engineering industry.

## Assessment criteria

### 1. Engineering company profiles

The learner can:

1.1 describe the different organisational structures that exist and their trading environments

1.2 describe the different job roles and career pathways that exist and how they vary according to the size of the company

1.3 recognise the contribution of engineers to the different functions in a company

1.4 carry out research as a member of a team:

a. allocating roles (TW3)

b. taking responsibility (TW3)

c. providing support and feedback to others (TW6).

### 2. The role of project management, and linking risk analysis to the requirements of current legislation

The learner can:

2.1 explain and use project management skills in order to optimise the use of resources throughout a project life cycle, including the use of sub-contracting services

2.2 explain the concept of risk analysis and the impact of current legislation on modern industrial practices

2.3 produce a business case for a project with associated simple risk assessments.

### 3. Environmental issues relevant to the Engineering industry

The learner can:

3.1 explain the environmental and social impacts of engineering activities on the sustainability and depletion of resources (IE5)

3.2 consider the short- and long-term initiatives to offset environmental change and the depletion of natural resources

3.3 carry out research, including data collection related to environmental sampling

3.4 apply mathematics to chemical processes and data analysis, and undertake simple chemical analysis (IE2,4).

Where the Assessment criteria show a direct link to an area of the PLTS framework, it is referenced here. Further information on PLTS is available in Section 3.1 of this specification and also within this unit in the section on Personal, Learning and Thinking Skills.

## Guided learning hours

It is recommended that a minimum of 60 guided learning hours be spent on this unit.

## Assessment

This unit is assessed through a centre set and marked assignment. Internal assessments are subject to moderation by City & Guilds.

Learners will complete an assignment, which must be planned so that they fully understand the functioning of a team and carry out various aspects of their research in small teams. They must evaluate their contribution to the team.

If all, or part of, the evidence produced by a learner relates to outcomes produced as a result of working in a group, it must be clear which evidence is to be credited to the individual learner.

The assignment will take approximately 20 of the 60 guided learning hours available for this unit. The learner should work under controlled conditions in accordance with the guidance in Section 4.4 of this specification, and evidence should be kept for moderation purposes.

## Evidence requirements

The learner must produce evidence of achievement of the Assessment criteria. In the assignment, the learner will produce:

1. results of research and investigation into engineering organisations, including the roles and career pathways of the people that work in them
2. explanations and diagrams to show how the different roles interrelate and the organisational structure
3. evidence of working in a team to carry out research
4. an overview of how project management is used to control the financial and commercial aspects of an engineering business venture, including risk analysis and the effect of legislation
5. a business plan for a project with any associated simple risk assessments
6. an explanation of the impact an Engineering sector can have on the physical environment, with a consideration given to legislation aimed at improving conservation
7. examples of conservation methods used to preserve raw materials and minimise pollution
8. evidence of carrying out environmental monitoring and data collection
9. a record of chemical analysis and associated mathematical techniques.

In order to attain a high mark in this unit, learners must address all of the above. It may, however, be possible to achieve a pass mark without producing every one of the Evidence requirements. A table showing how the assessment criteria topics are weighted is included below, and learners should be shown this in order that they understand how the final mark is determined.

## Assignment structure

A suggested Assignment structure, which would allow learners to meet the Evidence requirements, may include the following steps:

- Research and investigate commercial companies that have an engineering focus.
- Produce annotated diagrams to describe different organisational structures and how the roles interface within the organisations.
- Indicate any potential career development opportunities and pathways that exist at each level or place within the organisation.
- Explain how different job roles are involved at the various stages of a project life cycle.
- Using readily available data, provide a brief description of the trading position of a company involved in engineering activities.
- Describe how project management is used in a company.
- Provide a brief explanation of the conditions in which a company operates, and the impact environmental considerations have had on its policies.
- Produce a business plan for a project, including associated simple risk assessments.
- Produce a short environmental impact study based on the release or disposal of potential pollutants.
- Carry out environmentally related chemical analysis, and use mathematical techniques in support of this work.
- Evaluate individual contribution during any group activities undertaken as part of the assessment, and the performance of the team as a whole.

**Weighting of Assessment criteria topics**

| Assessment criteria topic | Weighting | Marks |
|---|---|---|
| 1. Engineering company profiles | 30% | 18 |
| 2. The role of project management, and linking risk analysis to the requirements of current legislation | 30% | 18 |
| 3. Environmental issues relevant to the Engineering industry | 40% | 24 |
| **Total** | 100% | 60 |

**Assessment grid**

This statement of performance should be read in association with the Assessment criteria for this unit. Please note that the descriptions in this marking grid relate to the top of each band. Further guidance on using marking grids is available in the Assessment section of this specification.

| **Assessment criteria topic** | **Band 1** | **Band 2** | **Band 3** |
|---|---|---|---|
| | The learner has: | | |
| 1. Engineering company profiles | **0 – 6 marks**<br><br>Relied predominantly on a single source of information or data<br><br>Investigated and interpreted a company structure from limited data with some guidance; described the company structure in simple terms; and identified some engineering roles within the organisation.<br><br>Had limited success in identifying a career pathway in the company<br><br>Made some attempt at producing a company profile<br><br>Made a minimal contribution to team research | **7 – 12 marks**<br><br>Collected and used information from more than one source and on more than one company<br><br>Investigated several company structures, and the roles and responsibilities of personnel; successfully identified a key engineering role within a company that links to its current trading status.<br><br>Identified a career pathway for one of the roles<br><br>Produced a company profile<br><br>Been actively involved in team research | **13 – 18 marks**<br><br>Collected and used detailed information from a variety of sources on a range of companies<br><br>Carried out detailed investigations of different company structures and identified how the key roles and responsibilities of the engineering personnel interface; provided detailed information on a company's current projects and trading position<br><br>Provided evidence of a personnel progression through an identified career pathway<br><br>Produced a comprehensive profile of a company<br><br>Co-ordinated the research activities of team members |

| | | | |
|---|---|---|---|
| 2. The role of project management, and linking risk analysis to the requirements of current legislation | **0 – 6 marks**<br><br>Worked with detailed but limited data to describe the use of project management in a company | **7 – 12 marks**<br><br>Worked with a range of data and described how project management is being used effectively in a company | **13 – 18 marks**<br><br>Obtained a comprehensive range of data and used analytical techniques to explain how project management is being used effectively in a company |
| | Shown little analysis of how resources or services have been optimised through the use of project management | Used some complex analysis of data to show how resources were being used to produce a good commercial operation | Used a thorough, complex analysis of data to confirm how resources have been optimised to produce an efficient commercial operation |
| | Produced a basic business case for a project | Produced an adequately researched and presented business case | Produced a well researched and presented business case |
| | Mentioned risk analysis but provided little context or mention of legislative constraints | Outlined a company's risk analysis strategy in the context of its product line, with some mention of the legislative constraints that influence policy | Explained a company's risk analysis strategy in the context of its product line and market position, including a full account of the legislative constraints within which it operates, and how these determine company policy |
| | Included basic information on project parameters; provided limited quantitative data on any measurement indicators that link to the project life cycle | Analysed all project parameters and provided incomplete quantitative data; made some attempt at linking the measurement indicators to the project life cycle | Accurately defined all stages of the project life cycle; provided a thorough analysis of project parameters with quantitative data on all aspects of the project life cycle |

| | | | |
|---|---|---|---|
| 3. Environmental issues relevant to the Engineering industry | **0 – 8 marks** | **9 – 16 marks** | **17 – 24 marks** |
| | Demonstrated some understanding of the need for environmental controls | Provided justification of the need to have environmental controls | Shown a keen awareness of environmental issues, and presented a strong case for environmental legislation |
| | Identified an example of where an engineering operation is depleting a natural resource | Identified more than one natural resource that is being depleted through engineering activities | Identified a range of natural resources that are being depleted through engineering activities, and identified a number of different approaches that companies might consider for conserving the environment whilst maintaining production targets |
| | Provided a basic example of a conservation initiative | Identified an example of where a company is using a conservationist approach to engineering manufacture | Presented more than one example of where companies are using resources in a more environmentally friendly manner |
| | Carried out basic research including limited data collection and environmental sampling | Carried out adequate research including data collection and environmental sampling | Carried out detailed research including data collection and environmental sampling |
| | Applied limited mathematics to a chemical process | Applied relevant mathematics to a chemical process | Used a range of mathematical techniques with a variety of chemical processes |
| | Undertaken very limited chemical analysis | Undertaken adequate chemical analysis | Undertaken very detailed chemical analysis |

**Guidance for delivery**

Learners should research and investigate an engineering or manufacturing company, or companies, to formulate ideas on structure and job roles. Different types of structures could include hierarchical, flat and matrix; and job roles could include:

- finance
- purchasing
- marketing and promotions
- sales
- research, product development and design
- quality assurance and control
- planning, production and manufacture
- product support.

Learners should understand how job functions interface in an organisation, and how they relate to the career pathways, eg vertical (operative, craftsperson, technician, chartered engineer etc) or horizontal (technician, quality assurance officer, product support, draftsperson, sales engineer etc). The following job functions could be included:

- researching and designing
- planning
- organising and facilitating
- managing and/or supervising
- directing and controlling
- marketing and product support.

The ways in which the above job functions interface in organisations could relate to level of responsibility, span of control, budgets and cost centres and lines of communication (reporting channels).

Learners should understand the concepts and key stages of project management and these should be linked to risk analysis and budgeting aspects. A project management outline should include consideration of specification and quality, cost and time, and schedule and budget.
When studying budget and costing considerations, the following could be included:

- direct/indirect
- variable and fixed
- break even point.

Learners should research and describe the short- and long-term effects of engineering and manufacturing activities on the physical environment by the consumption of raw materials and the effects on:

- Sustainability
- Pollution of land, sea and air
- employment patterns
- working practices and conditions including Health and Safety
- Technological advancement.

Learners should have an awareness of the effects of legislation on commercial functions and contractual obligations of engineering companies.

Learners should consider the impact of ergonomics in the workplace and its contributions to Health and Safety, in relation to:

- efficient workplace designs
- minimising harmful emissions
- improved hygiene.

When considering conservation, learners should assess the current methods for managing and conserving the environment, including:

- pollution controls including environmental monitoring
- waste management schemes
- recycling
- energy conservation schemes
- clean manufacturing
- renewable/low energy supplies.

Learners should be aware of the practical and legislative requirements for environmental monitoring and how to conduct associated chemical analysis. They also need to be able to carry out any required mathematical processes to support chemical analysis. This may provide opportunities for the use of data logging and allied spread sheet and statistical analysis.

This unit will have an integrating effect on content learnt in other units, and it is expected that applied learning gained from other units will be used as part of the activities involved in producing realistic business plans. Learners should be encouraged to draw on their knowledge of materials, manufacturing processes and maintenance practices when considering the environmental impact of modern manufacturing companies.

Learners should work to current standards and legislation, relevant details of which should be included in their Evidence requirements:

The following are some resources that may facilitate or enhance the learning covered in this unit:

- ICT facilities to support research and investigations into local/regional/national companies
- current legislation relevant to the areas under investigation
- current journals on pollution control initiatives
- books, journals and articles on project management
- contacts with local government.

## Opportunities for applied learning

This unit will be delivered through a combination of taught hours and investigative work, but the learners will benefit directly from visits to a range of different companies involved in engineering manufacture and services.

Visits will also allow learners to understand how the principles that underpin project management link to the business and commercial functions of engineering organisations, and how environmental management and pollution control for a particular product influence the selection of the process used in its manufacture. Through appropriate visits, learners will also gain an insight into current legislation, environmental factors and global conservation initiatives that influence a company's corporate planning strategy.

An important part of this unit is the opportunity to involve learners in practical investigative activities and analytical work. Environmental monitoring and associated chemical analysis will lead naturally into the use of mathematical techniques which have application in this area of study.

Learners should be given the opportunity to use a range of research media including company websites, trade journals, professional journals, and TV programmes or corporate videos.

### What activities might be involved in this unit?

- Researching and analysing business organisations and structures and the roles of people who work in them.
- Developing an awareness of career pathways.
- Producing  a business case linked to risk analysis.
- Contact with industry and local authority environmental monitoring.
- Environmental monitoring and chemical analysis.

**Personal, Learning and Thinking Skills**

The list below is indicative of the way this unit supports the development of PLTS, as opposed to the achievement of PLTS that are possible through the assessment. The unit supports the development of more PLTS than are covered through the Assessment criteria alone. Alternative approaches could be selected.

The learner could develop PLTS by:

**Independent enquirers**

- independently researching a company's activities to identify how project management is used in either manufacturing or servicing context
- organising group discussions to debate the relationship between global engineering operations and environmental issues

**Creative thinkers**

- explaining how different job roles interface within specific organisations

**Reflective learners**

- considering how to meet the challenges of long-term conservation strategies
- evaluating conservation ideas and identifying potential applications by companies in the research

**Team workers**

- working with others, discussing ideas and suggesting solutions to problems
- providing constructive advice and feedback to others involved in the research

**Self-managers**

- organising time and resources to investigate more than one type of company

**Effective participators**

- proposing practical ways of problem solving and breaking problems down into understandable elements.

# Level 3 Unit 2: Applications of Computer Aided Designing (ENG3U2)

**What is this unit about?**

The purpose of this unit is to familiarise learners with the use of Computer Aided Designing (CAD) for producing drawings and models to test or convey ideas. This unit is of particular importance to the industry, as much of the content relates to technologies widely used across a range of Engineering sectors. Learners who are able to develop this work in depth will produce drawings and models to professional standards.

Modelling and testing form important parts of this unit and learners are encouraged to design, model and test their ideas for engineering systems and components. Recording, interpreting and evaluating results are an integral part of the process and learners should be reminded of the importance of conforming to sector-specific standards throughout the process.

Learners should be aware of how CAD is used extensively in industry and the reasons for this, including the time taken to generate or alter drawings and the advantages of concurrent working in order to minimise the risks associated with conventional designing on larger scale projects. In addition, they need to be aware of the advantages of CAD in comparison with traditional manual drawing methods.

The work of this unit directly relates to Level 3 Unit 6: Production and manufacturing, and Level 3 Unit 7: Innovation design and enterprise. The activities completed as part of this unit's requirements can be incorporated and developed when exploring ideas or developing products in Units 6 and 7. It is important that work is relevant and that the learner gains the maximum benefit from cross-unit linking and the integration of scientific and mathematical aspects of their work in an applied learning context.

This unit, alongside the others within the Level 3 Principal Learning in Engineering, has been designed to allow learners the opportunity to develop a range of Personal, Learning and Thinking Skills (PLTS), and to demonstrate these on more than one occasion. This approach will allow them to build towards a full range of PLTS.

**Learning outcomes**

The learner will:

1. be able to design, model and test engineering products
2. be able to use 2D and 3D CAD software to produce drawings and models.

**Assessment criteria**

**1. Design, model and test engineering products**

The learner can:

1.1 compare the advantages of using CAD to traditional manual drawing office methods b

1.2 design for manufacture (CT1, 3)

1.3 design engineering systems and components (CT5)

1.4 model ideas and produce rendered presentation drawings (RL4)

1.5 test and simulate design ideas by using for example (IE3, 4):

- a. virtual test bed and virtual wind tunnel testing
- b. structural analysis programmes, including stress analysis
- c. simulations of mechanical and electronic systems

1.6 produce, modify and interpret drawings to current industrial standards, including:

- a. drawings which use orthographic or isometric projection showing components or assemblies
- b. drafting and using schematic and circuit diagrams, eg pneumatic, hydraulic, electrical or electronic symbols
- c. the use of commands including 3D features such as extrusion, projection, shell, chamfering and filleting
- d. control the view, eg by viewpoint, zoom or scale change

1.7 evaluate the use and implications of concurrent engineering systems with regard to (RL5):

- a. advantages
- b. time
- c. specialist input
- d. non-geographical workplaces

**2. Use 2D and 3D CAD software to produce drawings and models**

The learner can:

2.1 use 2D and 3D CAD software including solid modelling

2.2 use computer systems and data storage including input devices, storage and output devices, such as paper hard copy and rapid prototyping printers

2.3 use systems that ensure the secure storage and retrieval of data

2.4 apply and integrate CAD into combined design and manufacturing systems e produce conversion files for subsequent manufacture

2.5 produce drawings to specified current standards.

Where the Assessment criteria show a direct link to an area of the PLTS framework, it is referenced here. Further information on PLTS is available in Section 3.1 of this specification and also within this unit in the section on Personal, Learning and Thinking Skills.

**Guided learning hours**

It is recommended that a minimum of 60 guided learning hours be spent on this unit.

**Assessment**

This unit is assessed through a centre set and marked assignment. Internal assessments are subject to moderation by City & Guilds.

The learner will complete an assignment which will involve the design and testing or modelling of an engineering product. Learners need to recognise the importance of the application of CAD. The assignment set will ensure that they appreciate that an essential stage in the development of any engineering product is design modelling. At this stage, changes can be made which do not involve expensive alterations or modifications to be implemented.

The assignment should be in the context of designing engineering components or systems for use. Tasks should be drawn from situations which are accessible to the learner, and not be overly onerous in the level of technical demand if this proves to be an obstacle to achieving the primary learning objectives of the unit.

The assignment will take approximately 10 of the 60 guided learning hours available for this unit. The learner should work under controlled conditions in accordance with the guidance in Section 4.4 of this specification, and evidence should be kept for moderation purposes.

Learners will need to be provided with a product specification.

**Evidence requirements**

The learner must produce evidence of achievement of the Assessment criteria. In the assignment, the learner will produce:

1. CAD working drawings
2. a 3D CAD model of a product
3. records of design tests, methods and modifications
4. a drawing of their final design
5. a summary evaluation of the effectiveness of the proposed solution, and how the processes used have contributed to the eventual outcome.

In order to attain a high mark in this unit, learners must address all of the above. It may, however, be possible to achieve a pass mark without producing every one of the Evidence requirements. A table showing how the assessment criteria topics are weighted is included below, and learners should be shown this in order that they understand how the final mark is determined.

