Level 4 Diploma in Electrical and Electronic Engineering (9209-02)
April 2017 Version 3
## Qualification at a glance

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>City &amp; Guilds number</td>
<td>9209</td>
</tr>
<tr>
<td>Age group approved</td>
<td>18+</td>
</tr>
</tbody>
</table>

### Entry requirements
To take this qualification, learners should have achieved one of the following:
- 2850 Level 3 Diploma in Engineering
- 8030 Level 3 Technician Diploma in Electrical and Electronic Engineering
- National Diploma in Engineering or a suitable equivalent to any of the above.

### Assessment
- Assignments: externally set by City & Guilds, internally marked by centres, externally verified.
- Dated entry written exam papers

### Fast track
N/A

### Support materials
- Centre handbook
- Assessor Guidance
- Assignments
- Sample exam questions
- Online tutor and learner support material (Smartscreen)

### Registration and certification
Consult the Walled Garden/Online Catalogue for last dates

<table>
<thead>
<tr>
<th>Title and level</th>
<th>City &amp; Guilds number</th>
<th>Accreditation number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 4 Diploma in Electrical and Electronic Engineering</td>
<td>9209-02</td>
<td>601/5556/5</td>
</tr>
<tr>
<td>Version and date</td>
<td>Change detail</td>
<td>Section</td>
</tr>
<tr>
<td>------------------</td>
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<tr>
<td>v1.1 Nov 2014</td>
<td>NLH added</td>
<td>Individual units</td>
</tr>
<tr>
<td>v1.3 Jan 2015</td>
<td>Age 18+</td>
<td>Page 2 and Section 3</td>
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<tr>
<td></td>
<td>UAN added</td>
<td>Individual units</td>
</tr>
<tr>
<td></td>
<td>QAN added</td>
<td>Page 2</td>
</tr>
<tr>
<td>v2 Apr 2015</td>
<td>Updates to some learning outcomes and assessment criteria and updated range</td>
<td>Individual units</td>
</tr>
<tr>
<td></td>
<td>Test specification information</td>
<td>Assessment</td>
</tr>
<tr>
<td></td>
<td>Question paper resources</td>
<td></td>
</tr>
<tr>
<td>v3 Apr 2017</td>
<td>Updated range</td>
<td>Individual units</td>
</tr>
<tr>
<td></td>
<td>Updated test specification information and question paper resources</td>
<td>Assessment</td>
</tr>
</tbody>
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   - Unit 402 Principles of electrical/electronic engineering 37
   - Unit 403 Quality assurance and control 42
   - Unit 404 Human factors in the workplace 46
   - Unit 405 Engineering planning and scheduling 51
   - Unit 406 Statistical analysis for engineers 54
   - Unit 407 Computer Aided Design for manufacture 57
   - Unit 408 Data communication and networks 60
   - Unit 409 Principles and operation of electrical machines 66
   - Unit 410 Using electrical protection techniques for engineering operations 69
   - Unit 411 Electrical services and installation 72
   - Unit 412 Electrical supply and distribution 77
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   - Unit 414 Programmable logic controllers 88
   - Unit 415 Principles of analogue circuits 91
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</tbody>
</table>
## 1 Introduction

This document tells you what you need to do to deliver this qualification:

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who is this the qualification for?</td>
<td>This Diploma is aimed at learners who</td>
</tr>
<tr>
<td></td>
<td>• wish to gain employment as an Engineering Technician</td>
</tr>
<tr>
<td></td>
<td>• wish to progress into higher level Engineering qualifications</td>
</tr>
<tr>
<td></td>
<td>• intend to advance into the second year of a selected university engineering degree programme.</td>
</tr>
<tr>
<td></td>
<td>It also aims to contribute to recognition by professional institutions.</td>
</tr>
<tr>
<td>What does this qualification cover?</td>
<td>It allows learners to learn, develop and practise the advanced skills required for employment, career progression or university progression in the engineering sector.</td>
</tr>
<tr>
<td></td>
<td>It will also allow learners to build their knowledge of the principles of mathematics, science and technologies that underpin engineering.</td>
</tr>
<tr>
<td>Who did we develop the qualification with?</td>
<td>Please refer to our recognition list on our website.</td>
</tr>
<tr>
<td>What opportunities for progression are there?</td>
<td>It allows learners to progress into employment, university or to the following City &amp; Guilds qualifications:</td>
</tr>
<tr>
<td></td>
<td>• 9209-12 Level 5 Advanced Technician Diploma in Electrical and Electronic Engineering or other equivalent City &amp; Guilds qualifications.</td>
</tr>
</tbody>
</table>
## Structure

To achieve the **Level 4 Diploma in Electrical and Electronic Engineering** learners must achieve the 2 mandatory units and a minimum of 9 optional units.

<table>
<thead>
<tr>
<th>City &amp; Guilds unit number/UAN</th>
<th>Unit title</th>
<th>GLH</th>
<th>NLH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mandatory</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit 401 J/506/9243</td>
<td>Engineering mathematics</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Unit 402 L/506/9244</td>
<td>Principles of electrical/electronic engineering</td>
<td>70</td>
<td>150</td>
</tr>
<tr>
<td><strong>Optional</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit 403 R/506/9245</td>
<td>Quality assurance and control</td>
<td>42</td>
<td>150</td>
</tr>
<tr>
<td>Unit 404 Y/506/9246</td>
<td>Human factors in the workplace</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Unit 405 D/506/9247</td>
<td>Engineering planning and scheduling</td>
<td>66</td>
<td>150</td>
</tr>
<tr>
<td>Unit 406 M/506/9270</td>
<td>Statistical analysis for Engineers</td>
<td>45</td>
<td>100</td>
</tr>
<tr>
<td>Unit 407 T/506/9271</td>
<td>Computer Aided Design for manufacture</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Unit 408 F/506/9273</td>
<td>Data Communication and networks</td>
<td>65</td>
<td>150</td>
</tr>
<tr>
<td>Unit 409 J/506/9274</td>
<td>Principles and operation of electrical machines</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>City &amp; Guilds unit number/UAN</td>
<td>Unit title</td>
<td>GLH</td>
<td>NLH</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Unit 410 L/506/9275</td>
<td>Using electrical protection techniques for engineering operations</td>
<td>45</td>
<td>150</td>
</tr>
<tr>
<td>Unit 411 Y/506/9277</td>
<td>Electrical services and installation</td>
<td>41</td>
<td>100</td>
</tr>
<tr>
<td>Unit 412 F/506/9287</td>
<td>Electrical supply and distribution</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Unit 413 L/506/9289</td>
<td>Testing and measurement of electronic and electrical systems</td>
<td>66</td>
<td>100</td>
</tr>
<tr>
<td>Unit 414 F/506/9290</td>
<td>Programmable logic controllers</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Unit 415 D/506/9295</td>
<td>Principles of analogue circuits</td>
<td>97</td>
<td>150</td>
</tr>
<tr>
<td>Unit 416 T/506/9299</td>
<td>Sequential and combinational logic circuits</td>
<td>66</td>
<td>100</td>
</tr>
<tr>
<td>Unit 417 D/506/9300</td>
<td>Microprocessor based systems</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Unit 418 H/506/9301</td>
<td>Maintenance of engineering systems and equipment</td>
<td>56</td>
<td>150</td>
</tr>
<tr>
<td>Unit 419 M/506/9334</td>
<td>Engineering design</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Unit 420 K/506/9302</td>
<td>Programming using C</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Unit 421 T/506/9304</td>
<td>Planning and implementing change within businesses</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Unit 422 A/506/9305</td>
<td>Personal and professional development</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>City &amp; Guilds unit number/UAN</td>
<td>Unit title</td>
<td>GLH</td>
<td>NLH</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------</td>
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</tr>
<tr>
<td>Unit 423 F/506/9306</td>
<td>Managing information and knowledge</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Unit 424 T/506/9335</td>
<td>Engineering procurement</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Unit 425 J/506/9307</td>
<td>Principles of composite materials</td>
<td>75</td>
<td>150</td>
</tr>
<tr>
<td>Unit 426 L/506/9308</td>
<td>Principles of composites manufacture</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Unit 427 K/506/9333</td>
<td>Developing business improvement plans</td>
<td>35</td>
<td>100</td>
</tr>
</tbody>
</table>
3 Centre requirements

Approval
If there is no fast track approval for this qualification, existing centres who wish to offer this qualification must use the standard Qualification Approval Process.

Resource requirements

Physical resources and site agreements
The equipment, systems and machinery must meet industrial standards and be capable of being used under normal working conditions.

Centre staffing
Staff delivering this qualification must be able to demonstrate that they meet the relevant occupational expertise requirements, ie they should be occupationally competent or technically knowledgeable in the areas for which they are delivering training with experience of providing training. This knowledge must be to the same level as the training being delivered.

Trainers must also
• hold or be working towards a recognised training qualification
• have recent relevant experience in the specific area they will be assessing
• have credible experience of providing training.

Centre staff may undertake more than one role, e.g. tutor and assessor or internal quality assurer, but cannot internally verify their own assessments.

Assessors and Internal Quality Assurer

Assessors
Although not specifically required for this qualification, City & Guilds recommends that Assessors hold, or are working towards, the relevant Level 3 TAQA qualification, covering the assessment types required for this qualification. Further information about the City & Guilds TAQA qualification can be found at www.cityandguilds.com. Assessors must be able to demonstrate clear experience in assessing learning and understand City & Guilds’ quality assurance requirements. They must also have the required industry certification and experience as outlined above.