**Assignment structure**

A suggested Assignment structure, which would allow learners to meet the Evidence requirements, may include the following steps:

- Using the provided product specification, produce CAD working drawings of the product which can be used as a basis of manufacturing.
- Produce a 3D CAD model of the product.
- Carry out and record any tests devised for the design, explaining why the method used was appropriate.
- Explain any modifications made to the design as a result of testing.
- Produce a presentation drawing of the final design.
- Compare the design with the specification and state:
    - how closely it matches the specification
    - any procedures followed or problems encountered

**Weighting of assessment criteria topics**

| Assessment criteria topic | Weighting | Marks |
|---|---|---|
| 1. Design, model and test engineering products | 50% | 30 |
| 2. Use 2D and 3D CAD software to produce drawings and models | 50% | 30 |
| **Total** | 100% | 60 |

**Assessment grid**

This statement of performance should be read in association with the Assessment criteria for this unit. Please note that the descriptions in this marking grid relate to the top of each band. Further guidance on using marking grids is available in the Assessment section of this specification.

| Assessment criteria topic | Band 1 | Band 2 | Band 3 |
|---|---|---|---|
| | The learner has: | | |
| 1. Design, model and test engineering products | **0– 10 marks**<br>Conveyed ideas adequately with a basic range of drawing and modelling methods; produced working drawings which convey some essential information<br><br>Tested at least one idea to be able to draw reasoned conclusions<br><br>Worked with a single technology, eg electronics<br><br>Explained concurrent engineering | **11 – 20 marks**<br>Conveyed ideas well with the use of a sufficient range of drawing and modelling methods; used working drawings to impart detail to a good standard<br><br>Tested several ideas, and was able to compare and evaluate them<br><br>Worked with more than one technology, eg mechanical and pneumatic<br><br>Used concurrent engineering to design a component with others | **21 – 30 marks**<br>Conveyed ideas by means of presentation drawings, modelled solids and working drawings to a high standard; used a wide range of design techniques and ideas<br><br>Tested the viability of ideas through virtual testing, with evaluation resulting in subsequent modification(s)<br><br>Worked with a range of technologies including mechanical and electronic systems<br><br>Worked with others on design tasks, using concurrent engineering techniques |

| | | | |
|---|---|---|---|
| 2. Use 2D and 3D CAD software to produce drawings and models | **0 – 10 marks**<br>Used 2D and 3D CAD drawing packages to produce images of straightforward components | **11 – 20 marks**<br>Used 2D and 3D CAD drawing packages to produce images of components including assemblies | **21 – 30 marks**<br>Produced evidence of fluency with a variety of CAD software packages |
| | Produced simple assembly drawings and models | Used many features of the packages with a good level of success to produce accurate drawings and models | Produced drawings and models with precision, using a range of projections, conventions and techniques |
| | Produced drawings with a single technology, eg mechanical | Used many features of the packages with a good level of success to produce accurate drawings and models | Worked to a high level with several alternative technologies (eg electronics/pneumatics or mechanical) |
| | Demonstrated some consideration of CAM production | Generated files for 2D and 3D CAM Production | Generated accurate files for 2D and 3D CAM production |
| | Used 2D generated data for CNC Control | Used 2D and 3D generated data for CNC control of printers or prototyping equipment | Used 2D and 3D modified generated data for CNC control of printers or prototyping equipment |
| | Used provided standard library components in designs. Collection and environmental sampling | Worked individually, generating own images/profiles or by importing and incorporating the work of others including components or library items | Worked in conjunction with others, exchanging common data; incorporated others' contributions; contributed to common libraries of components or symbols |

**Guidance for delivery**

The use of both 2D and 3D software is required.
Wherever possible, real project scenarios which draw on the expertise and co-operation of local engineering companies should be used. Any task should be rooted in the context of designing engineering components or systems for use. Tasks should be drawn from situations which are accessible to the learner, and not be overly onerous in the level of technical demand if this proves to be an obstacle to achieving the primary learning objectives of the unit.

Working drawings (2D) need to conform to sector specific standards, normally British Standards, with the exception of situations in which tasks relate to the requirements of a company or sector which normally accepts another standard, eg electronics, which frequently uses American standards for logic symbols.

3D techniques, including both wire frame and solid models, can be used for both testing and presentation purposes. 2D will be mainly concerned with producing working drawings for production purposes.

Learners should be familiar with all of the common commands listed and be able to progress to tasks which involve independent or group work. Where facilities permit, some group tasks should be carried out under simulated concurrent engineering conditions; if this is not possible then learners should be introduced to this system by undertaking either an industrial visit or placement, or by using video interactive teaching materials.

Modelling and testing form important parts of this unit and should be used to reinforce the learning required by Level 3 Unit 8: Mathematical techniques and applications for engineers, and Level 3 Unit 9: Scientific principles and applications for engineers.
All learners following this course will need to appreciate how CAD is used extensively in industry and the reasons for this, including the time taken to generate or alter drawings, and the advantages of concurrent working minimising the risks associated with conventional designing on larger scale projects. In addition, they need to be aware of the advantages of CAD in comparison with traditional manual drawing methods in terms of quality, time, accuracy, and storage, transfer of information, applied geometric knowledge, and skill level.

The need for systems maintenance is an integral part of using CAD systems, and learners will realise the implications, both in cost and time, of neglect and consequent loss of efficiency. Learners will need to be proficient in the use of several CAD packages for different purposes, and be capable of carrying out the following actions:

- Absolute, relative and polar co-ordinate entry
- drafting lines and circles
- adding detail by text entry, hatching and dimensioning
- editing, including copying, moving, erasing, scaling, and altering colours and line types.
- The following are some resources that may facilitate or enhance the learning covered in this unit:
- ICT facilities, including computers, printing, plotting devices and the possibility of transferring data to rapid prototyping services
- Software for 2D and 3D drawing and modelling including mechanical, electrical/electronic and hydraulic/pneumatics
- Software which can produce presentation drawings and images
- Websites such as:

| | |
|---|---|
| **CAD/CAM in Schools** | **http://www.cadinschools.org/** |
| Pro/Desktop.net | **http://www.prodesktop.net** |
| CAD Tutor | **http://www.cadtutor.net** |
| Autodesk Inventor 6 & 7 Training | **http://trainingtutorial.com/Inventor_R7_Training.htm** |
| F1 in Schools | **http://www.f1inschools.co.uk** |
| 4x4 in Schools | **http://www.4x4inschools.co.uk** |
| Solid Works | **www.SolidWorks-cpd.co.uk** |

## Opportunities for applied learning

Much of the content of this unit relates to technologies widely used across a range of Engineering sectors. Learners will be able to use knowledge gained from this and other Level 3 units to their advantage when they are working during industrial placements or carrying out engineering activities in their school or college.

Learners who are able to develop this CAD work in depth will produce drawings and models to professional standards. Those who then progress to 3D rapid prototyping will be working close to engineering design practice in this area.

Several national competitions (eg F1 in Schools) encourage learners to use these technologies, and taking part in these high profile activities is a good way for learners to build enthusiasm for engineering. It will enable them to relate their learning to situations where they can apply the useful skills and technologies they have studied to real-life situations.

**What activities might be involved in this unit?**

- Using CAD to produce industrial standard working drawings.
- Producing a 3D CAD model and presentation drawing.
- Recording tests and modifications.
- Evaluating a design solution against its specification.

**Suggested prior learning**

Learners should be proficient in the use of PC-based systems, and have met the requirements for functional mathematics at Level 2. They may have used CAD-CAM systems at Level 2 of The Principal Learning or in KS4 GCSE Design and Technology.

**Personal, Learning and Thinking Skills**

The list below is indicative of the way this unit supports the development of PLTS, as opposed to the achievement of PLTS that are possible through the assessment. The unit supports the development of more PLTS than are covered through the Assessment criteria alone.

Alternative approaches could be selected.

The learner could develop PLTS by:

**Independent enquirers**

- identifying questions to answer and problems to resolve when carrying out design tasks
- planning and carrying out research, appreciating the consequences of decisions made as part of the design process

**Creative thinkers**

- generating ideas and exploring possibilities when designing
- asking questions to extend their thinking
- connecting their own and others' ideas and experiences in inventive ways when formulating designs
- questioning their own and others' ideas when testing
- questioning own and others' assumptions when evaluating proposed solutions
- trying out alternative or new solutions by designing, modelling and testing
- adapting ideas as circumstances change, when designs need to be altered through amendments in technical, economic or environmental constraints

**Reflective learners**

- assessing themselves and others, identifying opportunities and achievements
- setting goals with success criteria for their development and work
- reviewing progress and acting on the outcomes
- inviting feedback and dealing positively with praise and setbacks
- evaluating experiences and learning to inform future progress
- communicating their learning in relevant ways using different techniques to meet the needs of different audiences

**Team workers**

- co-operating with others to work towards common goals
- reaching agreements and managing discussions to achieve results
- taking responsibility and showing confidence in themselves and their contribution
- showing fairness and consideration to others
- providing constructive support and feedback to others

**Self-managers**

- seeking out challenges or new responsibilities
- showing flexibility when priorities change as a result of testing or modelling
- working towards goals, showing initiative, commitment and perseverance
- organising time and resources, and prioritising actions
- anticipating risks
- dealing with competing pressures
- responding positively to change, seeking advice and support when needed

**Effective participators**

- discussing issues of concern and seeking resolution when working in groups
- proposing practical ways forward, breaking these down into manageable steps
- identifying improvements that would benefit others as well as themselves
- trying to influence others, negotiating and balancing diverse views to reach workable solutions.

# Level 3 Unit 3: Selection and application of engineering materials (ENG3U3)

**What is this unit about?**

The purpose of this unit is to develop learners' understanding of the link between the materials used for engineering products and the selection of processes used in their manufacture. Learners will also gain an insight into how modern materials have influenced the design and reliability of products and services, and assisted the quality assurance side of manufacturing.

Through the use of workshop and laboratory tests, learners will apply analytical techniques to evaluate and record data.

This unit, alongside the others within the Level 3 Principal Learning in Engineering, has been designed to allow learners the opportunity to develop a range of Personal, Learning and Thinking Skills (PLTS), and to demonstrate these on more than one occasion. This approach will allow them to build towards a full range of PLTS.

**Learning outcomes:**

The learner will:

1. understand engineering specifications and be able to plan safe investigations and testing operations
2. know how to use tools, equipment, engineering materials and components to conduct testing techniques on a range of materials
3. be able to gather, record and analyse engineering material information.

**Assessment criteria**

**1. Engineering specifications, investigations, and testing operations**

The learner can:

1.1 identify the symbols for elements in the periodic table and outline the reason for their order of ascendancy, explaining how the strength and properties of materials depend on chemical and physical behaviour at an atomic level

1.2 differentiate between the main types of bonding:
   a. primary
   b. secondary

1.3 describe recent advances in materials technology and identify the fields of engineering in which these led to an impact on products and services (CT5)

1.4 produce a test schedule to analyse properties of materials, including Health and Safety considerations e investigate a range of materials and categorise them in relation to their (IE2):
   a. grouping
   b. structure
   c. properties
   d. behaviour
   e. applications.

**2. Use tools, equipment, engineering materials and components to conduct testing techniques on materials**

The learner can:

2.1 classify common materials into their main categories and link structure to their physical and mechanical properties:
   a. metals (crystalline)
   b. polymers (chain molecules)
   c. ceramics (amorphous)
   d. natural

2.2 describe the useful properties and the different forms of supply of engineering materials, and how together they contribute to the selection and design for an engineered product or structural component

2.3 identify key criteria for the selection of materials, and how their properties can be influenced by processing techniques

2.4 discuss how structure influences material properties and the methods and/or techniques used to improve or change them for specific applications:
   a. processing (form of supply)
   b. heat treatment

2.5 summarise some of the more recent developments in materials technology and testing, and provide examples of the application of modern materials in affiliated sectors of engineering.

**3. Gather, record and analyse engineering material information**

The learner can:

3.1 explain material behaviour through practical investigations of laboratory/workshop tests and examples of material failure

3.2 use testing techniques to obtain values for the chemical and physical properties of common engineering materials, and relate them to known quantities (SM3):
   a. workshop-based
   b. laboratory-based

3.3 comply with Health and Safety legislation for testing procedures

3.4 produce records of tests conducted, results, analysis and conclusions.

Where the Assessment criteria show a direct link to an area of the PLTS framework, it is referenced here. Further information on PLTS is available in Section 3.1 of this specification and also within this unit in the section on Personal, Learning and Thinking Skills.

**Guided learning hours**

It is recommended that a minimum of 60 guided learning hours be spent on this unit.

Assessment

This unit is assessed through a centre set and marked assignment. Internal assessments are subject to moderation by City & Guilds.

In Engineering industries, materials are tested for a variety of reasons, including quality assurance procedures which often require samples to be tested. In this assignment, learners will plan and carry out investigations and analyse the results.

The learner will complete an assignment, which will take approximately 10 of the 60 guided learning hours available for this unit. The learner should work under controlled conditions in accordance with the guidance in Section 4.4 of this specification, and evidence should be kept for moderation purposes.

**Evidence requirements**

The learner must produce evidence of achievement of the Assessment criteria. In the assignment, the Learner will produce:

1. schedule of destructive and non-destructive tests to determine physical and mechanical properties of engineering materials
2. records of data evaluation
3. records of personal protective equipment (PPE) and specific safety procedures used in order to carry out the tests
4. records of the investigations and research on engineering materials
5. a review of the tests that could be used or adapted to obtain the key properties of modern or smart materials
6. a summary of how the failure modes, which are determined by material properties, would have been influenced by material treatment or processing.

In order to attain a high mark in this unit, learners must address all of the above. It may, however, be possible to achieve a pass mark without producing every one of the Evidence requirements. A table showing how the assessment criteria topics are weighted is included below, and learners should be shown this in order that they understand how the final mark is determined.

**Assignment structure**

A suggested Assignment structure, which would allow learners to meet the Evidence requirements, may include the following steps.

- Using provided materials and specifications, produce a schedule of destructive and non-destructive tests, which identify the mechanical and physical properties of common engineering materials.
- Record of data evaluation, including any joint discussion that occurred when examining the materials or preparing the schedule of tests that confirm the key properties of specific metallic and non-metallic materials. The use of any additional reference data or information should also be recorded.
- Produce a list of the appropriate PPE required and specific safety procedures that should be followed when preparing for and carrying out tests.
- Carry out a series of tests on a range of engineering materials that include samples from at least three of the following categories:
    - ferrous metal
    - non-ferrous metal
    - thermoplastic
    - polymer natural
    - material ceramic.
- Record test data on each material and explain why the test was appropriate to the specific material and how the structure/bonding influenced its behaviour.
- Explain how material properties and behaviour under test conditions would have been influenced by material treatment or processing.
- Explain how certain tests might have been used or adapted to determine the properties of materials that have been developed more recently.

## Weighting of assessment criteria topics

| Assessment criteria topic | Weighting | Marks |
|---|---|---|
| 1. Engineering specifications, investigations, and testing operations | 25% | 15 |
| 2. Use tools, equipment, engineering materials and components to conduct testing techniques on materials | 60% | 36 |
| 3. Gather, record and analyse engineering material information | 15% | 9 |
| **Total** | 100% | 60 |

## Assessment grid

This statement of performance should be read in association with the Assessment criteria for this unit. Please note that the descriptions in this marking grid relate to the top of each band. Further guidance on using marking grids is available in the Assessment section of this specification.

| Assessment criteria topic | Band 1 | Band 2 | Band 3 |
|---|---|---|---|
| | The learner has: | | |
| 1. Engineering specifications, investigations, and testing operations | **0 – 5 marks**<br><br>Relied predominantly on a single source of information or data to investigate material structures | **6 – 10 marks**<br><br>Collected and used information from a variety of sources and made reference to atomic bonding and the position of some elements in the periodic table | **11 – 15 marks**<br><br>Analysed information and data from a number of sources and described in detail the principles and types of atomic bond; made some reference to polymorphic behaviour of certain elements in the periodic table |
| | Prepared a simple laboratory test schedule for determining the key properties of engineering metallic and non-metallic materials | Produced a detailed and clear test schedule for determining properties of engineering metallic and non-metallic materials; provided additional information on range of values outside the scope of the expected numerical test data | Produced a comprehensive and well- structured test schedule based on informed decisions, which explain the benefits and limitations of destructive and non-destructive testing methods for obtaining data on material behaviour |

| | | | |
|---|---|---|---|
| | Selected a limited range of different materials and distinguished between crystalline and chain molecular structures | Selected a range of materials and described how their different structures and types of bonding are linked to physical and chemical properties | Selected a range of materials and described accurately how the structure and type of bond in each influences its mechanical, electrical and chemical properties; described the improved properties achieved in 'Smart' materials |
| 2. Use tools, equipment, materials and components to conduct testing techniques on materials | **0 – 12 marks**<br>Worked with a limited or reduced range of engineering materials and testing techniques | **13 – 24 marks**<br>Used a range of materials and test equipment to produce suitable results which are within the range recorded in known references for each material | **25 – 36 marks**<br>Used a wide range of materials and testing techniques that highlight key differences between the different categories of materials, with references to structural characteristics |
| | Needed more than one attempt to produce satisfactory test results; the testing of some materials may be incomplete | Completed tests in accordance with the schedule and materials are linked to categories | Completed tests to schedule and recorded all results accurately in the correct format, and accurately linked materials to categories |
| | Given a limited explanation of the test and the usefulness of recorded data and, based on the results, identified an application for which the materials would be suitable | Given an acceptable explanation of tests on different categories of material and the usefulness of recorded data and, based on the results, described an application for which each material would be suitable | Given a detailed explanation of tests on different categories of material and the usefulness of recorded data and, based on the results, fully described an appropriate application for which each material would be suitable |
| | Provided limited information on the forms of supply for the materials under consideration | Made some reference to processability and influence material treatments would have on the results | Given a reasoned explanation on their processability and the type of material treatments that would |

| | | | |
|---|---|---|---|
| | | and provided accurate information on the forms of supply for each material under consideration<br><br>Briefly compared the tests used to those that may be more applicable to recent developments in materials technology | improve their respective properties and how this influenced the forms of supply for each material under consideration<br><br>Compared the types of test used to those that would be more applicable to recent developments in materials technology |
| 3. Gather, record and analyse engineering material information | **0 – 3 marks**<br><br>Gathered and analysed information from a restricted range of reference sources<br><br>Used basic methods and formats for recording results and describing material behaviour<br><br>Made conclusions based on insufficient data or evidence with minimal references to modes of material failure | **4 – 6 marks**<br><br>Gathered and interpreted relevant information from a range of reference sources<br><br>Used appropriate methods and formats for recording results accurately<br><br>Made reasoned judgements on a limited range of data and described common modes of material failure | **7 – 9 marks**<br><br>Gathered, analysed and interpreted complex information from a wide range of sources<br><br>Recorded in detail the testing procedures and test results, using appropriate methods and formats<br><br>Analysed complex information and data, justifying judgements in an engineering context; adequately justified any modifications to the testing procedure and given detailed descriptions of failure modes |

**Guidance for delivery**

This unit is designed to have an integrating effect on content learnt in other units, and it is expected that applied learning gained from other units will be utilised as part of the activities involved in evaluating the properties, applications and failures in modern engineering. It is recommended that this unit precedes Level

3 Unit 5: Maintaining engineering systems and products, and Level 3 Unit 6: Production and manufacturing.

Learners should be able to identify the key criteria for the selection of materials for specific applications,

Which are:

- properties (design constants)
- working environment
- processing ability
- joining ability
- cost.

An in-depth knowledge of materials and their properties needs to include the relationship between chemical and physical behaviour at an atomic level, and the properties of a material, including:

- atomic number
- atomic weight
- shell or sub-shell structure.

Learners should understand the differences between the primary bonding mechanisms: ionic, covalent and metallic.

Learners should research and investigate materials in each category and provide meaningful data from their findings to distinguish between common metals alloys (ferrous and non-ferrous) and polymers (thermoplastic and thermosetting). They should be able to compare them with natural materials and ceramics.

Learners should identify typical behaviour patterns of materials in each category, through their structural differences, and be aware of thermal, mechanical, physical/chemical and structural considerations when examining the following materials:

- Metals – Face centre cubic (FCC), Body centre cubic (BCC)
- Polymers – long regular chains, cross-linked
- Natural – latex, cellulose
- Ceramic – amorphous.

The influence of grain size and type on the mechanical properties of metals, and the influence of type of molecular chain structure on the mechanical properties of polymers, should be investigated in respect of:

- strength
- ductility
- malleability
- elasticity
- Toughness.

Microscopic examination of material structures would be a useful way of comparing material grain structures and linking the findings to basic atomic structures.

Learners need to understand why properties such as conductivity (thermal and electrical), permeability, permittivity, corrosion resistance and memory behaviour are important when selecting materials. Simple experiments that compare electrical and thermal characteristics would be a valuable method for obtaining meaningful data that would help learners to link a material(s) to a specific application(s).

Learners should be encouraged to use established techniques for recording test data and reliable reference sources against which to measure their findings when justifying material selection criteria.

When considering reasons for the selection or application of materials, learners should draw on their knowledge of the following basic material properties and how they are influenced by treatments and manufacturing processes:

- tensile and yield strength
- toughness (impact)
- hardness
- conductivity (thermal and electrical)
- elasticity
- fatigue strength (mean time to failure)
- durability.

They should investigate a simple material failure and determine the contributory factors to its malfunction in a working situation.

Learners should be able to recognise typical engineering applications of smart materials/shape memory alloys, and that they have one or more useful properties that can be altered in a controlled manner by external stimuli. Typical applications include:

- aeronautical
- medical (surgery)
- laboratory testing. External stimuli could be:
- stress
- temperature
- pressure
- humidity
- applied fields (electrical, mechanical).

The following are some resources that may facilitate or enhance the learning covered in this unit:

- ICT facilities to support research and investigations into materials science and technology
- material/physics laboratory
- the Internet
- reference literature and/or sources of professional organisations and material suppliers
- contacts with local companies.

**Opportunities for applied learning**

This unit should be delivered through a combination of taught hours, investigations and practical work, but the learners will also benefit from visits to companies involved in the manufacture of products using a range of different materials. Visits will also allow learners to understand how the selection of a material

For a particular product influences the selection of the process used in its manufacture. Larger companies that manufacture using more than one engineering process with a range of materials will also be able to provide evidence of product development and improvement through materials selection and processing.

Learners will gain an insight into how modern materials have influenced the design and reliability of products and services, and assisted the quality assurance side of manufacturing. When using basic workshop and laboratory tests, learners will need to apply analytical techniques to evaluate and record data using IT-based systems and software and presentation methods that are usually commensurate with this level of investigation.

Learners should be given the opportunity to use a range of different workshop and laboratory tests on different materials in the same group, and to compare the results with values from known reference sources. These activities will provide opportunities for the learner to follow set procedures and use a range of different tools and techniques that will link to the activities required in other activity-based units.

**What activities might be involved in this unit?**

- Exploring a range of engineering materials.
- Carrying out workshop and laboratory investigation.
- Testing techniques and recording results for analysis.

**Personal, Learning and Thinking Skills**

The list below is indicative of the way this unit supports the development of PLTS, as opposed to the achievement of PLTS that are possible through the assessment. The unit supports the development of more PLTS than are covered through the Assessment criteria alone.

Alternative approaches could be selected.

The learner could develop PLTS by:

**Independent enquirers**

- classifying materials through testing methods to confirm technical data drawn from known sources
- providing details of material properties and how they are influenced by processing techniques
- analysing material failure and producing viable reasons for breakdown in structure or resistant
- Properties

**Creative thinkers**

- evaluating the properties of smart materials and considering the scope for new applications
- evaluating the contribution of engineering design and material selection to minimising material failures

**Reflective learners**

- Considering constraints linked to selection of materials and processing techniques
- inviting advice or feedback when assessing the benefits of selecting polymers, ceramics or composite materials in preference to metals for given applications
- considering the environmental implications of depleting the world's raw materials

**Team workers**

- working with others and discussing ideas and providing feedback as necessary

**Self-managers**

- organising time and resources to investigate all categories of material
- organising and preparing tests appropriate to the material properties being investigated

**Effective participators**

- Proposing practical ways of problem-solving and breaking problems down into manageable steps.

# Level 3 Unit 4: Instrumentation and control engineering (ENG3U4)

**What is this unit about?**

The purpose of this unit is to help learners understand the link between specification and design, and the implementation of industrial engineering control systems. Learners will be encouraged to test their knowledge through practical applications. They will design and test a control system, ensuring that they investigate the various components within the control system for suitability to meet the specification.

This unit links to others at Level 3, such as Unit 6: Production and manufacturing, Unit 8: Mathematical techniques and applications for engineers, and Unit 9: Scientific principles and applications for engineers. Opportunities should be sought for learners to apply their learning in this unit to other situations and applications.

This unit, alongside the others within the Level 3 Principal Learning in Engineering, has been designed to allow, learners the opportunity to develop a range of Personal, Learning and Thinking Skills (PLTS), and to demonstrate these on more than one occasion. This approach will allow them to build towards a full range of PLTS.

**Learning outcomes**

The learner will:

1. be able to specify engineering control systems
2. be able to design and implement engineering control systems.

**Assessment criteria**

**1. Specify engineering control systems**

The learner can:

1.1 identify and select types of sensors and transducers that will measure and signal the following (IE1, 2):
   a. pressure
   b. level
   c. temperature
   d. flow
   e. velocity
   f. position
   g. composition

1.2 describe calibration methods; use these methods to calibrate sensors and transducers against reference methods; give a simple statistical analysis of the calibration; and identify modifications required (IE4)

1.3 describe degrees of protection for enclosures, using the Ingress Protection (IP) rating d use and represent the function of signals, wave guides, data communications and multiplexers, including:
   a. actuators and instrumentation displays
   b. AD/DA converters and operational amplifiers.

## 2. Design and implement engineering control systems

The learner can:

2.1 use PID controllers

2.2 use PLCs and program a PLC controller using one of the three common methods

2.3 test programs for modification requirements, and store using a recognised method

2.4 implement open loop, closed loop, feed forward and feedback control theory

2.5 describe the industrial and domestic applications of control engineering

2.6 design and use a simple control system (CT1)

2.7 report on the design of the control system (RL5).

Where the Assessment criteria show a direct link to an area of the PLTS framework, it is referenced here. Further information on PLTS is available in Section 3.1 of this specification and also within this unit in the section on Personal, Learning and Thinking Skills.

### Guided learning hours

It is recommended that a minimum of 60 guided learning hours be spent on this unit.

### Assessment

This unit is assessed through a centre set and marked assignment. Internal assessments are subject to moderation by City & Guilds.

The learner will design a simple engineering control system for an application specified by the centre. Instrumentation and design engineers must be able to devise solutions for a range of situations. These need to be reliable and to be capable of comparison with other methods, eg software versus hardware solutions. Decisions need to be justified and the system tested and calibrated for accuracy. In this assignment learners could be in a position of such an engineer and will need to suggest solutions, test and justify chosen methods to an employer or client.

Industry relies on PLCs to perform many control operations, and the programming of PLCs is undertaken on a daily basis in the manufacturing industry. Learners will need to be able to show that they can carry out these tasks.

The assignment will take approximately 8 of the 60 guided learning hours available for this unit. The learner should work under controlled conditions in accordance with the guidance in Section 4.4 of this specification, and evidence should be kept for moderation purposes.

### Evidence requirements

The learner must produce evidence of achievement of the Assessment criteria. In the assignment, the learner will produce:

1. an engineering control system which demonstrates the ability to select and use sensors, transducers and feedback in the system
2. a report which clearly records any research, analysis and decisions taken by the learner to implement a functioning and calibrated system
3. evidence of the design and demonstration of a PLC based system.

In order to attain a high mark in this unit, learners must address all of the above. It may, however, be possible to achieve a pass mark without producing every one of the Evidence requirements. A table showing how the assessment criteria topics are weighted is included below, and learners should be shown this in order that they understand how the final mark is determined.

To ensure full coverage of the Assessment criteria, two tasks are required to allow the use of PLC controllers and other methods including PID control, outlined in the Assessment criteria. Each requires a short technical report to be prepared which demonstrates the design thinking and implementation of the engineering control system. Evidence should also be included of the practical activities which accompany the writing of the report.

**Assignment structure**

A suggested Assignment structure, which would allow learners to meet the Evidence requirements, may include the following steps.

**Part A: An Engineering Control System based on instrumentation**

- Identify the need for an instrumentation system.
- Design, construct and test a system which requires an output to change dependent on information gained by sensing.
- Produce a report which includes:
    - a specification which justifies the choices made, with an accompanying evaluation which
    - evaluates options
    - systems diagrams which explain how the system is to operate
    - a list of all the components required for the system, including appropriate transducers
    - the planning of a suitable calibration scheme for the chosen transducer
    - use of the calibration results, in an assessment which considers whether the linearity, repeatability and resolution meet the requirements of the control system
    - evidence of the use of simulation or the construction of the system, including tuning the system an evaluation of the following control parameters: rise time, the percentage overshoot and the
    - settling time
    - a compiled table showing the changes in the system control parameters using the tuned system, and any resulting improvements to the control system
    - analysis of these results by comparison with the system's specification.

**Part B: A PLC based Engineering system**

- Explain a use for a PLC controlled system.
- Give an explanation of the function of the system including any inputs and outputs.
- Produce a design for a simple PLC system including reasons for module selection.
- Provide evidence of programming and operating the system using ladder logic or an industrially
- used alternative.
- Record a demonstration of the PLC system operating.

## Weighting of assessment criteria topics

| Assessment criteria topic | Weighting | Marks |
|---|---|---|
| 1. Specify engineering control systems | 50% | 30 |
| 2. Design and implement engineering control systems | 50% | 30 |
| **Total** | 100% | 60 |

## Assessment grid

This statement of performance should be read in association with the assessment criteria for this unit. Please note that the descriptions in this marking grid relate to the top of each band. Further guidance on using marking grids is available in the Assessment section of this specification.

| Assessment criteria topic | Band 1 | Band 2 | Band 3 |
|---|---|---|---|
| | The learner has: | | |
| Specify<br>1. engineering control systems | **0 – 10 marks**<br><br>Conveyed ideas and methods adequately, using a basic range of measurement and modelling methods<br><br>Produced graphs and drawings which convey all essential information<br><br>Tested and calibrated at least one transducer to be able to draw reliable conclusions | **11 – 20 marks**<br><br>Used a wide range of measurement methods and modelling techniques<br><br>Conveyed ideas to a good standard, by means of presentation, graphs, models and tables<br><br>Tested the viability of several methods using virtual testing, with some of the evaluation resulting in subsequent modification(s). | **21 – 30 marks**<br><br>Used a well-organised and accurate approach; worked with a range of technologies including actual and virtual instrumentation systems<br><br>Conveyed data by means of presentation and computer-modelled graphs and charts; produced presentations to a high standard<br><br>Tested the viability of methods through testing, with evaluation resulting in subsequent modification(s); evaluated the system and results obtained for accuracy and validity |

| | | | |
|---|---|---|---|
| 2. Design and implement engineering control systems | **0 – 10 marks** | **11 – 20 marks** | **21 – 30 marks** |
| | Used a computer package to produce a straightforward program | Used most features of the package well to produce accurate control programming | Produced evidence of fluency using a software package for control |
| | Incorporated sub-routines or library items produced by other people | Co-operated with another person on more complex tasks | Worked in conjunction with others, exchanging data |
| | Produced an effective control for a single output without considering storage and modification | Controlled a fairly complex operation using sensing and effective control of outputs, and considered modification | Worked to a high level with several alternative output technologies (eg temperature and speed control), and stored programs for possible modification after proving |
| | Used a limited command set | Considered several alternative methods in detail | Produced control procedures with precision, using a range of techniques |
| | Considered control loop theory | Displayed a good understanding of control theory | Considered the viability of possible options and alternative control systems |
| | Produced a report which provides basic information | Produced a well-documented report | Produced a detailed and well-documented report |

**Guidance for delivery**

It is suggested that the unit should be split into sections, as outlined:

**Section 1:** An introduction to the theory of, and practical experience in, the following:

- transducers and sensors
- actuators and displays
- data and control transmission (4 to 20mA etc)
- PID control with the implications of adding integral and derivative control.

**Section 2:** Practical example of control theory

The learners should form teams of two or three to design a simple control system, with each team looking at a different control measurement type, eg temperature, flow or level.

Learners should be aware of why the choice of hardware was made, how the individual components were integrated into the system, and how the system was tuned for optimum control using an industry standard method of tuning.

**Section 3:** The applications and theory of PLC control, covering the following:

- input/output (I/O)
- power supplies
- programming using ladder logic
- selection of units.

**Section 4:** Practical example of using PLC

Each learner should write a simple ladder logic program using a small number of I/O devices to show a basic understanding of PLC control. The learner should produce a short report.

**Detailed content**

In view of the complex and fast changing nature of this field of engineering, the list below is provided as an indication of the current recommendation. Centres should ensure that learners are familiar with these requirements, or suitable alternatives which enable them to accomplish the same level of achievement, precision and accuracy.

**1b Calibration methods**

Learners will use these methods to calibrate sensors and transducers against reference methods and to give a simple statistical analysis of the calibration. Learners should be able to define the following:

a. accuracy
b. linearity
c. repeatability
d. drift.

**1d Signals, wave guides, data communications and multiplexers**

To include:

- analogue types of signalling (4-20mA, 3-15 p.s.i., 0-10 volts, fibre optics)
- digital signalling (RS232, RS422, RS422)
- industry standard hardware required for signal conditioning and conversion using:
    - Data Acquisition Modules (ADAM)
    - HART communications
    - Fieldbus communications

a. actuators and instrumentation displays:
    - different types of flow control valve
    - valve positioners
    - Man Machine Interface (MMI)
    - Human Machine Interface (HMI)
    - Supervisory Control and Data Acquisition (SCADA)

b. AD/DA converters and operational amplifiers for the following purposes:
    - AD converter – range, resolution, sample and hold, acquisition time and offset errors
    - DA converters – Pulse Width Modulation type, Delta Sigma & Binary Weighted
    - operational amplifier used as inverting, non-inverting or summing amp, integrator, differentiator, comparator or instrument amplifier.

**2a PID controllers**

To include:

a. proportional control – system gain effects, proportional band
b. adding integral control (PI control) – effects on the system
c. integral (reset) time, rise time, derivative time, settling time
d. adding derivative control (PID) – effects on the system
e. step change
f. transfer and transport lag
g. overshoot and the effects of damping
h. Ziegler Nichol PID Tuning and other tuning methods.

**2b PLCs**

The three common methods are:

a. PLC hardware
b. PLC installation considerations
c. PLC programming (Ladder logic, function block diagram, instruction list).

**2c Recognised storage methods**

To include EEPROM and disc storage devices.

### 2d Open loop, closed loops, feed forward and feedback control theory

To include:

a. open loop control and open loop control transfer function
b. closed loop diagram
c. the effect of closing the loop on the system transfer function
d. feed forward block diagram and feed forward transfer function
e. feedback control transfer function
f. offset error
g. damping effects.

### 2e Industrial and domestic applications of control engineering

To include:

a. flow control
b. temperature control – ON/OFF and proportional
c. speed control – rotational and linear
d. position control
e. level control.

The following are some resources that may facilitate or enhance the learning covered in this unit.

### Books

W Bolton – Control Engineering – Pearson Education Ltd – ISBN 058232773-3
Andrew Parr – Industrial Control Handbook – Newnes - ISBN 0 7506 3934 2

### Information from the Internet

Items with suggested reference sites:

| | |
|---|---|
| HART and Fieldbus | • **http://www.romilly.co.uk/** |
| Data acquisition Modules | • **http://www.bb-elec.com/advantech_complete.asp** |
| Man Machine Interface MMI | • **http://www.allenbradley.com** |
| Control system description from Rockwell Automation | • **http://literature.rockwellautomation.com/idc/groups/literature/documents** |
| Wikipedia SCADA | • **http://en.wikipedia.org/wiki/SCADA**<br>• **www.midkentwater.co.uk** |

### Simulation software and hardware

| | |
|---|---|
| PID process control unit | • **http://www.bytronic.net** |
| Process control simulator | • **http://www.bytronic.net/html/pcu.html** |
| Ladder logic | • **http://www.bytronic.net/html/ladsim.html** |
| Electronic systems | • **http://www.ni.com/multisim** |
| Virtual instruments | • **http://www.ni.com/labview** |
| PLC | • **Technology Enhancement Programme** |

## Opportunities for applied learning

The learner will apply their knowledge by working in an industrial context when:

- investigating the various components within a control system for suitability to meet the specification
- designing a control system
- commissioning and tuning a control system
- investigating which I/O components should be used in a PLC system
- programming a PLC.

When designing or operating control systems, learners will apply the knowledge and understanding gained from their study of these areas of engineering, and from any associated mathematical, scientific and electronic units.

## What activities might be involved in this unit?

- Designing and developing a control system
- Reporting on the design and development of a control system
- Selecting the correct transducers and sensor type for the system being designed
- Describing how the transducers are calibrated
- Selecting the correct actuators and instrument displays for the system
- Demonstrating an understanding of the data transmission methods between the sensors, transducers and the controller
- Selecting the correct type of control to give optimum control of the system
- Tuning the system for optimum control using an industry standard method (this can be either simulated or carried out on an actual system)

## Suggested prior learning

Knowledge of electronic and electrical principles, and practical ability in the use of test equipment (multimeters, oscilloscopes, logic probes etc) gained from Level 2 Unit 5: Construct electronic and electrical systems would be useful.

**Personal, Learning and Thinking Skills**

The list below is indicative of the way this unit supports the development of PLTS, as opposed to the achievement of PLTS that are possible through the assessment. The unit supports the development of more PLTS than are covered through the Assessment criteria alone.

Alternative approaches could be selected.

The learner could develop PLTS by:

**Independent enquirers**

- independently deciding which components will be used in the design of the control system
- independently choosing the calibration method used on the sensor and transducers

**Creative thinkers**

- using their imagination when designing their control system
- using their imagination when programming the PLC

**Reflective learners**

- communicating what they have learned in their design report

**Team workers**

- working with others in the design and tuning of a control system

**Self-managers**

- organising time and resources in creating their control system design to ensure that deadlines and specifications are met

**Effective participators**

- proposing practical ways of design and tuning of a control system, breaking problems down into manageable steps.

# Level 3 Unit 5: Maintaining engineering systems and products (ENG3U5)

**What is this unit about?**

The purpose of this unit is to familiarise learners with planning and producing maintenance schedules and reports, and with carrying out essential maintenance work relating to general engineering systems and products.

Learners' maintenance schedules should contain key elements of maintenance operations and should incorporate risk assessments in order to minimise risks to people, plant, products and services; agreed timescales to ensure cost effectiveness and to avoid production loss; data analysis and technical information; and the relevant use of ICT to produce the schedules.

Learners will be encouraged to carry out maintenance procedures by using diagnostic procedures in order to identify problems and remove or replace worn or damaged components. These tasks could include the adjustment of clearances, gaps, levels, belts, pulleys, chains and bearings, and involve the use of fabrication and welding techniques.