Internal Verifiers / Internal Quality Assurers
Although not specifically required for this qualification, City & Guilds recommends that Internal Verifiers / Internal Quality Assurers hold, or are working towards, the Level 4 TAQA qualification. Further information about the City & Guilds TAQA qualification can be found at www.cityandguilds.com. Internal Verifiers / Internal Quality Assurers must be able to demonstrate clear experience in quality assurance
processes and understand City & Guilds’ specific quality assurance requirements. They must also have the required industry certification and experience as outlined above.

**Continuing professional development (CPD)**

Centres must support their staff to ensure that they have current knowledge of the occupational area, that delivery, mentoring, training, assessment and verification is in line with best practice, and that it takes account of any national or legislative developments.

**Learner entry requirements**

City & Guilds recommends that learners have completed a suitable engineering related qualification at level 3 or above prior to enrolling on the course.

To take this qualification, learners should have achieved one of the following:

- 2850 Level 3 Diploma in Engineering
- 8030 Level 3 Technician Diploma in Electrical and Electronic Engineering
- National Diploma in Engineering
- Physics and Mathematics A Level

or a suitable equivalent to any of the above.

Without evidence of formal qualifications, learners must demonstrate adequate prior knowledge and experience to ensure they have the potential to gain the qualification.

**Age restrictions**

City & Guilds cannot accept any registrations for learners under 18 years of age.
4 Delivering the qualification

Initial assessment and induction
An initial assessment of each learner should be made before the start of their programme to identify:

- if the learner has any specific training needs,
- support and guidance they may need when working towards their qualification.
- any units they have already completed, or credit they have accumulated which is relevant to the qualification.
- the appropriate type and level of qualification.

We recommend that centres provide an induction programme so the learner fully understands the requirements of the qualification, their responsibilities as a learner, and the responsibilities of the centre. This information can be recorded on a learning contract.

Support materials
The following resources are available for this qualification:

<table>
<thead>
<tr>
<th>Description</th>
<th>How to access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample exam questions</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>Sample schemes of work</td>
<td><a href="http://www.smartscreen.co.uk">www.smartscreen.co.uk</a></td>
</tr>
<tr>
<td>Further reading / links</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>Equipment lists</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>Recognition lists</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
</tbody>
</table>
Units 405, 407, 408, 410, 411, 413, 414, 415, 416, 418, 419, 420, 421, 422, 423, 424 and 427 are assessed by assignments set by City & Guilds, internally marked by centres and externally verified. These assignments are graded Pass, Merit and Distinction.

All the remaining units are assessed by dated entry written paper, which are also graded Pass, Merit and Distinction. Exam dates are available on the Catalogue and Walled Garden.

The assessments have all been developed with input from experts in the industry.

Please refer to the Assessor Guidance on www.cityandguilds.com for general assessment guidance for this qualification.

**Summary of assessment requirements**

To achieve this qualification, candidates will be required to complete the following assessments successfully:

- **one** dated entry written exam for **each** mandatory unit 401 and 402
- **one** dated written exam for **each** chosen optional unit assessed by dated written exam
- **one** assignment for **each** chosen optional unit assessed by assignment.

City & Guilds provides the following assessments:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Title</th>
<th>Assessment method</th>
<th>Where to obtain assessments</th>
</tr>
</thead>
<tbody>
<tr>
<td>9209-401</td>
<td>Engineering mathematics</td>
<td>Dated entry written exam paper 9209-401</td>
<td>Sample exam papers on <a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-402</td>
<td>Principles of electrical/electronic</td>
<td>Dated entry written exam paper 9209-402</td>
<td>Sample exam papers on <a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td></td>
<td>engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit</td>
<td>Title</td>
<td>Assessment method</td>
<td>Where to obtain assessments</td>
</tr>
<tr>
<td>----------</td>
<td>----------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>Optional units</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9209-403</td>
<td>Quality assurance and control</td>
<td>Dated entry written exam paper 9209-403</td>
<td>Sample exam papers on <a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-404</td>
<td>Human factors in the workplace</td>
<td>Dated entry written exam paper 9209-404</td>
<td>Sample exam papers on <a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-405</td>
<td>Engineering planning and scheduling</td>
<td>Assignment 9209-405 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-406</td>
<td>Statistical analysis for engineers</td>
<td>Dated entry written exam paper 9209-406</td>
<td>Sample exam papers on <a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-407</td>
<td>Computer aided design for manufacture</td>
<td>Assignment 9209-407 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-408</td>
<td>Data communication and networks</td>
<td>Assignment 9209-408 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-409</td>
<td>Principles and operation of electrical machines</td>
<td>Dated entry written exam paper 9209-409</td>
<td>Sample exam papers on <a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-410</td>
<td>Using electrical protection techniques for engineering operations</td>
<td>Assignment 9209-410 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>Unit</td>
<td>Title</td>
<td>Assessment method</td>
<td>Where to obtain assessments</td>
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<tr>
<td>--------</td>
<td>--------------------------------------------</td>
<td>------------------------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>9209-411</td>
<td>Electrical services and installation</td>
<td>Assignment 9209-411 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-412</td>
<td>Electrical supply and distribution</td>
<td>Dated entry written exam paper 9209-412</td>
<td>Sample exam papers on <a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-413</td>
<td>Testing and measurement of electronic and electrical systems</td>
<td>Assignment 9209-413 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-414</td>
<td>Programmable logic controllers</td>
<td>Assignment 9209-414 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-415</td>
<td>Principles of analogue circuits</td>
<td>Assignment 9209-415 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-416</td>
<td>Sequential and combinational logic circuits</td>
<td>Assignment 9209-416 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>Unit</td>
<td>Title</td>
<td>Assessment method</td>
<td>Where to obtain assessments</td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>9209-417</td>
<td>Microprocessor based systems</td>
<td>Assignment 9209-417 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-418</td>
<td>Maintenance of engineering systems and equipment</td>
<td>Assignment 9209-418 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-419</td>
<td>Engineering design</td>
<td>Assignment 9209-419 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-420</td>
<td>Programming using C</td>
<td>Assignment 9209-420 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-421</td>
<td>Planning and implementing change within businesses</td>
<td>Assignment 9209-421 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>9209-422</td>
<td>Personal and professional development</td>
<td>Assignment 9209-422 This assignment covers all the learning outcomes in this unit. Assignment set by City &amp; Guilds, internally marked, externally verified</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td>Unit</td>
<td>Title</td>
<td>Assessment method</td>
<td>Where to obtain assessments</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>-----------------------------</td>
</tr>
</tbody>
</table>
| 9209-423 | Managing information and knowledge         | Assignment 9209-423  
This assignment covers all the learning outcomes in this unit.  
Assignment set by City & Guilds, internally marked, externally verified | www.cityandguilds.com       |
| 9209-424 | Engineering procurement                    | Assignment 9209-424  
This assignment covers all the learning outcomes in this unit.  
Assignment set by City & Guilds, internally marked, externally verified | www.cityandguilds.com       |
| 9209-425 | Principles of composite materials          | Dated entry written exam paper 9209-425                                           | Sample exam papers on www.cityandguilds.com |
| 9209-426 | Principles of composites manufacture       | Dated entry written exam paper 9209-426                                           | Sample exam papers on www.cityandguilds.com |
| 9209-427 | Developing business improvement plans      | Assignment 9209-427  
This assignment covers all the learning outcomes in this unit.  
Assignment set by City & Guilds, internally marked, externally verified | www.cityandguilds.com       |
Unit assessment overview

Assignments
The following tables are designed to offer a summarised overview of how the tasks in each assignment demonstrate achievement of the assessment criteria in the units.

Some of the assignments in this qualification require that candidates have access to the following industry/international guidelines/standards:

IEEE 1016-2009; IEEE 2914.8-2011; ISO 9000; ISO 14000; RS232; V24; X21; CCITT; ISO; ANSI; IEEE; EIA; CENELEC; ATEX; IEC; National (BS7671); ANSI/IEEE Std 91a-1991; BS EN 60617-12:1999; ASCII.

It is indicated in the relevant units when this is the case and which guidelines/standards are required.

Unit 405  Engineering planning and scheduling

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment Criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Research Task: Explain engineering planning and scheduling processes</td>
<td>1.1, 12, 1.3, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2</td>
<td>20 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Produce a plan for an engineering activity</td>
<td>5.1, 5.2</td>
<td>6 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>

Unit 407  Computer Aided Design for manufacture

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drawing task: Computer aided design drawing creation and animation</td>
<td>1.1, 1.2, 4.1, 2.1, 2.2, 2.3, 3.1, 3.2, 1.3, 4.2, 4.3</td>
<td>6 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>
### Unit 408  Data communications and networks

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Serial DTE to DTE connection</td>
<td>4.1, 4.2</td>
<td>3 hours with an additional 30 minutes initial preparation time</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Communication protocol and configurations.</td>
<td>4.3, 6.5, 6.6, 6.8, 6.9, 7.1, 7.2, 8.2</td>
<td>2 hours and 30 minutes with an additional 30 minutes initial preparation time</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>

### Unit 410  Using electrical protection techniques for engineering operations

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prepare a one-line impedance diagram for an electricity supply system.</td>
<td>2.3</td>
<td>2 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Protection systems</td>
<td>3.3, 4.2, 4.3</td>
<td>2 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Earthing</td>
<td>5.1, 5.2, 5.3</td>
<td>2 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Short-answer questions</td>
<td>1.1, 1.2, 1.3, 2.1, 2.2, 3.1, 3.2, 4.1</td>
<td>1 hour</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>