This unit, alongside the others within the Level 3 Principal Learning in Engineering, has been designed to allow learners the opportunity to develop a range of Personal, Learning and Thinking Skills (PLTS), and to demonstrate these on more than one occasion. This approach will allow them to build towards a full range of PLTS.

**Learning outcomes**

The learner will:

1. be able to manage and organise maintenance operations for engineering systems and products
2. know how to conduct maintenance procedures for engineering systems and products.

**Assessment criteria**

**1. Manage and organise maintenance operations for engineering systems and products**

The learner can:

1.1 describe the legal requirements for Health and Safety in the workplace as stipulated by current legislation
1.2 explain how to plan risk assessments to maintain Health and Safety in the workplace
1.3 explain how to work to agreed timescales and keep others informed of progress
1.4 describe sources of statistical and technical information used to plan maintenance activities
1.5 explain the relationship between maintenance times, cost and profits
1.6 explain the impact poor maintenance has on profitability and the environment
1.7 explain the use of lean (just-in-time) maintenance methods
1.8 explain the importance of documenting maintenance operations (RL3)
1.9 plan risk assessments to minimise risks to (SM3):
    a. people
    b. plant
    c. products
    d. services
1.10 plan maintenance activities and effective strategies to reduce downtime and the impact on profitability (SM4)
1.11 source and analyse technical information and data to support all maintenance activities.

**2. Conduct maintenance procedures for engineering systems and products**

The learner can:

2.1 select and correctly use tools, equipment and materials for carrying out an engineering maintenance activity
2.2 use personal protective equipment (PPE) when carrying out maintenance operations
2.3 report problems and/or issues to the relevant person(s) promptly
2.4 remove and replace components to manufacturers' specifications
2.5 use correct diagnostic procedures
2.6 use correct investigative procedures for causes of failure (IE1, 2)
2.7 conduct maintenance operations using aural, visual and functional methods.

Where the Assessment criteria show a direct link to an area of the PLTS framework, it is referenced here. Further information on PLTS is available in Section 3.1 of this specification and also within this unit in the section on Personal, Learning and Thinking Skills.

**Guided learning hours**

It is recommended that a minimum of 30 guided learning hours be spent on this unit.

**Assessment**

This unit is assessed through a centre set and marked assignment. Internal assessments are subject to moderation by City & Guilds.

The learner will complete an assignment which will involve the production of a detailed written report to include charts, graphs, statistical data and risk assessments. The report should show:

- research
- planning
- resources and costings
- analysis
- evaluation.

The assignment can be based on any suitable maintenance activity including those outlined in the delivery guidance. To obtain accurate data, learners should carry out sample practical maintenance tasks. It is important that the assignment be as realistic as possible, and should conform closely with industrial practice.

The assignment will take approximately 10 of the 30 guided learning hours available for this unit. The learner should work under controlled conditions in accordance with the guidance in Section 4.4 of this specification, and evidence should be kept for moderation purposes. The centre must ensure that any evidence submitted for assignment is the learner's unaided work (this should be supported by a witness statement).

**Evidence requirements**

The learner must produce evidence of achievement of the Assessment criteria. In the assignment, the

learner will produce:

1. a written report including charts, graphs, statistical data and risk assessments
2. evidence of carrying out maintenance procedures.
3. In order to attain a high mark in this unit, learners must address all of the above. It may, however, be possible to achieve a pass mark without producing every one of the Evidence requirements. A table showing how the assessment criteria topics are weighted is included below, and learners should be shown this in order that they understand how the final mark is determined.

**Assignment structure**

A suggested Assignment structure, which would allow learners to meet the Evidence requirements, and produce the report, may include the following:

- maintenance intervals and scheduling, enabling the user to quickly identify equipment and
- operations required
- service operations, providing sufficient information to allow planning of operator time, equipment to be used and parts requirements
- contingency planning for breakdown and failure, including the cost of duplication of plant for standby, replace or hire considerations; operating priorities; and the allocation of resources to essential functions
- a policy of replacement and/or repair recommendations supported by analysis of statistical data and cost consideration
- evidence of carrying out sample maintenance operations which are related to the assignment; these should be used as a basis for identifying resource requirements and informing planning.

**Example scenario**

A company specialising in medium- and long-haul freight transport requires a new maintenance schedule. The fleet comprises a mixture of wagons and tractor units from various manufacturers. Length in service varies between three months and ten years.

- Produce a report which schedules:
- maintenance intervals
- service operations
- breakdown and failure contingency planning
- replacement recommendations.

**Weighting of assessment criteria topics**

| Assessment criteria topic | Weighting | Marks |
|---|---|---|
| 1. Manage and organise maintenance operations for engineering systems and products | 65% | 39 |
| 2. Conduct maintenance procedures for engineering systems and products | 35% | 21 |
| **Total** | 100% | 60 |

**Assessment grid**

This statement of performance should be read in association with the Assessment criteria for this unit. Please note that the descriptions in this marking grid relate to the top of each band. Further guidance on using marking grids is available in the Assessment section of this specification.

| Assessment criteria topic | Band 1 | Band 2 | Band 3 |
|---|---|---|---|
| | The learner has: | | |
| 1. Manage and organise maintenance operations for engineering systems and products | **0 – 13 marks**<br>Briefly described the importance of Health and Safety policies; briefly explained and included risk assessments in planning | **14 – 26 marks**<br>Clearly described the importance of Health and Safety policies; explained and produced risk assessments to ensure Health and Safety in the workplace | **27 – 39 marks**<br>Produced and evaluated risk assessments and any associated policies with the corresponding legal requirements for Health and Safety in the workplace |
| | Recorded any maintenance operations carried out | Accurately recorded all maintenance operations carried out; used statistical data to explain component failure | Accurately recorded maintenance operations so that statistical data and maintenance history can be used to track and predict component failure |
| | Briefly described a maintenance schedule which includes planned shutdowns | Shown a good understanding of the need to have maintenance schedules which include planned shutdown | Analysed the effectiveness of planned maintenance and shutdown operations; explained how lean maintenance methods can be used as part of a programme to balance cost, time and profits |

| | | | |
|---|---|---|---|
| | Sourced and used technical information | Sourced and used sources of technical information and data appropriately | Sourced and used sources of technical information and data which support the planning of maintenance operations; analysed technical information and statistical data when planning |
| 2. Conduct maintenance procedures for engineering systems and products | **0 – 7 marks**<br>Carried out some simple fault-finding | **8 – 14 marks**<br>Identified faults using investigative procedures including diagnostics | **15 – 21 marks**<br>Carried out investigations using a variety of methods, including specific diagnostics; identified faults and suggested possible rectification procedures to meet manufacturers' standards |
| | Attempted to use manufacturers' specifications and sources of technical information | Used manufacturers' specifications; used available sources for identifying and interpreting the correct technical information to use for a task | Used manufacturers' specifications to assure quality when removing or replacing components; used and interpreted sources of technical information as needed and when planning operations |
| | Carried out routine procedures safely | Carried out procedures safely, reporting any problem or issue promptly | Worked safely and reported problems or unexpected issues promptly and to the appropriate person |
| | Worked safely with a range of tools and equipment, using PPE as required | Selected and worked safely with tools, equipment and materials; routinely used and checked PPE when working on maintenance operations | Justified any decisions made regarding tools, equipment or materials used; worked safely both personally and with others, ensuring that PPE and the working environment were monitored at all times |

**Guidance for delivery**

Learners should be able to plan and produce maintenance schedules and reports which include:

- risk assessments (based on commercially available information)
- strict timescales with references to loss of production and cost effectiveness
- data analysis and technical information to include graphs and charts
- probability (likelihood of normal wear and tear and breakages)
- the use of ICT.

Production loss figures should attempt to replicate the situation in an actual engineering operation, while data analysis should provide ample opportunities for ICT work to be undertaken in a meaningful way which mirrors commercial practice. The use of statistics will allow learners to integrate some mathematics whilst providing a useful insight into how it is utilised on a daily basis.

Examples of suitable scenarios could include the following:

- transport logistics - maintenance of vehicles
- a manufacturing company - a maintenance shutdown
- a college engineering workshop - summer break maintenance schedule
- rail network - routine maintenance and overhaul
- airlines and/or aircraft - fit-for-flight maintenance.

**Service and maintenance components and procedures**

Although the examples cited below are mechanical, other sectors would be equally valid and electronic or electronic systems or components would fulfil the same functions.

Examples of components could include: belts, pulleys, gears, bearings, rollers, motors, chains or similar engineering products and services.

Examples of procedures could include:

- the adjustment of clearances, gaps, levels, belts, pulleys, chains and bearings
- fabrication and welding procedures
- removal and replacement operations
- diagnostic and analytical procedures.

The following are some resources that may facilitate or enhance the learning covered in this unit:

- a range of reading material to include Managing Maintenance Planning and Scheduling by Brown, M V, published by Audel (2004)
- Websites such as:

| | |
|---|---|
| Maintenance World | • **www.maintenanceworld.com** |
| SMGlobal | • **www.smglobal.com/fastmaint/preventive-maintenance-training.html** |
| IDCON,INC | • **www.idcon.com/maintenance-books.html** |

**Opportunities for applied learning**

There is ample opportunity within the maintenance areas of various Engineering sectors for learners to gain experience of maintenance activities. Maintenance can be carried out alongside production, or in a dedicated environment such as automotive servicing, electronic repair or computer repair.

Additionally, learners may work on group projects which require setting and adjusting operations to be carried out, such as a go-kart challenge, robotic competitions or mileage marathons.

In these and many other situations, learners will be able to apply the knowledge and understanding of the content of this unit to workplace situations. At this level it is anticipated that learners will take responsibility for supervising or organising the work of others.

**What activities might be involved in this unit?**

- Producing a written report based on a case study.
- Carrying out maintenance operations.
- Supervising maintenance operations.

**Personal, Learning and Thinking Skills**

The list below is indicative of the way this unit supports the development of PLTS, as opposed to the achievement of PLTS that are possible through the assessment. The unit supports the development of more PLTS than are covered through the Assessment criteria alone.

Alternative approaches could be selected.

The learner could develop PLTS by:

**Independent enquirers**

- exploring ways of maintaining machines and equipment
- planning and organising relevant maintenance procedures
- independently researching methods of diagnostic and repair and/or replacement procedures

**Creative thinkers**

- trying out cost-effective, efficient and eco-friendly methods of maintenance
- planning lean (just-in-time) maintenance methods

**Reflective learners**

- evaluating maintenance procedures for reliability and efficiency
- reviewing progress of maintenance procedures and action plan findings

**Team workers**

- communicating within a team to maintain machines and equipment
- providing constructive support and feedback to others

**Self-managers**

- organising time and resources to work within timescales that meet the needs of others

**Effective participators**

- proposing practical ways of problem-solving using analytical data and diagnostic techniques.

# Level 3 Unit 6: Production and manufacturing (ENG3U6)

**What is this unit about?**

The purpose of this unit is to provide learners with the opportunity to learn about the types and methods of production and manufacturing processes and systems, including the operation of computerised systems within engineering.

Learners will apply their understanding of manufacturing and production systems and develop a production plan, taking into consideration all the influencing factors, including implications of quality control and quality assurance.

This unit links to Level 3 Unit 2: Applications of Computer Aided Designing, and Level 3 Unit 4: Instrumentation and control engineering.

This unit, alongside the others within the Level 3 Principal Learning in Engineering, has been designed to allow learners the opportunity to develop a range of Personal, Learning and Thinking Skills (PLTS), and to demonstrate these on more than one occasion. This approach will allow them to build towards a full range of PLTS.

**Learning outcomes**

The learner will:

1. know the types, uses and importance of engineering manufacturing systems
2. understand quality control and quality assurance within the Engineering sector
3. know about and be able to carry out engineering production planning.

**Assessment criteria**

**1. Engineering manufacturing systems**

The learner can:

1.1 describe and analyse different types of manufacturing processes and applications including suitability for:
   a. one-off production
   b. mass production
   c. batch production
   d. continuous production

1.2 explain the importance and operation of computerised manufacturing systems such as:
   a. Computer Aided Engineering (CAE)
   b. Computer Aided Manufacturing (CAM)
   c. Computer numerical control (CNC)

1.3 describe and compare production systems used in Engineering industries including:
   a. lean manufacturing, continuous process improvement and waste reduction
   b. flexible manufacturing and automation
   c. just in time (JIT) and Kanban
   d. assembly systems and techniques.

**2. Quality control and quality assurance within the engineering sector**

The learner can:

2.1 critically analyse the factors influencing production systems, such as (IE4):
   a. quality control
   b. quality assurance

2.2 describe quality control and quality assurance requirements in manufacturing and production, such as:
   a. applying Six Sigma methodology
   b. process improvement
   c. applying basic statistical control

2.3 demonstrate analytical and problem-solving skills by using statistical methods as part of ensuring quality of manufacture (EP3).

## 3. Engineering production planning

The learner can:

3.1 explain production requirements, planning and scheduling, including:

a. costing:
- fixed
- variable

b. production control:
- Gantt charts
- inspection
- quality control

3.2 carry out the development of a production plan for a complex manufacturing operation (SM3)

3.3 carry out project planning and scheduling for a complex manufacturing operation (SM4).

Where the Assessment criteria show a direct link to an area of the PLTS framework, it is referenced here. Further information on PLTS is available in Section 3.1 of this specification and also within this unit in the section on Personal, Learning and Thinking Skills.

### Guided learning hours

It is recommended that a minimum of 60 guided learning hours be spent on this unit.

### Assessment

This unit is assessed through a centre set and marked assignment. Internal assessments are subject to moderation by City & Guilds.

The learner will complete an assignment based on the production of a complex product or component. This task will allow the learner to develop a production plan and carry out project planning and scheduling.

The assignment will take approximately 10 of the 60 guided learning hours available for this unit. The learner should work under controlled conditions in accordance with the guidance in Section 4.4 of this specification, and evidence should be kept for moderation purposes.

### Evidence requirements

The learner must produce evidence of achievement of the Assessment criteria. In the assignment, the

learner will produce:

1. a production plan which includes scheduling, quality control and quality assurance
2. a description of engineering manufacturing processes and systems, and any significant changes or innovations proposed.

In order to attain a high mark in this unit, learners must address all of the above. It may, however, be possible to achieve a pass mark without producing every one of the Evidence requirements. A table showing how the assessment criteria topics are weighted is included below, and learners should be shown this in order that they understand how the final mark is determined.

**Assignment structure**

A suggested Assignment structure, which would allow learners to meet the Evidence requirements, may include the following steps:

- Using appropriate resources, produce a production plan for a complex product or component, ensuring that there is a clear indication of time needed and how the production would be scheduled.
- Clearly indicate the scale of production.
- Include quality control and quality assurance requirements.
- Provide a description which includes an analysis of different types of manufacturing processes and how they could be used in the production of the product or component.
- Provide an explanation of the importance and operation of computerised manufacturing systems and how such a system could be used for all or part of the production of the product or component.

Suitable tasks should be devised to meet the differing learning styles of individuals.

**Example assignment**

Consider a complex product or component that has been developed commercially or in a school or college workshop.

- Select a suitable product.
- Use appropriate case study material and other suitable resources to develop a detailed production plan for the product.
- State the scale of production and how this affects the development of a production plan.
- Carry out project planning and scheduling by investigating and analysing the different types of manufacturing processes, including computerised manufacturing systems, which could be used to manufacture the product.
- Describe and compare these production systems, and critically analyse the factors influencing the selection and development of such production systems. Explain any difficulties that might be encountered in setting up or maintaining production, and what measures could be taken to overcome these problems.
- Give reasons for any suggestions made such as comparative cost, speed or reliability. If completely new methods or materials are suggested, justify these and explain any advantage.
- Include the quality control and quality assurance requirements which would ensure the product met its specification.

**Weighting of assessment criteria topics**

| Assessment criteria topic | Weighting | Marks |
|---|---|---|
| 1. Engineering manufacturing systems | 35% | 21 |
| 2. Quality control and quality assurance within the engineering sector | 25% | 15 |
| 3. Engineering production planning | 40% | 24 |
| **Total** | 100% | 60 |

**Assessment grid**

This statement of performance should be read in association with the Assessment criteria for this unit. Please note that the descriptions in this marking grid relate to the top of each band. Further guidance on using marking grids is available in the Assessment section of this specification.

| **Assessment criteria topic** | **Band 1** | **Band 2** | **Band 3** |
|---|---|---|---|
| | The learner has: | | |
| 1. Engineering manufacturing systems | **0 – 7 marks**<br><br>Gathered, recorded and analysed information about manufacturing systems from a limited range of sources | **8 – 14 marks**<br><br>Gathered, recorded and analysed information from a wide range of sources; described and analysed different types of manufacturing systems | **15 – 21 marks**<br><br>Gathered, analysed and evaluated relevant information about different manufacturing systems and recorded well-reasoned judgements about their effectiveness in a variety of complex engineering contexts |
| | Briefly described the suitability of the product for manufacture by different types of processes or applications | Assessed the suitability of the product for various types of processes or applications | Analysed the comparative merits of differing types of processes or applications for producing the product |
| | Described the operation of CAD or CAM as part of a manufacturing system | Explained how CAD or CAM could be used in forming part of the manufacturing system | Fully explained the part CAD or CAM plays in an integrated manufacturing system |
| | Explained in general terms how CAE operates | Explained how CAE could integrate various aspects of manufacturing systems and what benefits might result | Clearly explained how CAE would operate, in reducing time taken for operations and increasing flexibility. Shown in detail the contribution CAD and CAM would make |
| | Described the characteristics of different engineering production systems | Described the effectiveness of different engineering production systems | Evaluated and assessed the merits of a variety of engineering production systems |

| | | | |
|---|---|---|---|
| 2. Quality control and quality assurance within the engineering sector | **0 – 5 marks**<br>Produced a summary list of quality control points | **6 – 10 marks**<br>Produced a detailed and accurate list of quality control points | **11 – 15 marks**<br>Produced a detailed quality control programme and specified any associated parameters related to accuracy and precision |
| | Shown an understanding of quality assurance in context | Clearly documented a quality assurance procedure for the product's production; demonstrated how quality assurance procedures will be applied | Assessed all relevant quality assurance issues and produced a detailed quality assurance procedure which should prove effective |
| | Applied simple statistical methods | Used statistical and analytical methods | Evaluated using statistical and analytical methods |
| 3. Engineering production planning | **0 – 8 marks**<br>Produced a production plan for a simple product or, alternatively, produced a production plan for a complex product which contains omissions | **9 – 16 marks**<br>Produced an adequate production plan for a moderately complex product | **17 – 24 marks**<br>Produced an effective and detailed production plan for a complex product |
| | Included some aspects of production and supply scheduling | Included most aspects of production and supply scheduling | Scheduled production and supply requirements effectively, using accurate data gained from research |
| | Produced costings and schedules which are based on the obvious aspects of manufacturing the product | Produced costings and schedules which reflected the significant parts of the manufacturing process | Produced detailed and accurate costings and schedules for most aspects of the production process |
| | Adequately researched some production requirements | Analysed most production requirements to ensure efficient manufacturing | Analysed production requirements to optimise manufacturing capacity |

**Guidance for delivery**

This unit will provide learners with the opportunity to learn about production and manufacturing processes and systems. Learners should be encouraged to put the theory into practice by producing a complex item and applying production processes and methods of statistical control. It may therefore be possible to integrate the teaching of this unit with other Level 3 units, such as Unit 2: Applications of Computer Aided Designing, and Unit 4: Instrumentation and control engineering.