### Unit 411  Electrical services and installation

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electrical services and installation project</td>
<td>1.1, 2.1, 2.2, 2.3, 2.4, 2.5, 3.2, 3.3, 4.1, 4.2, 5.3</td>
<td>20 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>
### Unit 413  Testing and measurement of electronic and electrical systems

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inspection, Testing and Commissioning</td>
<td>7.1, 7.2, 8.1, 8.2, 8.3</td>
<td>3 hours</td>
<td>P / M / D / X</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Measurements</td>
<td>2.1, 2.2, 2.3</td>
<td>2 hours</td>
<td>P / M / D / X</td>
<td>2</td>
</tr>
</tbody>
</table>

### Unit 414  Programmable logic controllers

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PLC program design and testing.</td>
<td>3.3, 3.4, 4.1, 4.2, 4.3, 5.3, 5.4</td>
<td>3 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>

### Unit 415  Principles of analogue circuits

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Operation amplifiers (Op-amps)</td>
<td>5.1, 5.2, 5.3</td>
<td>2 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Oscillators</td>
<td>6.1, 6.2, 6.3, 6.4</td>
<td>4 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Op-amp filters</td>
<td>7.1, 7.2, 7.3, 7.4</td>
<td>3 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>

### Unit 416  Sequential and combinational logic circuits

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Combinational logic</td>
<td>2.3, 2.4, 2.5</td>
<td>1 hour 30 minutes</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Sequential logic</td>
<td>3.6, 3.7</td>
<td>2 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>
## Unit 417  Microprocessor based systems

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Software development and testing</td>
<td>2.1, 2.2, 2.3, 3.2</td>
<td>2 hours 30 minutes</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>

## Unit 418  Maintenance of engineering systems and equipment

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment Criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Research task: Produce a maintenance operation document incorporating a plan</td>
<td>1.3, 5.2, 1.1, 1.2, 5.1, 5.4, 5.3</td>
<td>10 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Carry out a maintenance procedure</td>
<td>6.1, 6.2, 6.3, 6.4</td>
<td>4 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Research task: Complete a written report on a mechatronic industrial system specification</td>
<td>2.1, 2.2, 2.3, 2.4, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6</td>
<td>20 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>

## Unit 419  Engineering design

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Assessment Criteria</th>
<th>Task duration</th>
<th>Grading</th>
<th>Weighting per task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Defining Design Task &amp; Scope</td>
<td>All</td>
<td>2-3 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>Task</td>
<td>Description</td>
<td>Assessment criteria</td>
<td>Task duration</td>
<td>Grading</td>
<td>Weighting per task</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------------------</td>
<td>---------------</td>
<td>---------</td>
<td>--------------------</td>
</tr>
<tr>
<td>1</td>
<td>Research report: Understanding Software development</td>
<td>1.1, 1.2, 1.3, 2.1, 2.2, 2.4, 2.5, 4.6, 5.3</td>
<td>8 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Programming Task: Implementation of a design specification in the C language</td>
<td>1.4, 1.5, 1.6, 2.3, 2.6, 3.1, 3.4, 3.5, 4.1, 4.4, 4.5, 5.1, 5.2</td>
<td>32 hours</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Short-answer questions</td>
<td>3.2, 3.3, 4.2, 4.3</td>
<td>1 hour</td>
<td>P / M / D / X</td>
<td>1</td>
</tr>
</tbody>
</table>
Dated entry written exam papers

Test specifications for the dated entry written exam papers are included here.

Test specifications

The way the knowledge is covered by each test is laid out in the tables below.

Test: 9209-401 Engineering mathematics
Duration: 3 hours
Grading: Pass/Merit/Distinction

<table>
<thead>
<tr>
<th>Unit</th>
<th>Outcome</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>401</td>
<td>1. be able to use algebraic methods to analyse and solve engineering problems</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>2. be able to solve engineering problems that require the use of trigonometric methods of analysis</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>3. be able to use methods of differential and integral calculus to solve engineering problems</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>4. be able to apply complex numbers and complex analysis to solve engineering problems</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>100</td>
</tr>
</tbody>
</table>

Test: 9209-402 Principles of electrical and electronic engineering
Duration: 3 hours
Grading: Pass/Merit/Distinction

<table>
<thead>
<tr>
<th>Unit</th>
<th>Outcome</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>402</td>
<td>1. understand basic magnetic theory</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>2. be able to solve design problems using electromagnetic theory</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>3. be able to apply electrical theorems or laws to solve network problems</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>4. be able to use complex notation theory in the analysis of single-phase a.c. networks</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>5. understand how to analyse RLC circuits</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>6. be able to analyse RLC circuits</td>
<td>12</td>
</tr>
<tr>
<td>Unit</td>
<td>Outcome</td>
<td>%</td>
</tr>
<tr>
<td>------</td>
<td>-------------------------------------------------------------------------</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>7. understand how to analyse electrical systems when modelled as two-port networks</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>8. be able to analyse electrical systems when modelled as two-port networks</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>9. be able to analyse three-phase circuits</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>10. be able to solve the transient response of first-order circuits</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

**Test:** 9209-403 Quality assurance and control

**Duration:** 3 hours

**Grading:** Pass/Merit/Distinction

<table>
<thead>
<tr>
<th>Unit</th>
<th>Outcome</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>403</td>
<td>1. understand the importance of quality assurance and quality control within an organisational culture</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>2. understand how total quality management systems operate</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>3. understand the implementation process of quality management systems</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>4. understand key principles of business excellence models</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>5. understand the principles of six sigma project management</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>6. understand the techniques and methods applied to the quality control of goods and services</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>7. understand the use and application of codes of practice, standards and design guides</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
## Test: 9209-404 Human factors in the workplace

### Duration: 3 hours

### Grading: Pass/Merit/Distinction

<table>
<thead>
<tr>
<th>Unit</th>
<th>Outcome</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>404</td>
<td>1. understand the importance of human factors in the workplace</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2. understand features and limitations of human performance</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>3. understand the interrelationship between different roles and responsibilities in the workplace</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>4. understand how physical and personal factors of the working environment affect human performance</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>5. understand how the execution of different tasks can affect human performance</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>6. understand how to communicate effectively in the workplace</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>7. understand causes of human error</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>8. be able to recommend ways to mitigate risk in the workplace</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>9. understand how to apply safety, occupational health and environmental policies within industry</td>
<td>13</td>
</tr>
</tbody>
</table>

**Total 100**

## Test: 9209-406 Statistical analysis for engineers

### Duration: 3 hours

### Grading: Pass/Merit/Distinction

<table>
<thead>
<tr>
<th>Unit</th>
<th>Outcome</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>406</td>
<td>1. understand the causes of variation in industrial processes</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>2. understand statistical concepts and functions</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>3. be able to calculate unbiased estimates of population parameters</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>4. be able to solve industrial problems using statistical analysis of sample data</td>
<td>56</td>
</tr>
</tbody>
</table>

**Total 100**
### Test: 9209-409 Principles and operation of electrical machines

**Duration:** 3 hours  
**Grading:** Pass/Merit/Distinction

<table>
<thead>
<tr>
<th>Unit</th>
<th>Outcome</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>409</td>
<td>1. understand the principles and operation of dc machines</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>2. understand the principles and operation of three-phase induction motors</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>3. understand the principles and operation of synchronous machines</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>4. understand the principles and operation of power transformers</td>
<td>41</td>
</tr>
</tbody>
</table>

Total: 100%

### Test: 9209-412 Electrical supply and distribution

**Duration:** 3 hours  
**Grading:** Pass/Merit/Distinction

<table>
<thead>
<tr>
<th>Unit</th>
<th>Outcome</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>412</td>
<td>1. understand principles, components and economic factors of electrical transmission and distribution systems</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>2. be able to analyse the characteristics of three-phase power transformers in parallel operation</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>3. be able to apply short transmission line theory for electrical supply configurations</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>4. understand operating characteristics of three-phase generators on infinite busbars</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>5. be able to solve fault levels on electrical supply system configurations</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>6. understand protection systems used in electrical supply systems</td>
<td>16</td>
</tr>
</tbody>
</table>

Total: 100%
Test: 9209-425 Principles of composite materials  
Duration: 2.5 hours  
Grading: Pass/Merit/Distinction

<table>
<thead>
<tr>
<th>Unit</th>
<th>Outcome</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>425</td>
<td>1. understand the principles and structure of composite materials</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>2. understand elementary polymer chemistry</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>3. understand the materials and techniques used with pre-impregnated (pre-preg) and pre-formed (pre-forms) materials</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>4. understand preparation and assembly methods for composite components in the manufacture of composite structures</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Test: 9209-426 Principles of composite manufacture  
Duration: 2.5 hours  
Grading: Pass/Merit/Distinction

<table>
<thead>
<tr>
<th>Unit</th>
<th>Outcome</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>426</td>
<td>1. understand the manufacturing processes used for composite components and structures</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>2. understand the implications of manufacturing processes on design for manufacture</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>3. understand types and sources of manufacture defects of composite components and structures</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>4. understand Non-Destructive Testing (NDT) methods of testing</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>5. understand process and quality systems required for composite component and structure manufacture</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Question paper resources

The following examination paper will require resource materials as listed below.

<table>
<thead>
<tr>
<th>Unit no.</th>
<th>Required source material (required on day of exam)</th>
<th>City &amp; Guilds or third party</th>
<th>Cost if third party</th>
<th>How to access</th>
</tr>
</thead>
<tbody>
<tr>
<td>406</td>
<td>9209-406 Statistical tables</td>
<td>City &amp; Guilds</td>
<td>n/a</td>
<td><a href="http://www.cityandguilds.com">www.cityandguilds.com</a></td>
</tr>
<tr>
<td></td>
<td>9209-406 Statistical formulae sheet</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Copies will be provided with exam question answer booklets. It is recommended to print a copy from the 9209 webpage to use throughout the course.

Time constraints

The following time constraints must be applied to the assessments of this qualification:

- each assignment has specific time constraints; please refer to the individual assignments and to the Assessor Guidance. Centre staff should guide learners to ensure excessive evidence gathering is avoided. Centres finding that assignments are taking longer should contact the Qualification Consultant for guidance
- all assignments must be completed and assessed within the learner’s period of registration. Centres should advise learners of any internal timescales for the completion and marking of individual assignments
- all dated entry written exam papers must be sat within the learner’s period of registration.

Assessment strategy

City & Guilds provide sample questions for each unit assessed by dated entry written exam paper.

The purpose of these sample questions is to provide examples of the type of question that will be set, giving an indication of the breadth and depth of knowledge that is expected. It should be noted that these are sample questions and not a full sample question paper.

Dated entry examinations will take place twice a year, in June / July and November / December, with the first exam series being in November / December 2015.

Recognition of prior learning (RPL)

Recognition of prior learning means using a person’s previous experience or qualifications which have already been achieved to contribute to a new qualification.

RPL is not allowed for this qualification.
6 Grade profile

Purpose and use of this qualification grade profile
City & Guilds has taken the decision to grade the individual assessments included in this qualification, and provide a grade associated with each unit. This decision is based on market research with employers and colleges that suggests grading can be of use both as a motivational tool within the learning environment, and also to learners presenting evidence of their skills to prospective employers.

For this reason, the tasks have been developed to extend learners beyond the minimum required for Pass. As a basis for developing the tasks and their related grading criteria, City & Guilds consulted a number of stakeholders to discover what the grades at each level should mean in practice, and how they might be used. The following descriptors are based on that consultation.

The descriptors were used in the development of the task grading criteria and should be used by assessors to understand the intended outcomes of the grading.

They should be referred to during the centre’s standardising exercises in addition to the specific grading criteria for the unit to support a consistent understanding of the standard across units, centres and assessors.

The grades achieved by a learner would be considered by universities for subsequent entry into the correct year of a degree programme.

Aims
The Level 4 and 5 Diplomas in Engineering focus on advanced engineering, with a wide choice of units to provide a flexible route to career success as a professional engineer. The qualifications have been developed closely with both industry and the deliverers of learning in order to ensure fitness for purpose.

Both Level 4 and Level 5 for this qualification are presented here to allow comparison and better understanding of progression.

Levels
Level 4
The Level 4 Diplomas in Engineering focus on advanced engineering. The learners will have the potential to fulfil a role within Engineering that requires a high level of responsibility, for example within first level management, requiring the use of personal initiative and critical judgement.

Holders of these qualifications may also be able to advance into the second year of a selected university engineering degree programme.

Level 5
The Level 5 Diplomas in Engineering focus on advanced engineering. The learner will have the potential to fulfil a role within Engineering that
requires a high level of responsibility, for example leading to middle management and/or project management, requiring the use of personal initiative and critical judgement.

Holders of these qualifications may also be able to advance into the third year of a selected university engineering degree programme.

To take this qualification a learner must first achieve the 9209 Level 4 Diploma in Engineering.

Both levels are also ideal for people wanting to advance as an Engineering technician within the fields of Mechanical Engineering, Electrical and Electronic Engineering, or Civil Engineering.

**Delivery of learning**

Learning is delivered by approved colleges and training providers in simulated learning environments, not in the workplace. Learners will however have access to real work environments in which to further develop the breadth of their skills and their experience.

**Grading**

The majority of tasks are graded Pass / Merit / Distinction. Pass reflects the minimum requirements that are expressed in the unit, with Merit and Distinction showing progression in skills and knowledge as well as recognising behaviours important to the industry.

<table>
<thead>
<tr>
<th>Pass</th>
<th>Merit</th>
<th>Distinction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 4</td>
<td><strong>Learner:</strong> Capable of making informed decisions, likely to have achieved a grade at Level 3 (Merit / Distinction), starting to have sufficient skills to bring value to the industry, is becoming comfortable with occupational systems and procedures. <strong>Evidence:</strong> Complex tasks may present some challenge, partial attempt at assessment, well defined tasks completed with a level of guidance, able to follow the.</td>
<td><strong>Learner:</strong> Broader understanding of systems and procedures, can work with minimal guidance, determination to resolve issues, taking ownership and responsibility for own learning, desire to progress. <strong>Evidence:</strong> Full attempt at assessment, well defined tasks completed with minimal guidance, able to follow the required process, higher level skills / knowledge / competence displayed for the industry, can plan, can solve problems more effectively and confidently. Sufficient reflection on the outcomes of the task.</td>
</tr>
<tr>
<td>Pass</td>
<td>Merit</td>
<td>Distinction</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>required process, acceptable skills / knowledge / competence displayed for the industry, can plan, can solve problems. Limited reflection on the outcomes of the task.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Level 5**

**Learner:**
Capable of making informed decisions, likely to have achieved a grade at Level 4 (Merit / Distinction), has sufficient skills to bring value to the industry, is fairly comfortable with occupational systems and procedures.

**Evidence:**
Complex tasks may present some challenge, but most assessments attempted, well defined tasks completed with a level of guidance, able to follow the required process, acceptable skills / knowledge / competence displayed for the industry, can plan, can solve problems. Satisfactory reflection on the outcomes of the task.

**Learner:**
Full understanding of systems and procedures, can work with minimal to no guidance, determination to resolve issues, taking ownership and responsibility for own learning, desire to excel.

**Evidence:**
Full attempt at assessment, well defined tasks completed with minimal guidance, able to follow the required process, higher level skills / knowledge / competence displayed for the industry, can plan, can solve problems more effectively and confidently. Good reflection on the outcomes of the task.

**Learner:**
High level of understanding, evaluation and competence in overall systems and procedures, clearly achieving a higher level of academic study. Has an ability to carry out tasks without guidance and shows own initiative.

**Evidence:**
Full achievement of assessment completely independently, within the time given, ie efficient use of time. Detailed / in-depth reflection on the outcomes of the task with recommendations for improvement / alternatives.
7 Units

Structure of units
These units each have the following:
- City & Guilds reference number
- title
- level
- UAN (Unit Accreditation Number)
- guided learning hours
- notional Learning hours
- unit aim
- assessment method
- learning outcomes which are comprised of a number of assessment criteria
- notes for guidance.
Unit 401  Engineering mathematics

Level: 4
UAN: J/506/9243
GLH: 60
NLH: 150
Assessment method: Dated written paper

Aim: The purpose of this unit is to enable learners to develop an understanding of a range of mathematical operations and analysis techniques that are required to solve engineering problems.

On completion of this unit, learners will be able to:

- apply algebraic methods to analyse and solve engineering problems
- apply trigonometric methods of analysis to solve engineering problems
- apply differential and integral calculus methods to solve engineering problems
- apply complex numbers and complex analysis methods to solve engineering problems

Note
This unit may be supported by the provision of computer-based mathematical software and the learner could have the opportunity to use this software to help reinforce understanding and application of the analysis techniques presented in the unit.

Learning outcome
The learner will:
1. be able to use algebraic methods to analyse and solve engineering problems

Assessment criteria
The learner can:
1.1 evaluate basic algebraic functions
1.2 solve engineering problems that are described by algebraic equations and exponential or logarithmic functions
### Range

**Basic algebraic functions**
Algebraic functions (graph of a function, inverse of a function, odd and even functions, linear functions, gradient of a linear function, common engineering functions (polynomial, rational, modulus, unit step, unit impulse)); use of symbols; indices (positive and negative); laws of indices; algebraic formulae (transposition, factorisation, evaluation of algebraic fractions)

**Algebraic equations**
Linear equations; quadratic equations; polynomial equations; simultaneous equations; solving inequalities; partial fractions

**Exponential and logarithmic functions**
Laws of logarithms; solving exponential and logarithmic equations

### Learning outcome
The learner will:
2. be able to solve engineering problems that require the use of trigonometric methods of analysis

### Assessment criteria
The learner can:
2.1 evaluate basic trigonometric functions
2.2 evaluate trigonometric identities to solve problems involving trigonometric equations

### Range

**Basic trigonometric functions**
Angles; sine; cosine; tangent; secant; cosecant; cotangent of an angle; inverse functions; sin⁻¹; cos⁻¹; tan⁻¹; trigonometric functions and their graphs; amplitude; frequency; phase and period of a sine or cosine function

**Trigonometric identities**
Compound and double angle formulae for sine and cosine; ‘sums to product’ and ‘product to sums’ formulae; solve trigonometric equations; application to resolution and resultant of forces; description of complex wave patterns

### Learning outcome
The learner will:
3. be able to use methods of differential and integral calculus to solve engineering problems

### Assessment criteria
The learner can:
3.1 evaluate first and higher order derivatives of a function involving algebraic and/or trigonometric expressions
3.2 use differential calculus to obtain solutions for engineering applications of algebraic and trigonometric equations
3.3 use methods of integration to determine indefinite and definite integrals of algebraic and trigonometric functions
3.4 use **integral calculus** to obtain solutions for engineering applications of algebraic and trigonometric equations

3.5 use **integration** to solve engineering applications of differential equations in which the variables are separable.