Large-scale engineering manufacturers such as Toyota, Ford, JCB, BAE Systems and Rolls Royce implement production and manufacturing systems, and may be located regionally. Smaller local engineering concerns will also provide a wealth of relevant information for learners engaged in work experience. These small and medium enterprises (SMEs) can be approached through organisations such as the British Engineering Manufacturers' Association.

Learners should develop an understanding of the strategies used in commercial operations to maximise efficiency and maintain quality standards. This means examining both 'push' and 'pull' methods of production management.

Learners should be aware of techniques such as:

- lead time analysis
- workplace organisation
- forecasting and stock level control
- quality monitoring
- using statistical tools, spreadsheets, process deviations and production tolerances.

This unit will familiarise learners with the concepts of innovation within engineering manufacturing themes. These concepts, as well as production techniques and the importance of quality assurance on the manufacturing process, will need to be applied.

The following are some resources that may facilitate or enhance the learning covered in this unit:

- National Academy of Engineering — **www.nae.edu/nae/naehome.nsf**
- Wikipedia: Manufacturing — **http://en.wikipedia.org/wiki/Manufacturing#Manufacturing_systems**

**Opportunities for applied learning**

Opportunities for applied learning will largely be through project work, often linked to other Level 3 units from the Principal Learning or process/manufacturing units at Level 3 taken as a part of additional learning. Investigation of particular topics and the opportunity to visit engineering businesses and science parks would also be beneficial. Use should also be made of guest speakers and examples of good practice to illustrate real world applications of manufacturing and production. In collaboration with other units, learners should develop a production plan for the manufacture of a complex product or component.

Learners may be encouraged to work in teams dealing with scheduling, quality issues forecasting or product improvement.

**What activities might be involved in this unit?**

- Producing production plans.
- Using CAM techniques.
- Applying statistical methods to quality processes.
- Producing components using industrial technologies.

**Personal, Learning and Thinking Skills**

The list below is indicative of the way this unit supports the development of PLTS, as opposed to the achievement of PLTS that are possible through the assessment. The unit supports the development of more PLTS than are covered through the Assessment criteria alone.

Alternative approaches could be selected.

The learner could develop PLTS by:

**Independent enquirers**

- analysing and evaluating the information obtained for a manufacturing process
- judging the relevance and value of the information obtained through analysis

**Creative thinkers**

- asking questions to further develop ideas
- considering alternative methods of production

**Reflective learners**

- setting goals on the achievement of the tasks required to carry out the research on manufacturing and production processes
- inviting feedback and reviewing progress on the research
- communicating their learning to meet target audience requirements

**Team workers**

- providing constructive support and feedback to others by offering hints and advice that improve production

**Self-managers**

- working towards goals and organising time and resources to meet effective production targets

**Effective participators**

- identifying improvements that would benefit others as well as themselves.

# Level 3 Unit 7: Innovative design and enterprise (ENG3U7)

**What is this unit about?**

The purpose of this unit is to provide learners with an understanding of the role of innovation in engineering design. Learners should be encouraged to study examples of good practice through the use of case studies or by working in conjunction with engineering companies in order to develop an awareness of technical and commercial constraints.

The process of idea to product goes through many stages, and learners should be able to use analytical skills when considering innovation and new technologies in order to assess their potential. As part of this process, learners should recognise that a number of people make contributions to the successful marketing of a product. How these people contribute, and the synergy that accompanies the process, is realised by first-hand experience, and learners should be encouraged to participate in group work in order to develop ideas and products, find solutions to engineering problems, and market the end results. It is also important that they appreciate the need for protecting new ideas and designs. They should be able to describe the methods of protecting intellectual property rights including copyright legislation.

Throughout this unit, there is a requirement to consider the environmental and social impact of engineering and the sustainability of resources used, in order to mirror the Engineering sector. These considerations should be taken into account throughout the design stages. Learners should look at key issues such as assessing energy requirements, energy use and pollution; analysing the visual appearance of the product taking into account material selection and its disposal and the possible impact on peoples' lives.

Learners must both review their own work and get feedback from others. They should use the review and the feedback to improve their work.

This unit, alongside the others within the Level 3 Principal Learning in Engineering, has been designed to allow learners the opportunity to develop a range of Personal, Learning and Thinking Skills (PLTS), and to demonstrate these on more than one occasion. This approach will allow them to build towards a full range of PLTS.

**Learning outcomes**

The learner will:

1. be able to analyse engineering innovation and new technologies
2. understand engineering opportunities, commercial issues, and how to protect new ideas
3. be able to develop engineering ideas, demonstrating design skills whilst recognising constraints
4. know how to evaluate environmental issues in relation to engineering designs.

**Assessment criteria**

**1. Engineering innovation and new technologies**

The learner can:

1.1 describe and analyse innovative engineering designs and new technologies, such as:
   a. computer and communications system design ii medical applications
   b. space research
   c. the advantages of nanotechnology and the benefits of fabricating devices with atomic or molecular precision

1.2 study and analyse the work of successful engineering entrepreneurs:
   a. justifying profiting from ideas
   b. assessing market competition
   c. evaluating innovations and inventions

1.3 apply analytical thinking and use data to aid decision-making (IE1-5).

**2. Engineering opportunities and the protection of ideas**

The learner can:

2.1 analyse the commercial issues of developing, marketing and selling a new product or idea, explaining the importance of the many aspects of designing and bringing a product to market, by:
   a. relating market research to the development of products
   b. assessing research and development and how it relates to:
   - design principles
   - design problems
   - concept

   c. explain the process of product development such as:
   - the use of expert systems
   - the appraisal of manufacturing constraints

   d. describing organisational behaviours, eg:
   - relating the effect of synergy
   - analysing the impact of outsourcing expertise
   - using technology brokers
   - analysing reliability and product failure
   - describing commercial considerations

2.2 describe the methods of protecting intellectual property rights

2.3 identify opportunities for technological or commercial advantage (CT1)

2.4 appreciate the need for protecting ideas and copyright legislation.

### 3. Developing engineering ideas and design

The learner can:

3.1 recognise and compare design constraints, for example:
   a. economic
   b. technical
   c. manufacturing

3.2 assess the need and effect of leadership

3.3 design for the environment:
   a. creating eco-friendly design (CT1)
   b. assessing energy requirements
   c. evaluating possible impact on peoples' lives (IE4)
   d. analysing visual appearance

3.4 demonstrate and record design thinking and problem-solving undertaken.

### 4. Environmental issues relating to engineering design

The learner can:

4.1 consider the environmental and social impact of engineering and sustainability of resources used, taking the following into consideration:
   a. energy use and pollution
   b. material selection and disposal
   c. impact on social behaviour

4.2 Evaluate environmental factors of design decisions (EP1, 4).

Where the Assessment criteria show a direct link to an area of the PLTS framework, it is referenced here. Further information on PLTS is available in Section 3.1 of this specification and also within this unit in the section on Personal, Learning and Thinking Skills.

### Guided learning hours

It is recommended that a minimum of 60 guided learning hours be spent on this unit.

### Assessment

This unit is assessed through a centre set and marked assignment. Internal assessments are subject to moderation by City & Guilds.

The learner will complete an assignment which evaluates an engineering innovation. The innovation can be proposed or take the form of a detailed evaluation of an existing innovation.

The assignment will take approximately 12 of the 60 guided learning hours available for this unit. The learner should work under controlled conditions in accordance with the guidance in Section 4.4 of this specification. The exception is the collection of research material which may be undertaken outside of the controlled conditions, but all sources must be acknowledged by the learner. Copies of the assignment set and the learner's evidence of its completion should be kept for moderation purposes.

The project titles offered should be capable of interpretation in numerous ways in order to give learners maximum choice of subject and approach.

**Evidence requirements**

The learner must produce evidence of achievement of the Assessment criteria. In the assignment, the learner will produce:

1. an evaluative report of the innovative design or new technology selected, to include:
    a. research findings
    b. analysis of the selected innovation
    c. commercial issues of development, marketing and selling
    d. investigation of viability
    e. design considerations
    f. environmental and social issues.

In order to attain a high mark in this unit, learners must address all of the above. It may, however, be possible to achieve a pass mark without producing every one of the Evidence requirements. A table showing how the assessment criteria topics are weighted is included below, and learners should be shown this in order that they understand how the final mark is determined.

**Assignment structure**

A suggested Assignment structure, which would allow learners to meet the Evidence requirements, may include the following steps:

- Select one area from a provided list of innovative designs or new technologies.
- Analyse what potential there is for this new design or technology.
- Research whether there are existing applications.
- Research the work of successful engineering entrepreneurs.
- Assess the commercial issues and viability.
- Suggest how a product using this technology or design could be marketed.
- Explain any associated social or environmental issues, positive or otherwise.

**Weighting of assessment criteria topics**

| Assessment criteria topic | Weighting | Marks |
|---|---|---|
| 2. Engineering innovation and new technologies | 25% | 15 |
| 3. Engineering opportunities and the protection of ideas | 25% | 15 |
| 4. Developing engineering ideas and design | 25% | 15 |
| 5. Environmental issues relating to engineering design | 25% | 15 |
| **Total** | 100% | 60 |

**Assessment grid**

This statement of performance should be read in association with the Assessment criteria for this unit. Please note that the descriptions in this marking grid relate to the top of each band. Further guidance on using marking grids is available in the Assessment section of this specification.

| **Assessment criteria topic** | **Band 1** | **Band 2** | **Band 3** |
|---|---|---|---|
| | The learner has: | | |
| 1. Engineering innovation and new technologies | **0 – 5 marks**<br><br>Relied predominantly on a single source of information to produce the report | **6 – 10 marks**<br><br>Collected and used information from a variety of sources when compiling the report | **11 – 15 marks**<br><br>Produced a report which conveys detailed information, drawn from accurate analysis and used data drawn from a wide variety of sources |
| | Described the contribution of an entrepreneur, or evaluated an innovation, in simple terms | Described the process of bringing an idea to market with some detail, using an existing product or entrepreneur as an example | Evaluated the contribution that a successful entrepreneur or product has made, including generating profit from ideas and the effect of market competition |
| | Produced a description which contains a limited examination of the emerging technology or design | Produced an account which includes most of the essential information about emerging technology or design | Produced a well-documented and easy to follow account which provides a detailed account of the emerging technology or design |
| | Provided limited evidence of analysis and data use | Undertaken adequate analysis and data use to justify decisions or suggestions | Included in-depth analysis and significant data use; offered substantiated conclusions that are drawn from accurate analysis |

| | | | |
|---|---|---|---|
| 2. Engineering opportunities and the protection of ideas | **0 – 5 marks** | **6 – 10 marks** | **11 – 15 marks** |
| | Produced a few suggestions which have limited potential and which need more development to be considered useful | Identified a clear opportunity and suggested a plan of development | Looked at several possibilities, compared or combined technologies to provide the basis of a potential commercial development |
| | Described how information obtained from limited sources could be used | Suggested methods of researching to meet the level of technical or commercial demand | Related market research to possible demand |
| | Discussed possible causes of failure | Evaluated the potential level of reliability and possible causes of failure | Explained how the competing factors of concept, manufacturing constraints, reliability and cost can be accomplished |
| | Included references to methods of ideas protection | Made explicit references to how protection methods would apply | Identified those aspects which would need protection, and identified methods of adequately protecting ideas |
| | Suggested a commercial application in the proposal | Shown a clear understanding of the important commercial considerations, including organisational behaviour | Produced a realistic proposal, and considered strategies which would add viability to the project |

| | | | |
|---|---|---|---|
| 3. Developing engineering ideas and design | **0 – 5 marks** | **6 – 10 marks** | **11 – 15 marks** |
| | Considered some constraints related to developing an idea or technology | Considered a range of issues and proposals related to the commercial development of an idea or technology | Considered several options with sufficient depth to justify any decisions or recommendations made in relation to the commercial development of an idea or technology |
| | Explained the role of leadership in design development | Used examples to illustrate how leadership has affected the design development process | Actively taken a leadership role when developing design ideas and fully explained the role of leadership |
| | Shown restricted evidence of design thinking | Used research and objective reasoning as a basis for decisions reached and presented in a range of designs; assessed energy requirements | Related market research to possible demand; clearly considered manufacturing and cost constraints and presented in a good range of designs; assessed any impact on people's lives, including visual appearance |
| | Produced limited recording or evidence of problem- solving | Recorded and problem-solved as an integral part of the process | Recorded thoroughly and used a range of problem-solving techniques to provide well-communicated possible solutions |

| | | | |
|---|---|---|---|
| 4. Environmental issues relating to engineering design | **0 – 5 marks** | **6 – 10 marks** | **11 – 15 marks** |
| | Considered a number of environmental design issues at a simplistic level | Considered most environmental factors both when designing and when assessing any longer term impact | Considered a wide range of environmental factors; included an analysis of impact and disposal, and any impact on social behaviour or the environment |
| | Discussed the use of energy and materials | Shown a good awareness of energy issues and materials | Produced a thorough and detailed analysis of energy and material requirements and costs |
| | Described problems of disposal | Considered aspects such as changes in social behaviour or material use or disposal | Described in detail the life-cycle of the product or system |

**Guidance for delivery**

This unit provides opportunities for a wide range of topics to be investigated by the learners and for them to generate ideas. Importantly, learners must look at the commercial aspects of designing and innovation and the essential requirement to protect ideas. As learners progress from ideas to marketable products, the development of evaluative techniques will form a major part of the approach which should be adopted.

Learners will need access to a range of case study materials. Case studies based on recent developments will also demonstrate the need for sufficient protection to be provided for designs. Clearly there will be issues of commercial sensitivity when dealing with local or national engineering companies.

Case studies should be selected to reflect the interests of the learner as part of matching to their individual learning style. However all case studies should take into consideration commercial considerations to ensure success, including:

- competitive advantage
- supply and demand
- sales and pricing strategies
- funding sources
- advertising
- business plans
- franchising

The case studies should also examine the need for protecting intellectual property rights by using patents, registered designs, copyright and trade marks.

## Opportunities for applied learning

This unit is intended to enable learners to understand the role of innovation in engineering design. Both successful and unsuccessful engineering innovations should be considered. They should show an awareness of both technical and commercial constraints.

Working in conjunction with local engineering companies, centres should facilitate the study of examples of good practice. This could be supported by using exemplar case studies of existing products, companies or individual entrepreneurs.

The process of idea to product goes through many stages, and learners need to be aware that numerous people normally make a contribution to the successful marketing of a product. How these people contribute, and the synergy that accompanies this process, is probably best realised by first-hand experience, so group work exercises to suggest solutions should be organised to allow learners' participation.

All the stages of the commercial design process need to be considered, from determining if there is a need in the market through to research and development, which can spawn new ideas without there being an existing market. Learners need to be aware of the effect known as 'Marketplace Pull versus Technology Push', where companies can be over-reliant on market research and not have new products available when the market changes.

The importance of protecting ideas in the form of both product designs and intellectual property such as software is an important part of the innovation process, and learners must understand the need for patents and copyright protection.

New and emerging technologies will have an important part to play in engineering design in the future, and although some technologies are not easily accessible, useful information is available via the Internet and DVD sources.

## Suggested prior learning

Level 2 design-based units or equivalent GCSE, eg Design and Technology, would be useful before commencing this unit.

## Personal, Learning and Thinking Skills

The list below is indicative of the way this unit supports the development of PLTS, as opposed to the achievement of PLTS that are possible through the assessment. The unit supports the development of more PLTS than are covered through the Assessment criteria alone.

Alternative approaches could be selected.

The learner could develop PLTS by:

### Independent enquirers

- identifying questions to answer and problems to resolve when carrying out design tasks
- planning and carrying out research, appreciating the consequences of decisions made as part of the
- design process

**Creative thinkers**

- generating ideas and exploring possibilities when designing
- asking questions to extend their thinking
- connecting their own and others' ideas and experiences in inventive ways when formulating designs
- questioning their own and others' ideas
- questioning own and others' assumptions when evaluating proposed solutions
- trying out alternatives or new solutions
- adapting ideas as circumstances change, when designs need to be altered through amendments in technical, economic or environmental constraints

**Reflective learners**

- assessing themselves and others, identifying opportunities and achievements
- setting goals with success criteria for their development and work
- reviewing progress and acting on the outcomes
- inviting feedback and dealing positively with praise, setbacks and work
- evaluating experiences and learning to inform future progress
- communicating their learning in relevant ways for different audiences

**Team workers**

- co-operating with others to work towards common goals
- reaching agreements and managing discussions to achieve results
- taking responsibility, showing confidence in themselves and their contribution
- showing fairness and consideration to others
- providing constructive support and feedback to others

**Self-managers**

- seeking out challenges or new responsibilities and showing flexibility when priorities change
- working towards goals, showing initiative, commitment and perseverance
- organising time and resources, prioritising actions
- anticipating, taking and managing risks
- dealing with competing pressures, including personal and work related demands
- responding positively to change, seeking advice and support when needed

**Effective participators**

- discussing issues of concern, seeking resolution where needed
- proposing practical ways forward, breaking these down into manageable steps
- identifying improvements that would benefit others as well as themselves
- trying to influence others, negotiating and balancing diverse views to reach workable solutions.

# Level 3 Unit 8: Mathematical techniques and applications for engineers (ENG3U8)

**What is this unit about?**

The purpose of this unit is for learners to use mathematics to model engineering problems and to understand how mathematics is an essential tool in engineering.

The unit encourages learners to work with standard mathematical techniques, resources, data, tables and graphs that engineers use in their designs and solutions to engineering problems. Learners will acquire skills that are essential for work in the engineering field.

This unit, alongside the others within the Level 3 Principal Learning in Engineering, has been designed to allow learners the opportunity to develop a range of Personal, Learning and Thinking Skills (PLTS), and to demonstrate these on more than one occasion. This approach will allow them to build towards a full range of PLTS.

**Learning outcomes**

The learner will:

1. be able to apply mathematics and mathematical modelling to solve engineering problems
2. know how to use trigonometry and co-ordinate geometry to solve engineering problems
3. know how to use algebra to solve engineering problems
4. know how to use statistics to solve engineering problems
5. know how to use calculus to solve engineering problems.

**Assessment criteria**

**1. Apply mathematics and mathematical modelling to solve engineering problems**

The learner can:

1.1 devise mathematical models and apply mathematics in an engineering context

1.2 apply mathematical skills to resolve engineering problems:

a. correctly determining solutions to engineering problems
b. using standard mathematical symbols, layouts and annotation
c. selecting appropriate information from resources (such as data tables and formulae) in order
d. to evaluate engineering solutions

1.3 use mathematical modelling and mathematical techniques:

a. using standard mathematical techniques to solve engineering problems
b. understanding and manipulating the equations that are used by engineers
c. using graphs to represent variables in engineering systems

1.4 identify mathematical solutions to real world problems such as:

a. electricity and electronics
b. structures
c. energy (CT5)
d. moving objects and machines
e. process control and quality.