<table>
<thead>
<tr>
<th>RANGE</th>
</tr>
</thead>
</table>
| **Differentiation between first and higher order derivatives** based on  
Rate of change of a function; derivative and gradient of a function;  
table of derivatives for common functions \((ax^n, (ax \pm b)^n, \sin^n(ax \pm b), \cos^n(ax \pm b), e^{(ax \pm b)}, \ln(ax \pm b)}\) and linear combinations of these;  
higher derivatives |

<table>
<thead>
<tr>
<th><strong>Differential calculus</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product rule; quotient rule; chain rule; implicit and logarithmic differentiation; maximum and minimum values of a function; points of inflection; applications of differentiation to engineering problems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Methods of integration</strong></th>
</tr>
</thead>
</table>
| Integration as the reverse of differentiation; indefinite integrals; table of integrals for common functions (constant, \(ax^n (n \neq -1), 1/x, \sin(ax \pm b), \cos(ax \pm b), e^{(ax \pm b)}, \ln(ax \pm b)}\); definite integrals; Integration methods:  
integration by parts; by substitution; using partial fractions; integration of trigonometric functions |

<table>
<thead>
<tr>
<th><strong>Integral calculus</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Applications of integration to areas; volumes of revolution; centres of mass; moments of inertia; mean value and root-mean-square (rms) value of an electrical signal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Integration</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Apply integration methods for the solution of differential equations in which the variables are separable; general and particular solutions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Learning outcome</strong></th>
</tr>
</thead>
</table>
| The learner will:  
4. be able to apply complex numbers and complex analysis to solve engineering problems |

<table>
<thead>
<tr>
<th><strong>Assessment criteria</strong></th>
</tr>
</thead>
</table>
| The learner can:  
4.1 evaluate complex equations using rectangular and polar forms of complex numbers  
4.2 use **complex function analysis** to obtain solutions to engineering problems |

<table>
<thead>
<tr>
<th><strong>Range</strong></th>
</tr>
</thead>
</table>
| **Complex numbers**  
Imaginary number; \( j = \sqrt{-1} \); real and imaginary parts of a complex number; complex conjugate; arithmetic of complex numbers; Argand diagram; polar form of complex numbers (modulus and argument); exponential form of complex numbers; Euler’s formula; de Moivre’s theorem |
Complex function analysis
Solve complex equations involving complex variables; find roots of complex numbers; phasors; complex impedances; analyse simple ac electrical circuits and measurement and control systems using complex numbers
**Unit 402**

**Principles of electrical/electronic engineering**

**Level:** 4

**UAN:** L/506/9244

**GLH:** 70

**NLH:** 150

**Assessment method:** Dated written paper

**Aim:**

The purpose of this unit is to enable learners to develop an understanding of the fundamental principles of electrical and electronic engineering.

**Learning outcome**

The learner will:

1. understand basic magnetic theory

**Assessment criteria**

The learner can:

1.1 explain the relationship between common electromagnetic **units of measurement**

1.2 explain the occurrence of **properties** in relation to the behaviour of magnetic materials undergoing cyclic magnetisation

1.3 explain the relationship between the shapes of hysteresis loops of **materials** and their application in magnetic and electromagnetic circuits

1.4 explain electromagnetic behaviour **laws**.

**Range**

**Units of measurement**

Magnetomotive force (m.m.f); Magnetic field strength; flux density; total flux; reluctance

**Properties**

Coercivity; remanence; saturation; permeability

**Materials**

Magnetically soft and magnetically hard

**Laws**

Faraday’s law; Lenz's law; Flemings rule
<table>
<thead>
<tr>
<th>Learning outcome</th>
<th>The learner will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>be able to solve design problems using electromagnetic theory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>The learner can:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>assess the reluctance of magnetic materials</td>
</tr>
<tr>
<td>2.2</td>
<td>calculate the inductance of magnetic circuits using applied variables</td>
</tr>
<tr>
<td>2.3</td>
<td>solve values relating to magnetic circuit operation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>m.m.f, circuit dimensions and permeability</td>
<td></td>
</tr>
</tbody>
</table>

| Values | Magnetic field strength; flux density; total flux; magnetomotive force (m.m.f) |

<table>
<thead>
<tr>
<th>Learning outcome</th>
<th>The learner will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>be able to apply electrical theorems or laws to solve network problems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>The learner can:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>explain methods of resolving network problems using electrical theorems or laws</td>
</tr>
<tr>
<td>3.2</td>
<td>use electrical theorems or laws to solve problems involving networks.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
<th>Theorems and laws</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohm’s law; Kirchhoff’s current and voltage laws; Thévenin’s theorem; Norton’s theorem; Maximum power transfer theorem; Superposition theorem</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning outcome</th>
<th>The learner will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td>be able to use complex notation theory in the analysis of single-phase a.c. networks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>The learner can:</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>explain the properties of R, L and C circuits</td>
</tr>
<tr>
<td>4.2</td>
<td>explain the representation of series R, L and C circuits</td>
</tr>
<tr>
<td>4.3</td>
<td>evaluate complex variables in operations</td>
</tr>
<tr>
<td>4.4</td>
<td>convert electrical values between polar and rectangular form</td>
</tr>
<tr>
<td>4.5</td>
<td>calculate power using relationships.</td>
</tr>
</tbody>
</table>
### Properties
Voltage, Current, Phase Angle, Frequency, Resistance, Reactance and Impedance ($R$, $X_L$, $X_C$, $Z$)

### Representation
By complex impedance and complex admittance

### Operations
Addition; subtraction; multiplication; division

### Power
Real; Reactive; Apparent; Power Factor

### Relationships
\[ P = \text{Re}[VI^*] \text{ and } Q = \text{Im}[VI^*] \]

### Learning outcome
The learner will:
5. understand how to analyse RLC circuits

### Assessment criteria
The learner can:
5.1 represent differing types of R, L and C circuits using phasor diagrams
5.2 explain the conditions of resonance for RLC circuits
5.3 explain power factor relationships using diagrams.

### Range
**Types**
Series; parallel

**RLC circuits**
Series; parallel

**Relationships**
Real power; Reactive power; Apparent power

### Learning outcome
The learner will:
6. be able to analyse RLC circuits

### Assessment criteria
The learner can:
6.1 produce plots of the frequency responses of tuned RLC circuits
6.2 solve problems of resonance in RLC circuits
6.3 solve problems relating to power-factor improvement.

### Range
**Resonance**
Quality factor; bandwidth; impedance; reactance; capacitance

**RLC circuits**
Series; parallel
<table>
<thead>
<tr>
<th>Learning outcome</th>
<th>The learner will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>understand how to analyse electrical systems when modelled as two-port networks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>The learner can:</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1</td>
<td>explain the parameters used in two-port models</td>
</tr>
<tr>
<td>7.2</td>
<td>explain the deriving of input and output equations for parameter models.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z (impedance model); Y (admittance model); h (hybrid model); g (inverse hybrid model)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning outcome</th>
<th>The learner will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>be able to analyse electrical systems when modelled as two-port networks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>The learner can:</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1</td>
<td>convert circuit values using parameters from different models</td>
</tr>
<tr>
<td>8.2</td>
<td>solve problems involving gain of two-port model networks.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z (impedance model); Y (admittance model); h (hybrid model); g (inverse hybrid model)</td>
</tr>
<tr>
<td></td>
<td>Gain</td>
</tr>
<tr>
<td></td>
<td>Low frequency; mid-band; high frequency</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning outcome</th>
<th>The learner will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.</td>
<td>be able to analyse three-phase circuits</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>The learner can:</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.1</td>
<td>illustrate three-phase systems using phasor diagrams</td>
</tr>
<tr>
<td>9.2</td>
<td>solve problems in balanced three-phase loads</td>
</tr>
<tr>
<td>9.3</td>
<td>evaluate methods of three-phase power measurement for different systems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Involving line values (voltage and current); phase values (voltage and current); power and power-factor; Star connection and Delta connection</td>
</tr>
<tr>
<td></td>
<td>Systems</td>
</tr>
<tr>
<td></td>
<td>Balanced; unbalanced; star (three-wire, four-wire); delta</td>
</tr>
</tbody>
</table>
### Learning outcome

The learner will:
10. be able to solve the transient response of first-order circuits

### Assessment criteria

The learner can:
10.1 produce graphs of growth and decay of transient components in circuits
10.2 solve problems relating to time and steady state values of circuits

### Range

<table>
<thead>
<tr>
<th>Components</th>
<th>Voltages and currents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuits</td>
<td>RL and RC</td>
</tr>
<tr>
<td>Time</td>
<td>Time constant; rise-time and fall-time</td>
</tr>
<tr>
<td>Circuits</td>
<td>RL and RC</td>
</tr>
</tbody>
</table>


Unit 403 Quality assurance and control

Level: 4
UAN: R/506/9245
GLH: 42
NLH: 150
Assessment method: Dated written paper

Aim: The purpose of this unit is to enable learners to develop the skills and knowledge required to assess and evaluate quality management systems in a manufacturing environment.

Learning outcome
The learner will:
1. understand the importance of quality assurance and quality control within an organisational culture

Assessment criteria
The learner can:
1.1 explain the importance of creating an appropriate organisational culture
1.2 evaluate the attributes of successful organisational management
1.3 evaluate opportunities to improve or develop an organisational culture.

Range
Appropriate organisational culture
Quality assurance; Quality control
Attributes
Leadership; people management and motivation; process capability; communication; customer focus; decision making
Opportunities to improve or develop
Within appropriate area of responsibility; strategic aims of the business; SWOT and PESTLE analysis
### Learning outcome
The learner will:
2. understand how total quality management systems operate

### Assessment criteria
The learner can:
2.1 explain the **principles** of total quality management
2.2 evaluate **organisational management structures**
2.3 evaluate **quality policies** of organisations.

### Range

#### Principles
Total company commitment to quality oriented leadership and management; zero errors or zero defects; internal and external customer focus; standardisation of procedures / policies to meet customer needs; total employee involvement; a process approach; use of innovation through quality improvement techniques / methodology; quality circles, Kaizen; continuous improvement policy; factual approach to decision making; supplier partnerships

#### Organisational management structures
Flat; hierarchical; functional; divisional; bureaucratic; matrix; team-based; network-based

#### Quality policies
Business benefits and outcomes: Customer loyalty, repeat business, reduced costs, competitive advantage, added value, improved effectiveness and efficiency

### Learning outcome
The learner will:
3. understand the implementation process of quality management systems

### Assessment criteria
The learner can:
3.1 describe **quality management systems**
3.2 identify **key factors** that must be implemented for quality management systems to be successful
3.3 evaluate internal and external quality **audits**.

### Range

#### Quality management systems
Quality Assurance; Quality Control

#### Key factors
Goals of an organisation; mission statement; focus on quality; control of quality achieved through inspection, tools and techniques used; measurement, testing and checking; teamwork; feedback

#### Audits
Costs of production (fixed, variable, break even); waste; internal failures; external failures; appraisal; prevention costs
<table>
<thead>
<tr>
<th>Learning outcome</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The learner will:</td>
<td>4. understand key principles of business excellence models</td>
</tr>
<tr>
<td>Assessment criteria:</td>
<td>The learner can:</td>
</tr>
<tr>
<td></td>
<td>4.1 explain the nature and concepts of business excellence models</td>
</tr>
<tr>
<td></td>
<td>4.2 analyse essential components and interrelationships of business excellence models.</td>
</tr>
</tbody>
</table>

**Range**

**Concepts**
EFQM; BEM; Framework; adding value for customers; sustainability; strong, effective management; improvement through creativity and innovation; leading with vision and clear strategic direction; create a culture of empowerment; outstanding results.

**Interrelationships of BEMs**
Enablers and Results; Leadership; strategic planning; Partnerships and resources; processes, people; creating the appropriate culture; meeting or exceeding needs of customers; products and services; sustainability; soft and hard metrics; fostering innovation and inventiveness.

<table>
<thead>
<tr>
<th>Learning outcome</th>
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</thead>
<tbody>
<tr>
<td>The learner will:</td>
<td>5. understand the principles of six sigma project management</td>
</tr>
<tr>
<td>Assessment criteria:</td>
<td>The learner can:</td>
</tr>
<tr>
<td></td>
<td>5.1 explain the key factors of six sigma methodology</td>
</tr>
<tr>
<td></td>
<td>5.2 evaluate the application of six sigma project management.</td>
</tr>
</tbody>
</table>

**Range**

**Key factors**
Commitment of whole organisation; communication within organisation; involvement of the whole organisation; management of Six Sigma philosophy as a project; setting measurable goals and objectives; education and training of the workforce; cultural change; customer focus; identification of ‘champions’.

**Application**
DMAIC; root cause analysis; use of statistical tools, continuous improvement techniques.
Learning outcome
The learner will:
6. understand the techniques and methods applied to the quality control of goods and services

Assessment criteria
The learner can:
6.1 explain the application of techniques and methods used in supply quality control
6.2 explain how quality control metrics are used to rate suppliers.

Range

Techniques and methods
Use of key performance indicators and the supplier balanced scorecard; TQM; use of ‘soft’ metrics such as delivery standards, customer satisfaction; use of ‘hard’ metrics such as checks and tests for mass, weight, length; sampling plans; national and international certification; supplier partnerships; specifications; SLAs.

Quality control metrics
Compliance/non-compliance; supplier audit; corrective action; conformance/non-conformance.

Learning outcome
The learner will:
7. understand the use and application of codes of practice, standards and design guides

Assessment criteria
The learner can:
7.1 describe relevant codes of practice, standards and design guides
7.2 evaluate the application of codes of practice, standards and design guides.

Range

Codes of practice, standards and design guides
Local, national and international (eg ISO 9000).

Application
Local, national and international standards such as ISO 9000/14000, BS, ASME; industry and engineering specific codes of practice; design guides including technical specification, drawings, parts lists, support services.
Unit 404  Human factors in the workplace

Level: 
UAN: 
GLH: 
NLH: 
Assessment method: Dated written paper

Aim: The purpose of this unit is to enable learners to develop an understanding of the principles of human factors in manufacturing environments. Learners will look at the importance and impact of human factors on performance in the workplace, gain an appreciation for workplace company culture, recognise effective methods of communication, know principles of leadership and management, and will be able to carry out risk assessments.

Learning outcome
The learner will:
1. understand the importance of human factors in the workplace

Assessment criteria
The learner can:
1.1 assess the impact of human factors on human performance
1.2 describe categories of human factors important to staff.

Range
Impact
Murphy’s law; safety of employees; assets; long-term health of employees; efficiency of organisation

Categories
Working environment; work patterns; social habits; work load; communication; employee health
**Learning outcome**
The learner will:
2. understand features and limitations of human performance

**Assessment criteria**
The learner can:
2.1 explain how low and very high light levels affect visual performance
2.2 explain how levels of noise affect human performance
2.3 explain factors that affect limitations of the human memory
2.4 assess how working in challenging environments increases risks occurrence

<table>
<thead>
<tr>
<th>Range</th>
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<tbody>
<tr>
<td><strong>Visual performance</strong></td>
</tr>
<tr>
<td>Fatigue; visual inspection; residual image; long term sight damage</td>
</tr>
<tr>
<td><strong>Levels of noise</strong></td>
</tr>
<tr>
<td>Prolonged; intermittent; percussive</td>
</tr>
<tr>
<td><strong>Effects on human performance</strong></td>
</tr>
<tr>
<td>Communication errors; fatigue</td>
</tr>
<tr>
<td><strong>Factors</strong></td>
</tr>
<tr>
<td>Attention span; time from exposure to information; fatigue; age; complexity of information; artificial stimulants; depressants; overconfidence; boredom; repetitive work</td>
</tr>
<tr>
<td><strong>Challenging environments</strong></td>
</tr>
<tr>
<td>Claustrophobia; fear of heights; limited access; confined space; time constraints; poor vision; environmental extremes; peer pressure</td>
</tr>
</tbody>
</table>

**Learning outcome**
The learner will:
3. understand the interrelationship between different roles and responsibilities in the workplace

**Assessment criteria**
The learner can:
3.1 explain the principles of workplace company culture
3.2 explain areas of individual and group responsibility in the workplace
3.3 evaluate the relationship between managers, supervisors and operatives
3.4 explain the principles and characteristics of leadership.
<table>
<thead>
<tr>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td><strong>Company culture</strong></td>
</tr>
<tr>
<td>Different types of culture (shift, teams, social); safety culture; individuals; compromise; blame culture; no blame culture</td>
</tr>
<tr>
<td><strong>Individual and group responsibility</strong></td>
</tr>
<tr>
<td>Roles and responsibilities and the interaction between; groups and teams; individuals; inter group dynamics; shift handovers</td>
</tr>
<tr>
<td><strong>Relationship</strong></td>
</tr>
<tr>
<td>Differentiate between management and supervisor roles; expectations; organisations</td>
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<thead>
<tr>
<th>Learning outcome</th>
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<tbody>
<tr>
<td>The learner will:</td>
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<tr>
<td>4. understand how physical and personal factors of the working environment affect human performance</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
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</thead>
<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>4.1 analyse <strong>sources</strong> of stress</td>
</tr>
<tr>
<td>4.2 explain the effects of setting <strong>deadlines</strong> on work performance</td>
</tr>
<tr>
<td>4.3 analyse the effects of <strong>external environmental factors</strong> on individual performance.</td>
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<tr>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td><strong>Sources</strong></td>
</tr>
<tr>
<td>Domestic; work</td>
</tr>
<tr>
<td><strong>Deadlines</strong></td>
</tr>
<tr>
<td><strong>Realistic</strong> (improve performance; minimal errors; motivated workforce; improved time management skills; efficiency of resources; staff retention) <strong>Unrealistic</strong> (poor quality of work; increased amount of errors/accidents; decrease in morale; staff turnover)</td>
</tr>
<tr>
<td><strong>External environmental factors</strong></td>
</tr>
<tr>
<td>Noise; fumes; illumination; climate; motion; working environment</td>
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</tbody>
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<thead>
<tr>
<th>Learning outcome</th>
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</thead>
<tbody>
<tr>
<td>The learner will:</td>
</tr>
<tr>
<td>5. understand how the execution of different tasks can affect human performance</td>
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</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>5.1 explain the importance of <strong>planning and executing</strong> tasks</td>
</tr>
<tr>
<td>5.2 explain how <strong>demanding work</strong> can affect human performance</td>
</tr>
<tr>
<td>5.3 analyse the <strong>aspects</strong> of working in complex organisations.</td>
</tr>
</tbody>
</table>
## Range

### Planning and executing tasks
Define the tasks; resources; personal skills and proficiency information; planning of repetitive tasks (complacency; assumption of time)

### Impact of demanding work
Health and physical condition; effects of lack of physical fitness against the work standard for the occupation; work environment; physical effort; effects of ageing; visual inspection (importance of good eyesight, knowledge of inspection, illumination, concentration, systematic search)

### Aspects
Clear understanding of the purpose of the organisation; pooling of knowledge and skills; comprehensive information and guidance; associated hazards; managing resources; stakeholder management and relationships

### Learning outcome
The learner will:

6. understand how to communicate effectively in the workplace

### Assessment criteria
The learner can:

6.1 explain the importance of interpersonal and communication skills in optimising performance

6.2 evaluate the effectiveness of feedback when developing communication skills

6.3 assess methods of communication appropriate to different audiences.