**2. Use trigonometry and co-ordinate geometry to solve engineering problems**

The learner can:

2.1 use trigonometry and co-ordinate geometry to solve engineering problems by:

a. understanding common methods of finding the position of objects and determining how they move in relation to each other
b. expressing these changes mathematically and graphically.

**3. Use algebra to solve engineering problems**

The learner can:

3.1 use algebra to solve engineering problems by:

a. using equations to solve engineering problems
b. expressing equations graphically to show changes in engineering systems.

**4. Use statistics to solve engineering problems**

The learner can:

4.1 appreciate how statistics are used to improve engineering designs by:

a. using statistics to inform and control systems
b. understanding how statistics are an essential part of quality systems (IE4) (CT2).

**5. Use calculus to solve engineering problems**

The learner can:

5.1 use calculus to solve engineering problems by:

a. determining the rate of change of engineering systems
b. understanding how the gradient and area under graphs helps find the solution to
c. engineering problems
d. using common calculus techniques to solve engineering problems (IE1).

Where the Assessment criteria show a direct link to an area of the PLTS framework, it is referenced here. Further information on PLTS is available in Section 3.1 of this specification and also within this unit in the section on Personal, Learning and Thinking Skills.

**Guided learning hours**

It is recommended that a minimum of 60 guided learning hours be spent on this unit.

**Assessment**

This unit is assessed through an external examination set and marked by City & Guilds.

This assessment method has been selected for this unit because it offers an economical and valid means of measuring learners' mathematical ability. However, it is expected that the learning included in this unit will have wide application in other units and offer opportunities for learners to contextualise their learning and to develop their knowledge through experiences of using techniques and comparing results with their peers for real world engineering situations.

Examinations will be available twice a year and the dates will be published at the start of each academic year. The examination will take place under controlled examination conditions. Learners will be allowed to use a non-programmable scientific calculator in the examination. The examination will consist of a written paper that consists of Sections A and B.

**Section A** will consist of relatively short questions based on the whole of the mathematical specification. Here learners will be required to answer all the questions.

**Section B** will include a set of more demanding, longer questions, which focus on the engineering application of mathematics. Here the learner may choose to answer any three from five questions, thus enabling them to demonstrate their particular skills, knowledge and enthusiasms. The questions in Section B will not necessarily cover the whole of the specification at each assessment.

**Examination specification**

Duration: 2½ hours

Assessment type: Written test

Number of marks: 60

| Assessment criteria topic | Subtopic | Qs x Marks Section A | No of Marks Section A | Qs x Marks Section B | No of Marks Section B | Total mark | % |
|---|---|---|---|---|---|---|---|
| 1. Apply mathematics and mathematical modelling to solve engineering problems | Use mathematics from any of the Assessment criteria to solve engineering problems. | N/A | N/A | Any 3 from 5 x 8 | 24 | 24 | 40 |
| 2. Use trigonometry and co-ordinate geometry to solve engineering problems | Use the sine and/or cosine rule. | 1 x 2 | 3 | N/A | N/A | 7 | 11.7 |
| | Use and convert angles in both degrees and radians. | 1 x 2 | 2 | | | | |
| | Vectors, addition and subtraction. | 1 x 2 | 2 | | | | |
| 3. Use algebra to solve engineering problems | Change the subject and manipulate equations. | 1 x 2 | 2 | N/A | N/A | 14 | 23.3 |
| | Understand and use graphs to express common equations, such as equations of a straight line, conic sections, trigonometrical and exponential functions. | 1 x 3 | 3 | | | | |
| | Cartesian (x,y) and polar (r,θ) co-ordinates and graphs, including conversion. | 1 x 2 | 2 | | | | |
| | Find solutions to quadratic equations. | 1 x 4 | 4 | | | | |
| | Use rules of indices, laws of logarithms, including changing the base, and/or understand and use exponentials and logarithms (ex, 1nx,10 x and log x). | 1 x 3 | 3 | | | | |
| 4. Use statistics to solve engineering problems | Use statistical techniques, such as mean, median and mode, cumulative frequency, variance and standard deviation. | 1 x 4 | 4 | N/A | N/A | 4 | 6.7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5. Use calculus to solve engineering problems | Use basic calculus techniques such as differentiation of a product and/ or a quotient, and/or by substitution and/or the use of second derivatives. | 1 x 4 | 4 | | | | |
| | Identify turning points, maximum, minimum and optimum values. | 1 x 3 | 3 | N/A | N/A | 11 | 18.3 |
| | Use integration – indefinite and definite integrals and/or integration by substitution. | 1 x 4 | 4 | | | | |
| | Totals | 12 | 36 | 3 | 24 | 60 | 100 |

**Guidance for delivery**

To ensure that this unit is relevant to engineering applications, it is best planned in the context of the other learning activities and themes within the Level 3 Principal Learning programme. The learning activities in this unit should be co-taught with other units.

Every opportunity should be taken to root the mathematics in an engineering context. The unit is closely related to the scientific principles that underpin engineering. It would be advantageous if taught in conjunction with Level 3 Unit 9: Scientific principles and applications for engineers.

Where learners look at engineering systems and processes in other units, the opportunity should be taken to extract the mathematical aspects from these units. For example, if a visit is planned to look at engineering processing, materials and properties, the learner should also consider the mathematics that underpin the observed applications. By using these examples, the teacher and the learner can relate mathematics to real engineering.

**Using computers**

The learner should not be expected to undertake repetitive tasks unnecessarily. For example, whilst producing graphs helps the learner understand the interaction of engineering variables, it can be laborious.

Handling large quantities of statistical data can often be time consuming; the use of a common spread sheet program overcomes the tedium for the learner, yet ensures they understand the processes. Similarly teachers can generate lots of data with known characteristics by using common spread sheet programs. By using computer programs, labour is reduced, the results of changing variables quickly demonstrated and concepts more easily understood. The use of programmable and graphical calculators is encouraged.

**Developing mathematical skill**

There is a need for practice to hone any skill. The learner should use a variety of contexts to refine skills, and practice a particular mathematical technique. Learners will need regular opportunities to test their mathematical skills, knowledge and understanding. This will provide them with specific feedback and encouragement whilst identifying areas of success and any areas for further development. These opportunities might consist, for example, of formal and informal testing, private study, and group work outside a formal teaching context.

**Detailed content**

Devising mathematical models and applying mathematics in an engineering context could include:

- moments applied to leavers and beams. Centroids of area to find areas and volumes of engineering components. Equations of motion applied to, for example, cars and motorcycles. Sinusoidal waves applied to electricity – r.m.s. values - signals, phasors. Equations that model energy, heat transfer, and friction. Properties of materials such as stress strain and elastic modulus.
- Using trigonometry and co-ordinate geometry to solve engineering problems could involve the following:
- Using the sine and cosine rules to determine heights of building, angles in engineering structures, and position of engineering machines.
- Understanding trigonometrical waveforms and phase angles, and how these are applied to a.c. electricity. Measuring and converting angles in both degrees and radians, and understanding why it
- is advantageous to the engineer to measure angles in radians. Vectors, their addition and subtraction applied to resolving engineering forces and electrical problems.
- Using algebra to solve engineering problems could involve the following:
- Using and manipulating equations to solve engineering problems in areas such as:

Power – P = VI cos ø

Angle – θ = $\boldsymbol{Wit} + {}^{\mathbf{1}}/_{\mathbf{2}}$ at²

Resonant frequency $f = \frac{1}{2\pi\sqrt{LC}}$

Periodic time – T=$2\pi\sqrt{\frac{a^2+\mathrm{kG}^2}{ag}}$

- Understanding how graphs can express the behaviour variables of equations commonly found in engineering, such as equations of a straight line, the distance between two points and conic sections. Cartesian (x, y) and polar (r, θ) co-ordinates and graphs, including conversion, and where they are used by engineers.
- Solution to quadratic equations by factorisation, formula, completing the square and graphically. How quadratics are used to solve engineering problems such as volumes and areas and where parabolas naturally occur eg suspension bridges, satellite dishes.
- Rules of indices, laws of logarithms, including changing the base. Understanding and using exponentials and logarithms ( ex,1nx,10x and log x ), to solve engineering problems, such as growth and decay in areas like electricity and electronics, radiation etc.
- Understanding how statistics are used to improve engineering designs could involve using statistical techniques, mean, median and mode, cumulative frequency, variance and standard deviation to show how the engineer is able to predict the outcome of engineering systems and the quality of the processes used.

Using calculus to solve engineering problems could involve the following:

- Using basic calculus techniques such as differentiation of a product and a quotient. Using first And second derivatives to solve engineering problems such as position, velocity, and acceleration. Identifying turning points. Maximum, minimum and optimum values to engineering problems such as volumes, velocities and heights of projectiles.
- Understanding how the area under a graph can be used to solve engineering problems. Integration – indefinite and definite integrals and areas under curves. Differentiation and Integration by substitution.

The following differential coefficients and integrals could be used at this level:

| $y$ | $\frac{\mathrm{d}y}{\mathrm{d}x}$ |
|---|---|
| $ax^n$ | $anx^{n-1}$ |
| $\sin ax$ | $a \cos ax$ |
| $\cos ax$ | $-a \sin ax$ |
| $\log x$ | $\frac{1}{x}$ |
| $\mathrm{e}^{ax}$ | $a\,\mathrm{e}^{ax}$ |

| $y$ | $\int y \,\mathrm{d}x$ |
|---|---|
| $ax^n$ | $\frac{a}{n+1} x^{n+1}$ |
| $\sin ax$ | $-\frac{1}{x} \cos ax$ |
| $\cos ax$ | $\frac{1}{a} \sin ax$ |
| $\sec^2 x$ | $\tan x$ |
| $\frac{1}{x}$ | $\log_e x$ |
| $\mathrm{e}^{ax}$ | $\frac{1}{a} \mathrm{e}^{ax}$ |

In terms of resources that may facilitate or enhance the learning covered in this unit, learners would greatly benefit from the use of a standard Level 3 Engineering mathematics text book. Learners should also have access to a library of more advanced reference books that might include:

- Mathematics for Scientific and Technical Students by Davies & Hicks. Published by Longman (1998)
- Introduction to Engineering Mathematics by Croft, Davison & Hargreaves. Published by Prentice Hall (1995)
- Tables, Data and Formulae for Engineers and Mathematicians by Greer & Hancox. Published by Nelson Thornes Ltd (1998)
- Engineering mathematics by Stroud & Booth. Published by Palgrave Macmillan (2007).

Learners may gain an understanding of the interaction of variables more quickly by using a computer to draw graphs. There is a variety of software that can be used; however learners working alone at home can achieve quite good results by using standard software such as MS Excel. A good reference for this is A Guide to Microsoft Excel for Scientists and Engineers by Liengme. Pub. Butterworth Heinemann.

**Opportunities for applied learning**

Learners should be given every opportunity to see how mathematics is used in engineering systems. Work in many Level 3 units will be dependent on learners' understanding of the mathematical concepts contained in this unit. Design- and instrumentation-based projects will rely on learners applying mathematical modelling. The need to analyse statistical data for production and maintenance purposes will provide further opportunities for the integration of mathematical methods into engineering processes.

While visits to industry will be advantageous, it should also be possible to use mathematics in engineering situations in the learner's immediate environment, for example:

- energy efficiency in their home
- energy use in their school or college
- electrical, heating and lighting systems in their school or college
- Quality systems, monitoring and analysis in their school or college.

**Suggested prior learning**

In order to be well prepared for this unit, the learner would benefit from having achieved a good grade in a Level 2 mathematics qualification, such as grade C or above in GCSE Mathematics.

**Personal, Learning and Thinking Skills**

The list below is indicative of the way this unit supports the development of PLTS, as opposed to the achievement of PLTS that are possible through the assessment. The unit supports the development of more PLTS than are covered through the Assessment criteria alone.

Alternative approaches could be selected.

The learner could develop PLTS by:

**Independent enquirers**

- identifying engineering mathematical problems to resolve
- planning their work so that they are able to complete solutions in the time required
- evaluating their solutions to engineering mathematical problems and judging that answers are sensible solutions

**Creative thinking**

- exploring possible solutions to engineering mathematical problems
- asking questions to extend their mathematical thinking
- trying alternatives to find correct mathematical solutions

**Reflective learners**

- setting goals in mathematics
- reviewing progress with mathematics and taking action
- asking for feedback about their engineering mathematics and dealing with success and difficulties

**Team workers**

- co-operating with others when asked to work on mathematics in a group
- showing fairness and consideration to others when working together
- taking responsibility within a group for a fair proportion of the work

**Self-managers**

- showing commitment and perseverance when seeking solutions to engineering mathematical problems
- organising and prioritising time to ensure that the required mathematics can be accomplished
- seeking help and support when needed

**Effective participators**

- discussing issues and concerns about their work with others when needed
- Making practical suggestions for managing difficulties with their work.

# Level 3 Unit 9: Scientific principles and applications for engineers (ENG3U9)

**What is this unit about?**

The purpose of this unit is to develop learners' understanding of the fundamental scientific principles that engineers use in order to carry out investigations into engineering problems. Learners will be able to apply these principles in order to select the most appropriate scientific data and make judgements about the best engineering designs and solutions to solve engineering problems. These skills are particularly important as learners will develop the ability to apply scientific principles to applications of science in systems within their immediate environment such as transport, electrical and electronic devices, buildings and bridges, alternative energy resources, and materials in the home.

Learners will also be encouraged to use the correct signs, symbols and scientific notation when presenting a persuasive case of their ideas and judgments about the application of scientific principles in order to ensure that others are able to follow their design solutions.

This unit, alongside the others within the Level 3 Principal Learning in Engineering, has been designed to allow learners the opportunity to develop a range of Personal, Learning and Thinking Skills (PLTS), and to demonstrate these on more than one occasion. This approach will allow them to build towards a full range of PLTS.

**Learning outcomes**

The learner will:

1. be able to apply scientific knowledge to real engineering systems
2. be able to demonstrate analytical and problem-solving skills in engineering
3. know how to use mathematical methods to solve engineering problems
4. know how to use IT to solve engineering science problems
5. be able to construct engineering science experiments and record data.

**Assessment criteria**

1. **Applying knowledge to real engineering systems**

The learner can:

1.1 apply the scientific principles of electricity and electronics in engineering by considering and analysing the behaviour of common components in AC and DC circuits such as:
   a. solenoids
   b. motors
   c. transformers
   d. semiconductors

1.2 apply the principles of statics and dynamics in engineering systems by considering how moving and stationary forces are applied in engineering, using examples such as:
   a. beams
   b. bridges
   c. engineering materials
   d. cars
   e. motorcycles

1.3 apply the principles of energy and heat to the solution of engineering problems:
   a. analysing how energy is quantified, stored and transferred in simple machines
   b. describing and analysing the effects of heat on engineering materials and gases, such as conduction and expansion

1.4 apply basic chemistry in engineering by:
   a. describing how the properties of engineering materials are affected by chemical processing and applying this to how the engineer uses chemistry to change properties
   b. understanding that corrosion is a chemical process and how to minimise the effects of corrosion

1.5 apply fluid flow to the solution of engineering problems by:
   a. explaining how fluids are used in machines, and fluid flow and pressure are measured
   b. describing the effects of aerodynamics on the design of engineering structures such as bridges

1.6 appreciate how waves occur in light, sound and other aspects of engineering by:
   a. describing the characteristics of wave patterns and their particular characteristics when they
   b. occur in engineering
   c. explaining the characteristics and application of light in engineering, such as optical fibre computer cables.

**2. Analytical and problem-solving skills in engineering**

The learner can:

2.1 demonstrate their analysis and problem-solving skills by:
   a. suggesting a variety of possible solutions to an engineering problem
   b. devising the criteria by which to evaluate an engineering solution
   c. judging, using defined criteria, which of many possible solutions is likely to offer the best solution to an engineering problem
   d. testing an engineering solution using defined criteria
   e. evaluating test results of engineering solutions/systems.

### 3. Using mathematical methods to solve engineering problems

The learner can:

3.1 determine solutions to engineering problems
   a. use standard mathematical techniques to solve engineering problems
   b. understand and manipulate formulae used by engineers
   c. use graphs to represent variables in engineering systems
   d. use standard scientific and mathematical symbols, layouts and annotation
   e. select appropriate information from resources (such as data tables and formulae) in order to evaluate engineering solutions (RL5).

### 4. Using IT to solve engineering science problems

The learner can:

4.1 demonstrate skills in using IT:
   a. as an engineering research tool
   b. to gather and analyse data from experiments and engineering systems (IE1)
   c. to present scientific and engineering information for dissemination.

### 5. Constructing engineering science experiments and recording data

The learner can:

5.1 safely carry out experiments that underpin the scientific principles of engineering

5.2 devise a small number of experiments that will help solve engineering problems (SM1-3)

5.3 accurately record the results from scientific experiments

5.4 present the results from scientific experiments appropriately, taking account of the context of the

5.5 presentation and the audience

5.6 make sound analytical judgements based on the result of scientific experiments and knowledge

5.7 make recommendations based on the outcome of scientific experiments, the solution criteria and the context of engineering problems (CT1).

Where the Assessment criteria show a direct link to an area of the PLTS framework, it is referenced here. Further information on PLTS is available in Section 3.1 of this specification and also within this unit in the section on Personal, Learning and Thinking Skills.

### Guided learning hours

It is recommended that a minimum of 90 guided learning hours be spent on this unit.

### Assessment

The assessment method for this unit will be a combination of an external assessment (Assessment A) and an internal assessment (Assessment B). Both assessments A and B are marked separately and contribute to the overall unit and therefore Principal Learning grade.

It is expected that the content covered in this unit will have applications in other units. Learners will have the opportunity to contextualise their learning and to develop their knowledge through experiences of using techniques and comparing results with their peers for real world engineering situations. To bring together this practical activity, the internal assessment is required for this unit.

The assessments are not dependent on each other and the learner can enter for them at different times, including resits.

## Weighting of assessment

Each assessment contributes to the overall unit grade according to its weighting in the unit:

| Assessment type | Weighting for overall unit | Assessment criteria topic |
|---|---|---|
| A – External | 67% | 1 & 3 |
| B – Internal | 33% | 2, 4 & 5 |
| **Total** | 100% | |

### Assessment A

External assessment consists of a written examination. The written examination will consist of Sections A and B.

1. **Section A** will consist of relatively short questions based on Assessment criteria topic 1. In this section, learners will be required to answer all the questions.
2. **Section B** will include a set of more demanding, longer questions, which focus on the use of mathematical principles in engineering science. Here the student may choose to answer any three from five questions, thus enabling them to demonstrate their particular skills, knowledge and enthusiasms. The questions in Section B will not necessarily cover the whole of the specification at each assessment.

Students will be allowed to use a non-programmable scientific calculator in the examination. They will also receive a data and formulae sheet which can be used during the examination.

Examinations will be available twice a year and the dates will be published at the start of each academic year. The examination will take place under controlled examination conditions.

### Examination specification for External Assessment A

Duration: 2 hours

Assessment type: Written test

Number of marks: 60

| Assessment criteria topic reference | Subtopic | Qs x Marks Section A | No of Marks Section A | Qs x Marks Section B | No of Marks Section B | % |
|---|---|---|---|---|---|---|
| 1a Electricity and electronics | Solve problems involving DC circuits. Resistors in series and parallel. Circuit measurement and analysis. Resistivity.<br>Solve problems of capacitance and the effects of capacitors in circuits. Dielectric strength.<br>Identify the (junction) characteristics of semiconductors devices such as diodes and transistors.<br>Solve problems involving common electrical laws, eg Ohms law, Kirchoff's Law, Lenz's Law, Lorentz force.<br>Identify the characteristics and applications of magnetic fields and electromagnetic induction.<br>Solve problems involving forces in current carrying coils such as | 2x4 | 8 | | | 13.3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | generators, transformers, magnetic circuits, magnetic flux. Identify the characteristics of magnetisation curves and hysteresis loops for magnetic materials. | | | | | |
| 1b Statics and dynamics | Solve problems involving systems of coplanar forces. Determine resultants and equilibrants using vectors or mathematical methods.<br>Solve problems involving moments and forces on simply supported loaded beams.<br>Solve problems involving the properties of materials, stress, strain, elastic modulus and Poisson's ratio. Identify appropriate materials based on these properties.<br>Solve problems involving Newton's laws of motion. Linear and angular motion, velocity and acceleration, linear momentum, centripetal force.<br>Solve problems involving simple machines and power transmission – gear trains belt drives, torque, friction, and efficiency of transmission systems. | 3 x 3 | 9 | | | 15 |
| 1c Heat and energy | Solve problems involving work energy, power and the principle of conservation of energy. These may be linked to friction and the efficiency of simple engineering machines, such as ramps, screw jacks and hoists.<br>Solve problems of kinetic, potential energy, and gravitational force. These may be set in a context of falling objects and head of fluids.<br>Solve problems involving thermal capacity, specific heat capacity, coefficient of linear expansion, and thermal conductivity. By considering these as properties of materials, state how this affects their use.<br>Solve problems involving latent heat of fusion and vaporisation and explain how these characteristics are used to transfer energy in heat pumps.<br>Solve problems involving gas laws and explain how these are applied in engineering.<br>Solve problems involving heat flow across material boundaries, conduction, convection and radiation, and explain the application of these in engineering. | 2 x 3 | 6 | | | 10 |
| 1d Engineering chemistry | State how changes of state and phase changes shown in equilibrium diagrams can account for the | 1 x 2 | 5 | | | 8.3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | change in properties of alloys, such as carbon - iron and tin - lead.<br>State how heat treatment is used to change properties of metals such as carbon steels and precipitation hardening of aluminium alloy.<br>State how cold working, crystallisation and dislocations affect the properties of metals.<br>Explain the electrochemical series, corrosion and how differing metals are used to reduce corrosion.<br>Apply basic chemistry to polymer materials. Monomers and polymerisation, alkane structures, eg methane – pentane, and how these relate to common polymers including polythene, polypropylene, PTFE.<br>Recognise cross linking of polymers and how these affect their properties, manufacture and application. Explain the structure of rubber and vulcanisation. | 1 x 3 | | | | |
| 1e Fluids | Solve problems involving the basic principles of hydraulics and pneumatics, pressure in fluids including head of fluids, application of Bernoulli's equation, and fluid flow through orifices.<br>Identify fluid flow measuring devices and their application in engineering.<br>State the characteristics of aerodynamic 2D fluid flow over common objects, stagnation points, separation regions, turbulence and vortices. | 1 x 2<br>1 x 3 | 5 | | | 8.3 |
| 1f Waves, sound and light | Solve problems and explain the characteristics of sinusoidal wave including frequency, amplitude and periodic time. This may be related to sound waves, the measurement of sound and noise, and waves in the context of AC electrical signals.<br>Identify light reflection, refraction, and engineering applications. | 1 x 3 | 3 | | | 5 |
| 3 Using mathematical methods to solve engineering problems | Use integration – indefinite and definite integrals and/or integration by substitution. | | | Any 3 from 5 x 8 | 24 | 40 |
| | Totals | 36 | | 24 | | 100 |
| | | | 60 Marks | | | |

**Assessment B**

For the internal assessment, learners will complete a centre set and marked assignment. Internal assessments are subject to moderation by City & Guilds.

Learners will be required to research and review scientific principles in an engineering context, complete a scientific experiment and produce a short, focused piece of work that reflects their findings. Learners will be required to submit their synopsis as a presentation, such as a poster (at least A2) or report that delineates the scientific principles in their chosen engineering system.

The findings may be focused on any engineering science topic of their choice; this includes the scientific principles employed in the learner's main engineering project. The learner should be urged to choose a topic that enables them to demonstrate their scientific skills, knowledge and understanding at this level. Learners must be monitored and guided to ensure that any experiments are carried out safely.

The assignment will take approximately 15 of the 90 guided learning hours available for this unit. The learner should work under controlled conditions in accordance with the guidance in Section 4.4 of this specification, and evidence should be kept for moderation purposes.

**Evidence requirements**

The learner must produce evidence of achievement of the Assessment criteria. In the assignment, the learner will produce a piece of work in an appropriate presentation format that contains:

1. a description of the scientific principles within their chosen engineering system
2. a prediction and/or description of the effectiveness of the chosen engineering system
3. a description of an engineering experiment(s) or monitoring process for the chosen engineering system
4. a collection of data (results) using IT where appropriate, from the chosen engineering system and/or experiment(s)
5. an evaluation or judgements about the effectiveness of the engineering system in the light of the research and monitoring and/or experiment(s).

In order to attain a high mark in this unit, learners must address all of the above. It may, however, be possible to achieve a pass mark without producing every one of the Evidence requirements. A table showing how the assessment criteria topics are weighted is included below, and learners should be shown this in order that they understand how the final mark is determined.

**Assignment structure**

A suggested Assignment structure, which would allow learners to meet the Evidence requirements, may include the following steps:

- Use scientific principles to predict the behaviour of an engineering system.
- Use scientific principles to evaluate the behaviour of an engineering system.
- Use IT as a research and presentation tool.
- Use IT to gather and/or analyse scientific data.
- Safely construct engineering science experiments to test ideas.
- Present the results of scientific experiments.
- Evaluate the results of scientific experiments

Each element is likely to appear as an explanatory paragraph together with diagrams where appropriate. The learner should take care to ensure that their work is properly referenced to its source, including the detailed work of their own experiments. A photograph of the learner's experiments may also be included.

**Example assignment**

An example of a topic might be solar energy in the home.

The piece of work (eg poster) would contain the following elements:

- a brief description of the variety of current solar systems
- the application of scientific principles to predict and evaluate the behaviour of a solar system, eg heat transfer, use of solar charts, thermal gradients, efficiency of galvanic cells, power output in differing conditions, energy storage devices, cost effectiveness, and pay to back periods
- IT used to research the topic, and gather performance data from experiments; IT may also be used to present the poster
- a description of experimental set up to test the performance of a solar system; results of experiments displayed in the form of graphs
- judgements based on the results of experiments and recommendations about how the systems could be improved and/or used more effectively.

**Weighting of Assessment criteria topics for Internal Assessment B**

| Assessment criteria topic | Weighting | Marks |
|---|---|---|
| 2. Analytical and problem-solving skills in engineering | 30% | 18 |
| 4. Using IT to solve engineering science problems | 30% | 18 |
| 5. Developing engineering ideas and design | 40% | 24 |
| **Total** | 100% | 60 |

**Assessment grid**

This statement of performance should be read in association with the Assessment criteria for this unit. Please note that the descriptions in this marking grid relate to the top of each band. Further guidance on using marking grids is available in the Assessment section of this specification.

| **Assessment criteria topic** | **Band 1** | **Band 2** | **Band 3** |
|---|---|---|---|
| | The learner has: | | |
| 1. Analytical and problem-solving skills in engineering | **0 – 6 marks**<br>Demonstrated basic knowledge of the scientific principles used | **7 – 12 marks**<br>Applied scientific principles to the solution of an engineering problem | **13 – 18 marks**<br>Analysed an engineering problem accurately and effectively; used and accurately applied scientific principles to the solution of the problem |
| | Suggested a few basic solutions to an engineering problem | Suggested solutions to an engineering problem based on scientific principles | Suggested realistic and workable solutions to an engineering problem based on scientific principles |
| | Briefly evaluated the solutions to an engineering problem | Evaluated the solutions to an engineering problem using appropriate scientific principles | Accurately evaluated the solutions to an engineering problem using appropriate scientific principles, criteria and analytical methods |
| 2. Using IT to solve engineering science problems | **0 – 6 marks**<br>Used IT in a limited capacity to research scientific information | **7 – 12 marks**<br>Used IT to research scientific information | **13 – 18 marks**<br>Used IT appropriately and effectively to research scientific information |
| | Shown limited use of IT to gather and analyse data | Used IT to gather and analyse data | Used IT appropriately and effectively to gather and analyse data |
| | Shown limited presentation of results using IT | Presented results using IT | Used IT effectively and correctly to present results |

| | | | |
|---|---|---|---|
| 3. Constructing engineering science experiments and recording data | **0 – 8 marks**<br><br>Devised and completed basic scientific experiments safely | **9 – 16 marks**<br><br>Devised scientific experiments to resolve an engineering problem; completed scientific experiments based on proposal safely | **17 – 24 marks**<br><br>Devised experiments safely, based on sound scientific principles that enable analysis of an engineering problem; completed scientific experiments based on proposal accurately and safely |
| | Kept a basic record of the experiment and listed results | Accurately recorded and presented the experiments, results and related data | Accurately and appropriately recorded the experiments and results and manipulated data to produce calculated results |
| | Drawn basic conclusions from the results and attempted to make a recommendation | Drawn conclusions from the results in the context of the original engineering problem identified and made recommendations | Analysed and accurately presented the results of scientific experiments taking account of context and audience; made valid judgements and recommendations based on results and scientific knowledge |

## Guidance for delivery

### Planning delivery in the context of other units

As engineering should essentially have a practical outcome, learners should be encouraged to use scientific principles in all their design and practical work. Wherever possible the learner should use scientific principles while working on other units in this programme eg, Level 3 Unit 3: Selection and application of engineering materials, Level 3 Unit 4: Instrumentation and control engineering, and Level 3 Unit 5: Maintaining engineering systems and products. The teacher should use these opportunities to cross reference the units to provide relevance, an efficient learning framework and a cohesive programme for the learner.

### Using real world engineering systems

Learners should also have opportunities for observing the effects of scientific principles. This not only includes practical scientific laboratory work but should also include the observation of current engineering practice, projects and systems. The learner will then be able to identify and review the scientific principles used in real engineering within their environment.

**Including an empirical approach**

Engineering science should not be exclusively analytical. The learner should also gain skills, knowledge and understanding empirically. There are many examples of where good engineers do not wholly understand why things behave the way they do; nevertheless engineers use their knowledge of how things behave to develop successful designs. Learners should not be afraid of adopting a similar approach when studying this unit.

**Using computers and other data resources**

The learners will not be expected to remember all the formulae and detailed information required in principles of engineering science. They should routinely use a good engineering science data book and other engineering resources as an aid to the application of scientific principles. They should develop their skills, knowledge and understanding of scientific information, data, properties of materials, codes of practice etc, to enable them to solve engineering problems.

**Detailed content**

Applying the scientific principles of electricity and electronics in engineering ould include the following:

- D.C circuits. Resistors in series and parallel. Circuit analysis and the use of common instrument to measure quantities such as resistance current, voltage and frequency. Resistivity.
- Ohms law. Kirchoff's Law. Lenz's Law. Lorentz force exerted on a current carrying conductor within a magnetic field.
- Magnetic fields and electromagnetic induction, and their application in engineering, eg motors and transformers.
- Forces in current carrying coils such as generators, transformers etc.
- Magnetic circuits. Magnetic flux. Magnetisation curves. Hysteresis loops for magnetic materials.
- Capacitance and the effects of capacitors in circuits. Dielectric strength.
- The (junction) characteristics of semiconductors devices such as diodes and transistors.

Applying the principles of statics and dynamics in engineering systems could include the following:

- Systems of coplanar forces. Resultants and equilibrants using vectors and mathematical methods.
- This could be applied to problems of forces on cranes, hoists, cranes, cables on masts etc.
- Moments and forces on simply supported loaded beams.
- Stress and Strain. Elastic Modulus and Poisson's ratio. Consideration of the properties of materials and how this helps the engineer predict material behaviour.
- Newton's laws of motion. Linear and angular motion – velocity and acceleration. Linear momentum.
- Centripetal force. These could be applied to any moving engineering objects such as cars and motorcycles.
- Simple machines and power transmission – gear trains belt drives. Torque. Friction. Efficiency of transmission systems.

Appreciating and applying the principles of energy and heat to the solution of engineering problems could include the following:

- Work energy, power and the principle of conservation of energy. This should be linked to friction and the efficiency of simple engineering systems such as ramps, screw jacks and hoists.
- Kinetic energy, potential energy and gravitational force, consideration of falling objects and head of fluids.
- Thermal capacity, specific heat capacity, coefficient of linear expansion, thermal conductivity, as properties of materials and how these affect their use.
- Latent heat of fusion and vaporisation and how these characteristics are used o transfer energy in heat pumps.
- Gas Laws – engineering examples of how energy levels depend upon volume, pressure and temperature.
- Heat flow across material boundaries. Conduction, convection and radiation and their application to engineering situations such as house insulation.

Appreciating and applying basic chemistry in engineering could include the following:

- How changes of state and phase changes shown in equilibrium diagrams can account for the change in properties of alloys, such as carbon - iron and tin – lead.
- Basic heat treatment to change properties of metals such as carbon teels and precipitation hardening of aluminium alloy.
- How crystallisation and dislocations affect the properties of metals and the effects of cold working.
- Electrochemical series and corrosion. How differing metals are used to reduce corrosion.
- Basic applications of organic chemistry to polymer materials. Monomers and polymerisation. Basic alkane structures, eg methane – pentane and how these relate to common polymers such as polythene, polypropylene, PTFE etc.
- Significance of cross linking and how these affect the properties, manufacture and application of polymers.
- Structure of rubber. Vulcanisation.
- Appreciating and applying fluid flow to the solution of engineering problems could include the following:
- Basic principles of hydraulics and pneumatics. Pressure in fluids including head of fluids. Application of
- Bernoulli's equation to solve engineering problems. Fluid flow through orifices.
- Measuring fluid flow, eg orifice plate, venturi tube, Pitot static tube, floats and tapered tube.
- Electromagnetic flow meters and their application to particular engineering situations.
- Aerodynamics 2D fluid flow over common objects. Stagnation points, separation regions, turbulence and vorticies. For example, discuss the aerodynamics of suspension bridges and, perhaps, the failure of the Tacoma Narrows Bridge.

Appreciating how waves occur in light, sound and other aspects of engineering could include the following.

- Characteristics of sinusoidal wave including frequency, amplitude and periodic time. This should be related to sound waves' loudness and amplitude, and applications such as the measurement of sound and noise. Waves should also be discussed in the context of AC electrical signals.
- Light reflection, refraction and engineering applications such as optical fibre computer network cables. Learners should have access to a library of reference books. The following are some titles that may facilitate or enhance the learning covered in this unit:
- Newnes Engineering and Physical Science Pocket Book by Bird & Chivers. Published by Newnes (1996)
- Engineering Science by W Bolton. Published by Newnes (2006)
- Science for Engineering by J Bird. Published by Newnes (2003)
- Tables, Data and Formulae for Engineers and Mathematicians by Greer & Hancox. Published by Nelson Thornes Ltd (1998).

**Opportunities for applied learning**

Learners should be given every opportunity to see how science is used in engineering systems. While visits to industry will be advantageous it should also be possible to look at applications of science in systems within their immediate environment, for example:

- transport, cycles, motorcycles, cars
- materials in the home
- electrical and electronic devices
- alternative energy resources to solar heating systems
- structures to buildings and bridges
- waste systems in school or college.

**What activities might be involved in this unit?**

- Applying knowledge to real engineering systems.
- Analysis and problem-solving in engineering.
- Use of mathematical methods to solve engineering problems.
- Use of IT to solve engineering science problems and record data.
- Construction of engineering science experiments.

**Suggested prior learning**

In order to ensure that the learner has a realistic opportunity of succeeding in this unit, the learner should have achieved a good grade in a Level 2 physical science qualification, eg GCSE Science.

**Personal, Learning and Thinking Skills**

The list below is indicative of the way this unit supports the development of PLTS, as opposed to the achievement of PLTS that are possible through the assessment. The unit supports the development of more PLTS than are covered through the Assessment criteria alone.

Alternative approaches could be selected.

The learner could develop PLTS by:

**Independent enquirers**

- suggesting scientific questions to be answered in order to address engineering problems
- planning and carrying out experiments
- analysing and evaluating scientific information gathered, and judging its relevance and value to finding solutions to engineering problems
- suggesting objective, reasoned conclusions, using evidence and data gathered

**Creative thinkers**

- generating scientific ideas and exploring their potential to provide engineering solutions
- asking scientific questions to extend their own thinking about engineering problems
- discussing and working with others to develop scientific principles into imaginative solutions to engineering problems
- questioning their own assumptions to avoid subjective thinking
- being prepared to try alternative solutions, based on scientific principles, to engineering problems
- being prepared to adapt ideas which result from applying scientific principles to engineering problems

**Reflective learners**

- assessing their own scientific work and the work of others to identify achievements and further opportunities
- setting goals to facilitate progress when working on science investigations
- reviewing progress with scientific principles and applications to engineering and taking action
- asking for feedback about their investigations and dealing with success and difficulties during the process
- communicating and presenting the outcome of experiments and their own findings in relevant ways to different audiences

**Team workers**

- co-operating with others when working with scientific principles
- showing fairness and consideration to others when working together
- taking responsibility within a group for a fair proportion of the work
- providing constructive support and feedback to others

**Self–managers**

- seeking out challenges and showing commitment and perseverance when seeking solutions to scientific and engineering problems
- organising and prioritising time to ensure that the required task can be achieved
- seeking help and support when needed

**Effective participators**

- discussing issues and concerns about their work with others when needed
- presenting a persuasive case for acting on scientific principles to solve engineering problems
- making practical suggestions in achievable steps for managing difficulties with complex scientific investigations
- trying to influence others, negotiating and balancing diverse scientific views to reach a workable solution to engineering problems.

# 4 Assessment

## 4.1 Aims

Principal Learning courses based on this specification should encourage learners to:

1. develop a broad understanding and knowledge of the engineering industries
2. develop skills in the broad context of the engineering industries
3. understand the contribution engineering makes to modern life
4. apply:
   - 4.1 Functional Skills at Level 2 in Mathematics, English and ICT
   - 4.2 transferable Personal, Learning and Thinking Skills (PLTS) in independent enquiry, creative thinking, reflective learning, team working, self-managing and effective participation
   - 4.3 investigative and project management skills through a Principal Learning project
   - 4.4 skills gained through work experience
5. learn through experience of applying knowledge and skills to tasks or contexts including those that have the characteristics of real work eg the minimum 10 days' work experience, including:
   - 5.1 planning and reflecting on their experience
   - 5.2 drawing out and articulating lessons learnt
   - 5.3 applying their learning to new activities or situations.