## Range

### Interpersonal and communication skills
Writing; verbal; visual; outcomes; key points; intonations; accuracy; urgent; level of importance; adaptation; audience; barriers; achieved purpose; audience; formality; situations

### Effectiveness of feedback
Analysis of formal and informal feedback; reflection

### Methods of communication
Written; verbal; visual; format; layout; presentation; objectives; discussion; adaptation

### Learning outcome
The learner will:

7. understand causes of human error

### Assessment criteria
The learner can:

7.1 explain causes of error that occur during work

7.2 evaluate methods of managing and avoiding errors.
### Range

**Causes of error**
Complacency; overconfident; lack of knowledge; poor training; lack of information; lack of interest; inattention; distractions; environmental; violations; communication

**Methods of managing and avoiding errors**
Self-discipline; safety management system; anonymous and blame-free reporting; review of error logs; formal briefing; coaching; mentoring; training (new and refresher)

### Learning outcome

The learner will:
8. be able to recommend ways to mitigate risk in the workplace

**Assessment criteria**

The learner can:
8.1 explain the five steps to risk assessment
8.2 evaluate the risks for workplace hazards
8.3 propose solutions to minimise risk in the workplace.

### Range

**Five steps**
Identify hazards; evaluate risks; develop controls; implement controls; review and update

### Learning outcome

The learner will:
9. understand how to apply safety, occupational health and environmental policies within industry

**Assessment criteria**

The learner can:
9.1 analyse personal legal obligations of individuals within industry
9.2 evaluate the impact and implications of legislation concerning health and safety in the workplace
9.3 evaluate environmental policies within industry.

### Range

**Personal legal obligations**
Alcohol; drugs; legislation; health and safety

**Impact and implications of legislation**
Current local; national; international legislation monitored; regulated; controlled

**Environmental policy**
Material inputs and outputs; waste energy; process efficiency; ISO 14001
# Unit 405  Engineering planning and scheduling

<table>
<thead>
<tr>
<th>Level:</th>
<th>4</th>
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<tbody>
<tr>
<td>UAN:</td>
<td>D/506/9247</td>
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<tr>
<td>GLH:</td>
<td>66</td>
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<tr>
<td>NLH:</td>
<td>100</td>
</tr>
<tr>
<td>Assessment method:</td>
<td>Assignment</td>
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</tbody>
</table>

**Aim:**
The purpose of this unit is to enable learners to develop an understanding of how maintenance/manufactured products and their associated processes are planned, monitored and controlled. Learners will extend their knowledge to apply both manual and computer-assisted methods and procedures.

The unit covers process plans (eg forecasting, network analysis), capacity assessment and scheduling and maintenance strategies. This leads the learner into inventory management with stock control and documentation systems. The last two outcomes require the learner to examine group technology, process plans and production/maintenance scheduling.

<table>
<thead>
<tr>
<th>Learning outcome</th>
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<tbody>
<tr>
<td>The learner will:</td>
</tr>
<tr>
<td>1. understand the use of process planning, capacity assessment and scheduling techniques</td>
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<table>
<thead>
<tr>
<th>Assessment criteria</th>
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<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>1.1 assess the uses of different <strong>process planning techniques</strong></td>
</tr>
<tr>
<td>1.2 evaluate the use of <strong>capacity assessment techniques</strong> for different types of engineering process</td>
</tr>
<tr>
<td>1.3 evaluate the use of a range of <strong>scheduling techniques</strong>.</td>
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<td>Range</td>
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</tr>
<tr>
<td><strong>Process planning techniques</strong>&lt;br&gt;Forecasting; network analysis; critical path method (CPM); project evaluation and review technique (PERT); failure mode and effects analysis (FMEA); material requirement planning (MRP); equipment and tooling; make or buy decisions; computer aided-planning and estimating.</td>
</tr>
<tr>
<td><strong>Capacity assessment techniques</strong>&lt;br&gt;Bill of materials; economic batch size; assessment of load and capacity; effects of re-working and scrap; methods of increasing/decreasing capacity; time phased capacity planning.</td>
</tr>
<tr>
<td><strong>Scheduling techniques</strong>&lt;br&gt;Lead times; critical path analysis (CPA); supplier and production schedules; Kanban; optimised production technology (OPT) philosophy; influence of scheduling on capacity planning dispatching; material requirement planning (MRP).</td>
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<th>Learning outcome</th>
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<tbody>
<tr>
<td>The learner will:</td>
</tr>
<tr>
<td>2. understand inventory management documentation</td>
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<tr>
<th>Assessment criteria</th>
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<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>2.1 explain the principles of inventory management</td>
</tr>
<tr>
<td>2.2 assess workplace documentation systems.</td>
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<th>Range</th>
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<tbody>
<tr>
<td><strong>Principles</strong>&lt;br&gt;Types of inventory; dependent and independent demand; role of buffer stock; cost of inventory</td>
</tr>
<tr>
<td><strong>Systems</strong>&lt;br&gt;Works orders; routing document; job tickets; recording of finished quantities; re-work and scrap; stock records.</td>
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<tr>
<th>Learning outcome</th>
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</thead>
<tbody>
<tr>
<td>The learner will:</td>
</tr>
<tr>
<td>3. understand the use of shop control systems</td>
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</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
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</thead>
<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>3.1 explain the uses of shop control</td>
</tr>
<tr>
<td>3.2 evaluate different stock control systems.</td>
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</tbody>
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<tr>
<th>Range</th>
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<tbody>
<tr>
<td><strong>Uses of shop control</strong>&lt;br&gt;Scheduled release of works orders; progressing; data collection and feedback</td>
</tr>
<tr>
<td><strong>Stock control systems</strong></td>
</tr>
</tbody>
</table>
Periodic review; re-order points; two bin system; basic economic order quantities; just in time; Kanban

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<tr>
<th>Learning outcome</th>
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</thead>
<tbody>
<tr>
<td>The learner will:</td>
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<tr>
<td>4. understand group technology processing</td>
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<thead>
<tr>
<th>Assessment criteria</th>
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</thead>
<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>4.1 explain methods of classifying and coding component parts into family groups</td>
</tr>
<tr>
<td>4.2 explain how family groups of components are sequenced for processing through grouped facilities.</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Range</th>
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<tbody>
<tr>
<td>Methods</td>
</tr>
<tr>
<td>Sequential; product; production; design; Opitz method; classification of parts into families</td>
</tr>
<tr>
<td>Sequence</td>
</tr>
<tr>
<td>Layout; product; process; fixed position; group; sequencing of families for groups of facilities</td>
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<tr>
<th>Learning outcome</th>
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</thead>
<tbody>
<tr>
<td>The learner will:</td>
</tr>
<tr>
<td>5. be able to plan engineering activities</td>
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<thead>
<tr>
<th>Assessment criteria</th>
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</thead>
<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>5.1 produce process plans from given data</td>
</tr>
<tr>
<td>5.2 produce schedules from process plans.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>Process plans</td>
</tr>
<tr>
<td>Forecast to identify timings and completion dates; materials required; equipment and tooling required; methods or processes employed; labour requirements and planning for quality checks; proposal for data logging; use of computers; MRP</td>
</tr>
<tr>
<td>Schedule</td>
</tr>
<tr>
<td>Developed from the process planning and customer requirements; lead times; using scheduling techniques such as CPA, Gantt charts, software packages (CMMS, CPS, CAM, CAPP, CIM), OPT philosophy, MRP</td>
</tr>
</tbody>
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Unit 406  
Statistical analysis for engineers

<table>
<thead>
<tr>
<th>Level:</th>
<th>4</th>
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<tbody>
<tr>
<td>UAN:</td>
<td>M/506/9270</td>
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<tr>
<td>GLH:</td>
<td>45</td>
</tr>
<tr>
<td>NLH:</td>
<td>100</td>
</tr>
<tr>
<td>Assessment method:</td>
<td>Dated written paper</td>
</tr>
</tbody>
</table>

**Aim:**
The purpose of this unit is to enable learners to gain an understanding of statistical concepts and techniques used in analysis and be able to apply these techniques in industrial problems. Learners will understand the need to collect valid and appropriate sample data. They will acquire knowledge of statistical analysis techniques and develop practical analysis skills and apply these to the study of engineering products and processes. Learners will be able to provide unbiased conclusions and recommendations arising from the analysis undertaken.

**Note**
This unit may be supported by the provision of computer-based statistical analysis software and the learner could have the opportunity to use this software to reinforce understanding and help in the practical application of the analysis techniques presented in the unit.