## 4.2 National criteria

This Principal Learning Engineering specification complies with the following:

- Criteria for the specialised Principal Learning qualifications in engineering at levels 1, 2 and 3 (published QCA November 2006)
- Criteria for the accreditation of Principal Learning qualifications at levels 1, 2 and 3 (published QCA April 2007)

## 4.3 Prior learning

There are no prior learning requirements.

## 4.4

## 4.5 Internal assessment

Internally assessed units will comply with the JCQ Instructions for conducting coursework/portfolios - please see JCQ website:

**http://www.jcq.org.uk**

### Task setting

Clear guidance, with exemplars of suitable internal assessment, is available to all consortia centres in order to ensure that suitable tasks are set. City & Guilds will give guidance on task setting and the moderator will review a selection of proposed tasks to check that they are suitable at the early advisory visits.

The teacher at a centre with overall responsibility for internal standardisation is also responsible for the standardisation of task setting.

Guidance is provided on the total amount of time that a task should take, on the amount of time that specific activities within a task should take and on the form of supervision expected.

**Control criteria for tasks**

The internally assessed assignments are to be taken under controlled conditions and the forms of evidence required in each unit will drive the controls needed. Where specific guidance is required, it will be found in the assessment section of the unit concerned. The following controls should be in place where appropriate for individual tasks.

**Activity – A** video or DVD recording of the activity, or a witness testimony describing the activity, will be necessary as evidence of ephemeral work.

**Research of relevant sources of material** – A bibliography or list of sources eg museums, businesses, organisations, websites will provide evidence of research. The teacher may also question learners on their research and submit signed notes from these questions as evidence.

**Record of interviews with business, industry or third party representatives** – Transcripts or audio recordings (if permitted by the individual concerned), or the learner's own record of the interview and evidence of permission or observation or witness statement by an observer may be used as evidence of interactions with learners.

**Outcome or Production** – Where this is produced over time, it is possible that the teacher may not supervise the whole of the process; however, sufficient supervision must take place to ensure that the material for assessment is the unaided work of the learner. Photographs, recordings and witness testimony can also be utilised to confirm that the work belongs to an individual learner.

**Practical assignment –** These must be conducted under supervision and the outcome should be submitted for moderation if possible.

**Portfolio of evidence** – This must be submitted for moderation.

The above controls are summarised for reference in the following table.

| **Forms of evidence** | **Method of control** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Video/DVD recording | Photographs | Witness Statement | Bibliography or list of sources | Signed notes evidencing questions asked by teacher | Transcript or audio recording | Learners own records | Supervision | Submission of artefact or product |
| Activity | 1 | | 2 | | | | | | |
| Research of relevant sources of materials | | | | 1 | 2 | | | | |
| Record of interview with business, industry or third party representatives | | | 2 learner's own record | | | 1 evidence of permission | 2 with witness statements | | |
| Outcome or production | 2 | 2 | 2 | | | | | 1* | 1* |
| Practical assignment | 2 | 2 | 2 | | | | | 1* | 1 if possible |
| Portfolio of evidence | | | | | | | | | 1* |

**Please note:**

Control methods rated 1 are the most preferable type to be used. Those rated 2 may be used if employing the favoured method is not practical, or as a way of providing additional evidence of the learner having met the assessment criteria.

* Where the number 1 is followed by an asterisk, this indicates that any other control method may accompany but not substitute the use of this method.

### Guidance by the teacher

The work assessed must be solely that of the learner. Any assistance given to an individual learner which is beyond that given to the group as a whole must be recorded.

### Unfair practice

At the start of the course, the supervising teacher is responsible for informing learners of the City & Guilds Regulations concerning malpractice. Learners must not take part in any unfair practice in the preparation of work to be submitted for assessment, and must understand that to present material copied directly from books or other sources, without acknowledgement, will be regarded as deliberate deception. Centres must report suspected malpractice to City & Guilds.

### Applying the assessment grid

When assessing learners' work, teachers/assessors should consider the level of attainment demonstrated in four broad areas within the demands and context of the specific unit being assessed:

- the depth and breadth of understanding
- the level of skills
- the level of synthesis, analysis and evaluation
- the level of independence and originality.

In the assessment grid for each unit, mark ranges are specified for each assessment criteria topic. When assessing a learner's work, teachers/assessors should use their professional judgement to identify for each assessment criteria topic, the mark band description within which that work falls and then the mark within that range that best describes the depth and quality of the work.

To achieve the higher mark bands, learners should show greater depth and breadth of understanding, higher level skills, higher levels of synthesis, analysis and evaluation and higher levels of independence and originality as required in the assessment criteria. Work that clearly meets all the requirements of the mark band description should be awarded the maximum mark identified.

Aspects of the work that might fall short of meeting, in full, the description but which do not, in the judgement of the teacher/assessor, sufficiently influence the overall level of achievement to merit the work being assigned to a lower mark band, will reduce the mark awarded within the identified range available. This can be expressed as identifying the 'best-fit' approach, where the areas of strength in the work submitted by the learner can be allowed to compensate for weaknesses in other areas.

Assessors will use archived exemplars as they become available as a reference point. By comparing their own learners' work with archive work which has an assessment commentary attached, the assessor will be able to position the work either on a higher or lower point.

**Assessment of group work**

Group work is a useful way of obtaining information for some activities but it is important that individual learners meet the assessment criteria requirements. Teachers/assessors assessing the evidence will need to be convinced of its individual authenticity. Questioning can be used in order to clarify the validity, authenticity and sufficiency of evidence and, under these circumstances, the teacher/assessor may wish to include a dated witness statement detailing this evidence. It is expected that the use of such statements will be kept to a minimum, so that they constitute a very minor part of the submitted evidence.

Annotation of written/photographic evidence can also be used to detail an individual's contribution.

It is recognised that there can be instances where learners are required to carry out tasks as part of a group and that group-working skills are an integral part of the assessment requirements. In such cases this general guidance on group work will be superseded by the specific requirements and instructions of the individual unit(s).

**Internal standardisation of marking**

The centre is required to standardise the assessment across different teachers and teaching groups, within and across units, to ensure that all work at the centre has been judged against the same standards. If two or more teachers are involved in marking units, one teacher must be designated as responsible for internal standardisation.

Common pieces of work must be marked on a trial basis and differences between assessments discussed at a training session in which all teachers involved must participate.

The teacher responsible for standardising the marking must ensure that the training includes the use of reference and archive materials such as work from a previous year or examples provided by City & Guilds.

## 4.6 Supervision and authentication of internally assessed work

The Head of Centre is responsible to City & Guilds for ensuring that internally assessed work is conducted in accordance with City & Guilds instructions and JCQ instructions.

City & Guilds requires:

- **learners** to sign the record form to confirm that the work submitted is their own
- **teachers/assessors** to confirm on the record form that the work assessed is solely that of the learner concerned and was conducted under the conditions laid down by the specification
- the teacher/assessor responsible for internal standardisation also to sign the Centre Declaration Sheet (CDS) to confirm that internal standardisation has taken place and that the work presented is that of the learners named. If only one teacher has undertaken the marking, that person must sign this form.

The completed record form must be attached to each learner's work and the Centre Declaration Sheet must be sent to the moderator. Failure to sign either or both the record form and the CDS may delay the processing of the learners' results.

The teacher should be sufficiently aware of the learner's standard and level of work to appreciate if the work submitted is beyond the ability of the learner.

In most centres teachers are familiar with learners' work through class and assignments. Where this is not the case, teachers should make sure that all internally assessed work is completed under direct supervision or controls listed in Section 4.4.

In all cases, some direct supervision is necessary to ensure that the work submitted can be confidently authenticated as the learner's own.

If it is believed that a learner has received additional assistance and this is acceptable within the guidelines for the internally assessed units, the teacher/assessor should award a mark which represents the learner's unaided achievement. The authentication statement should be signed and information given on the relevant form.

If the teacher/assessor is unable to sign the authentication statement for a particular learner, then the learner's work cannot be accepted for assessment.

## 4.7 Malpractice

Teachers should inform learners of the JCQ Regulations concerning malpractice. Learners must not:

- submit work which is not their own
- lend work to other learners
- allow other learners access to, or the use of, their own independently-sourced material (this does not mean that learners may not lend their books to another learner, but learners should be prevented from plagiarising other learners' research)
- include work copied directly from books, the Internet or other sources without acknowledgement or an attribution
- submit work typed or word processed by a third person without acknowledgement.

These actions constitute malpractice, for which a penalty (eg disqualification from the examination) will be applied. If malpractice is suspected, the Examinations Officer should be consulted about the procedure to be followed.

Where suspected malpractice in internally assessed work is identified by a centre after the learner has signed the declaration of authentication, the Head of Centre must submit full details of the case to City & Guilds at the earliest opportunity. The form, JQM/M1, should be used. Copies of the form can be found on the JCQ website: http://www.jcq.org.uk.

Malpractice in internally assessed work discovered prior to the learner signing the declaration of authentication need not be reported to City & Guilds, but should be dealt with in accordance with the centre's internal procedures. City & Guilds would expect centres to treat such cases very seriously. Details of any work which is not the learner's own must be recorded on the cover sheet or other appropriate place.

## 4.8 Moderation

City & Guilds will ensure that in consortia where learners from more than one centre are taught and assessed together, a single moderator for each line of learning will be appointed subject to consideration of workload.

Moderation of internally assessed work will take place in two stages and the same moderator will be responsible for each.

**Stage 1** – a visit from a moderator representing City & Guilds at a fairly early stage during the delivery of Principal Learning

The moderator will inspect some work and check such matters as:

- task setting against assessment criteria
- understanding of controlled conditions

- taking and marking of internal assessments
- arrangements for internal standardisation
- coverage of PLTS
- coverage of Applied Learning.

The moderator will give advice, feedback and guidance on each of the above. Stage 1 will be seen as a technical advisory visit and will cover the Principal Learning units.

**Stage 2** – a check by the moderator on the taking and marking of samples of Principal Learning units

Internally assessed work will normally be reviewed at the centre but may be sent to the moderator. The samples to be moderated will be agreed with the centre for each identified unit in accordance with the moderation procedures. During the moderation visit, the moderator will normally assess samples of work with the teacher and discuss the standards in order to ensure that they are in line with the national standards for this qualification. If necessary, further samples may be requested and adjustments may be applied to the centres' marks. Mark adjustments will normally preserve the centre's order of merit, but if major discrepancies are discovered, City & Guilds reserves the right to alter the order of merit.

Centre marks for all units must be submitted to City & Guilds and to the moderator by the specified deadline. Claiming and moderation of internal assessment is only available in the summer term.

Further details will be given in moderation procedures documentation to be issued by City & Guilds.

## 4.9 Post-moderation procedures

On publication of the results for Principal Learning units, City & Guilds will provide centres with details of the final marks for the internally assessed units.

The learners' work will be returned to the centre after moderation has taken place. The centre will receive a report with, or soon after, despatch of published results giving feedback on the appropriateness of the task set, the accuracy of the assessments, and the reasons for any adjustment to the marks.

City & Guilds reserves the right to retain some learners' work for archive or standardising purposes.

## 4.10 Retaining evidence and re-using marks

The centre must retain the work of all learners for each internally assessed unit, with record forms attached, under secure conditions, from the time it is assessed, to allow for the possibility of an enquiry about results. The work may be returned to learners after the deadline for enquiries about results. If an enquiry about a result has been made, the work must remain under secure conditions in case it is required by City & Guilds.

## 4.11 External assessment

The external assessments will be timetabled twice a year, in January and June, and the dates will be published at the start of the academic year.

Unit 9 of this specification, Scientific principles and applications for engineers, contains both internal and external assessment which will be treated as separate assessment opportunities. The assessments are not dependent on each other and learners can take them in isolation if they so wish. Each assessment will be marked and graded in the same way as other 'single' assessment units but the points derived from each component will then be multiplied by the appropriate weighting. This is given in the weighting tables within individual units. Re-sits can be taken independently.

## 4.12 Factors affecting individual learners

Teachers should be able to accommodate the occasional absence of learners by ensuring that the opportunity is given for them to make up missed assessments.

If work is lost, City & Guilds should be notified immediately of the date of the loss, how it occurred, and who was responsible for the loss. Centres should use the JCQ form, JCQ/LCW, to inform City & Guilds Candidate Support of the circumstances.

Learners who move from one centre to another during the course may require individual attention. Possible courses of action depend on the stage at which the move takes place. If the move occurs early in the course, the new centre should take responsibility for assessment. If it occurs late in the course it may be possible to arrange for the moderator to assess the work through the 'Educated Elsewhere' procedure. Centres should contact City & Guilds at the earliest possible stage for advice about appropriate arrangements in individual cases.

# 5 Administration

## 5.1 Availability of Principal Learning units

All internally assessed Principal Learning units for this specification are available once a year only, commencing in June 2013. External assessments will be timetabled twice a year, in January and June, and the dates will be published at the start of the academic year.

## 5.2 Centre registration

Centres wishing to prepare learners for this specification should apply for approval to offer Principal Learning before teaching begins. Completed application forms should be submitted to your local City & Guilds Regional Office. Further details of the approval process are available on the website at: www.cityandguilds.com

## 5.3 Centre requirements

**Resources**

Centres must have access to sufficient equipment in the centre or in other centres within the consortium to ensure that learners have the opportunity to cover all the practical activities. Any requirement for specialised equipment is to be found in the description of the units themselves.

**Health and safety**

The importance of safe working practice and the demands of the Health and Safety at Work Act 1974 must be stressed to all learners. Learners have responsibilities for maintaining the safety of others as well as their own. Anyone behaving in an unsafe fashion must be stopped and a suitable warning given by the teacher responsible. It is essential that all learners acquire habits required to promote health and safety in the workplace and that their learning avoids potentially unpleasant or dangerous consequences.

**Centre staff**

Centre staff should be technically competent in all the areas for which they are delivering education and training and/or should also have relevant experience of providing the necessary practical training.

**Continuing Professional Development (CPD)**

Centres are expected to support their staff in ensuring that their knowledge and skills in the vocational area remain current and take account of any national or legislative developments.

## 5.4 Quality assurance

**Internal quality assurance**

Registered centres must have effective quality assurance systems to ensure optimum delivery and assessment of qualifications. Quality assurance includes initial centre registration by City & Guilds and the centre's and/or consortium's own internal procedures for monitoring quality. Centres are responsible for internal quality assurance and City & Guilds is responsible for external quality assurance.

National standards and rigorous quality assurance are maintained by the use of:

- City & Guilds external examinations
- City & Guilds externally set briefs or assignments
- internal quality assurance
- City & Guilds external moderation.

To meet the quality assurance criteria for this qualification, the centre must ensure that the following procedures are followed:

- the setting of appropriate tasks (see Section 4.4)
- the application of appropriate control of tasks (see Section 4.4)
- training in the use of the assessment grid (see Section 4.4)
- completion by the person responsible for internal standardisation of the Centre Declaration Sheet to confirm that internal standardisation has taken place (see Sections 4.4 and 4.5)
- the completion by learners and teachers/assessors of the record form for each learner's work (see
- Section 4.5).

**External quality assurance**

External quality assurance is provided by the two stage moderation system described in Section 4.7. External moderation of internally assessed work is carried out to ensure that assessment is valid and reliable, and that there is good assessment practice in centres and that national standards are maintained.

In order to carry out their quality assurance role, external moderators must have appropriate teaching and vocational knowledge and expertise. City & Guilds will appoint external moderators and will ensure that they attend regular training and development meetings designed to keep them up-to-date, to ensure standardisation of all assessments and to share good practice.

External moderators will:

- provide advice and support to staff in centres
- ensure the quality and consistency of assessments within and between centres and over time by the use of systematic sampling
- regularly visit centres to ensure that they continue to meet the centre registration requirements of
- City & Guilds
- provide feedback to centres and to City & Guilds.

In order to monitor compliance with JCQ requirements, particularly for administering external tests, JCQ inspectors will regularly visit centres.

City & Guilds requires the Head of Centre to:

1. facilitate any inspection of the Centre which is undertaken on behalf of City & Guilds
2. make secure arrangements to receive, check and keep examination material secure at all times, maintain the security of City & Guilds confidential material from receipt to the time when it is no longer confidential and keep scripts secure from the time they are collected from the candidates to their despatch to City & Guilds.

## 5.5 Irregularities

Centres must inform City & Guilds of any irregularity, including any candidate who arrives late for a test. For detailed instructions please refer to the current JCQ Instructions for Conducting Examinations which is available to view or to download from the JCQ's website:http://www.jcq.org.uk

## 5.6 Awarding grades and reporting results

The Level 3 Engineering Principal Learning will be reported on a six-grade scale: A*, A, B, C, D and E. Learners who fail to reach the minimum standard for grade E will be recorded as U (Unclassified) and will not receive a qualification certificate.

## 5.7 Enquiries about results

The services available for enquiries about results include a clerical check, re-mark of external assessments and re-moderation of internally assessed work. Requests must be submitted within the specified period after the publication of results for individual assessments.

In cases where a post-results enquiry reveals inaccurate assessment, the result may be confirmed, raised or lowered.

For further details of enquiries about results services, please consult the current version of the JCQ

Post-Results Services booklet.

## 5.8 Re-sits and shelf-life of unit results

Unit results remain available to count towards certification, whether or not they have already been used, as long as the specification is still valid.

Learners may re-sit a unit any number of times within the shelf-life of the specification. The best result for each unit will count towards the final qualification.

Learners will be graded on the basis of the work submitted for assessment.

## 5.9 Access arrangements and special consideration

We have taken note of the provisions of equalities legislation in developing and administering this specification.

We follow the guidelines in the Joint Council for Qualifications (JCQ) document: Regulations and Guidance Relating to Candidates who are Eligible for Adjustments in Examination GCSE, GCE, GNVQ, AEA, Entry Level, Basic Skills & Key Skills Access Arrangements and Special Consideration. This is published on the JCQ website:

http://www.jcq.org.uk/access_arrangements/

### Access arrangements

We can make arrangements so that learners with disabilities, special educational needs and temporary injuries can access the assessment. These arrangements must be made before the examination. For example, we can produce a Braille paper for a learner with visual impairment.

### Special consideration

We can give special consideration to learners who have had a temporary illness, injury or indisposition at the time of the examination. Where we do this, it is given **after** the examination.

Applications for either access arrangements or special consideration should be submitted to City & Guilds by the Examinations Officer at the centre.

## 5.10 Language of examinations

We will provide units for this specification in English only.

## 5.11 Qualification titles

The qualification based on this specification is:

City & Guilds Level 3 Principal Learning in Engineering.

# Appendix 1 Other Issues

**European Dimension**

City & Guilds has taken account of the 1988 Resolution of the Council of the European Community in preparing this specification and associated specimen units.

**Environmental Education**

City & Guilds has taken account of the 1988 Resolution of the Council of the European Community and the Report Environmental Responsibility: An Agenda for Further and Higher Education 1993 in preparing this specification and associated specimen units.

**Avoidance of Bias**

City & Guilds has taken great care in the preparation of this specification and specimen units to avoid bias of any kind.