**Learning outcome**
The learner will:
1. understand the causes of variation in industrial processes

**Assessment criteria**
The learner can:
1.1 explain sources of variation due to **assignable causes** in industrial processes
1.2 explain the importance of identifying and removing assignable causes
1.3 explain the **nature of random variation** in industrial processes.
### Range

#### Assignable causes
Human factors; mistakes in computation and measurement; disinterest and/or carelessness; systematic error sources (faulty equipment calibration or observer bias)

#### Nature of random variation
Occur after systematic errors have been accounted for; result from range of uncontrollable effects; ambient/environmental conditions; temperature; humidity; instrument uncertainties

### Learning outcome
The learner will:

2. understand statistical concepts and functions

### Assessment criteria
The learner can:

2.1 explain the relationship between sample data and the total data population

2.2 identify different distributions used for sample statistics

2.3 explain the importance of the normal probability distribution for sample statistics

### Range
#### Relationship
- Terminology (observational data, variables, attributes, population, sample)
- Probability (sets, events, definitions, conditional probability, Bayes theorem)
- Random variables (discrete, continuous)
- Sampling methods

#### Different distributions
*Probability distributions* (histograms, continuous density, discrete and cumulative functions); *Theoretical distributions* (uniform, exponential, Normal, Weibull, Bernoulli, binomial, Poisson)

**Normal probability distribution**
Central limit theorem

### Learning outcome
The learner will:

3. be able to calculate unbiased estimates of population parameters

### Assessment criteria
The learner can:

3.1 explain common statistical techniques for summarising data

3.2 use statistical techniques to calculate unbiased estimates of population parameters using sample data.
**Summarising data**
Mean; median; mode; variance; standard deviation; proportion

**Statistical techniques**
Sampling statistics (central limit theorem, standard error of the mean and its distribution); sampling distributions (Normal, Chi-square, Student t, F-distributions); sampling intervals (confidence intervals for mean and difference of two means when variance is or is not known)

**Learning outcome**
The learner will:
4. be able to solve industrial problems using statistical analysis of sample data

**Assessment criteria**
The learner can:
4.1 test proposed statistical hypotheses about given populations
4.2 use tests to identify population distributions
4.3 conduct one-way analyses of variance (anova)
4.4 evaluate correlation coefficients and perform a linear regression
4.5 evaluate the reliability of manufactured engineering products.

**Statistical hypotheses**
Null and alternative hypotheses (type 1 and 2 errors, level of significance, operating characteristic curves); tests for means (one sample and two sample t-tests with known or unknown variance, paired t-tests)

**Tests to identify population distributions**
Chi-square goodness of fit test; Kolmogorov-Smirnov goodness of fit test

**Analysis of variance**
Assumptions; single factor (one-way) tests; fixed effects model; random effects model

**Correlation coefficients**
Coefficient of determination; correlation coefficient; coefficients of linear (one-dimensional) regression

**Reliability**
Failure rate function (hazard function); reliability modelling and estimation; repairable and non-repairable systems; exponential failure law; mean time to failure (MTTF); mean time between failures (MTBF); reliability of systems comprising components in serial and parallel combinations with active or standby redundancy
Unit 407  Computer Aided Design for manufacture

Level:  
4

UAN:  
T/506/9271

GLH:  
60

NLH:  
150

Assessment method:  
Assignment

Aim:  
The purpose of this unit is to enable learners to develop an understanding of CAD/CAM systems used in advanced manufacturing. Learners will understand the benefits of using both systems, their application in the workplace and will be able to recommend the implementation of CAD/CAM in manufacturing processes.

Learning outcome

The learner will:
1. be able to produce 3D parts using Parametric Modelling

Assessment criteria

The learner can:
1.1 create 2D & 3D Sketches with the CAD Environment
1.2 create 3D Models using a range of Feature Commands
1.3 Export 3D CAD Models for CNC, 3D Printing or Laser/Plasma Cutting.

Range

2D & 3D Sketches, 3D Models
Drawing Tools, Constraints, Solid Geometry
Feature Commands
Extrude, Revolve, Loft, Fillet, Chamfer, Shell, Sweep, Work Planes, Patterns
CNC, 3D Printing or Laser/Plasma Cutting
DXF, IGES, STL, STEP
Learning outcome
The learner will:
2. be able to produce 3D working assemblies

Assessment criteria
The learner can:
2.1 create **3D Assemblies using Modelled Parts** and **Content Libraries**
2.2 create **3D Functional Assemblies** using correct **constraining procedures**
2.3 create **3D Exploded Assemblies** to demonstrate the assembly/disassembly process.

Range
**3D Assemblies using Modelled Parts**
Multiple part models
**Content Libraries**
Nuts, Bolts, Screws, Washers, Bearings
**3D Functional Assemblies**
Rotary and Linear Motion
**constraining procedures**
Flush, Parallel, Joint
**3D Exploded Assemblies**
Presentation Files
**assembly/disassembly process**
Putting the assembly together or taking apart

Learning outcome
The learner will:
3. be able to create drawings

Assessment criteria
The learner can:
3.1 create **2D drawings of individual parts** for manufacture to **BS8888**
3.2 Create **2D Assembly Drawings** to BS8888.

Range
**2D drawings of individual parts**
Orthographic, Sections, Break Outs, Detail
**BS8888**
Templates, Line Types, Dimensioning, View Layouts, Metric units,
Surface Finish, GDT
**2D Assembly Drawings**
General Assembly view, Exploded Assembly view, BOM
Learning outcome
The learner will:
4. be able to produce rendered images and animations

Assessment criteria
The learner can:
4.1 create rendered images of parts and assemblies
4.2 create animations of assembly/disassembly processes
4.3 create animations of assembly functionality

Range
Rendered Images
Photo Realistic, Lighting, Environment
Animations
e.g. MP4, avi files
Assembly/Disassembly Processes
Exploding & Reassembling
Assembly Functionality
Rotary & Linear Motion, Gears, Chains, Sprockets
Unit 408  Data communication and networks

Level: 4
UAN: F/506/9273
GLH: 65
NLH: 150
Assessment method: Assignment

Aim: The purpose of this unit is to enable learners to develop an understanding of data communication and networks used for electrical and electronic engineering operations. The unit also enables learners to practically apply skills and knowledge to given communication/network applications.

Learning outcome
The learner will:
1. understand data communication media, connectors and methods of data transmission

Assessment criteria
The learner can:
1.1 explain different types of data transmission media
1.2 explain attenuation and interference with different transmission media
1.3 explain the applications of different cable connectors
1.4 compare analogue and digital signals for data transmission
1.5 explain the effects of bandwidth limitations for data transmission
1.6 describe modulation techniques used for data transmission
1.7 explain simplex, duplex and half-duplex communications
1.8 assess different methods and techniques of data transmission
1.9 explain how data channels may be shared using different methods of multiplexing.

Range
Types
Coaxial cable; twisted pair (shielded and unshielded); optical fibre; radio waves; Microwave; infra-red
Cable connectors
BNC (plugs, sockets, ‘T’ connectors, terminators); RJ45 connectors; D-Type; USB
Effects
Interference and data rates
Modulation techniques
Amplitude; frequency; phase

Methods
Serial; parallel; baseband and broadband

Techniques
Asynchronous and synchronous

Methods
Time Division Multiplexing (TDM); Frequency Division Multiplexing (FDM)

Learning outcome
The learner will:
2. understand basic network theory and applications

Assessment criteria
The learner can:
2.1 explain the operation of network models
2.2 describe network applications and services.

Range
Network models
ISO/OSI; TCP/IP

Applications and services
Electronic mail (e-mail) for electronic communication, browser for access to internet and Worldwide Wide Web (WWW), scheduling for group meetings and appointments, File Transfer Protocol (FTP) for the transfer of files, Hypertext Transfer Protocol (http) for retrieval of world wide web pages (WWW)

Learning outcome
The learner will:
3. understand how to make direct connections between devices

Assessment criteria
The learner can:
3.1 explain different codes used for data transmission
3.2 describe standard character sets for data representation
3.3 describe standards used for data transmission
3.4 explain connection formats
3.5 explain the protocols used between connections
3.6 explain the function of modems used in connections.

Range
Codes
Character; control signal

Character sets
ASCII; EBCDIC

Standards
RS232; V24; X21
### Connection formats
RS232 (9-way and 25-way D type); USB

### Protocols
XON; XOFF; CTS; RTS

### Connections
DTE to DTE; DTE to DCTE

### Connections
DTE to DTE; DTE to PSTN

### Learning outcome
The learner will:

4. be able to safely establish connections between similar devices for data transfer

### Assessment criteria
The learner can:

4.1 use **safe working practices** on mains-powered equipment

4.2 use **cables and connectors** to provide a serial port direction connection

4.3 apply **communication software protocol** to allow file transfer.

### Range
**Safe working practices**  
Safe isolation methods; appropriate to national standards; use of anti-static equipment

**Cables and connectors**  
Construction and testing of serial port interfaces and connections

**Connection**  
DTE to DTE; USB,

**Communication software protocol**  
Number of data bits; parity; number of start bits; number of stop bits; baud rate

### Learning outcome
The learner will:

5. understand communication network concepts and components

### Assessment criteria
The learner can:

5.1 explain the **advantages and disadvantages** of networking devices

5.2 evaluate attributes of local area networks (LAN) and wide area networks (WAN)

5.3 explain the purpose and **types of servers** available on a network

5.4 evaluate types of **network topologies**

5.5 explain **methods** used for accessing a data transmission network

5.6 explain **types** of data error detection methods

5.7 describe the operational principles of **main hardware components** in networks

5.8 explain the functions of **network components**
5.9 evaluate different **protocols** used in networks
5.10 explain the relevance of using **international standards** for data transmission
5.11 describe **communication network technologies**.

**Range**

<table>
<thead>
<tr>
<th>Advantages and Disadvantages</th>
<th>Shared devices; cost; item failure; accessibility; security; management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types or servers</td>
<td>File; web; mail; database; media; application</td>
</tr>
<tr>
<td>Network topologies</td>
<td>Bus; ring; mesh; star</td>
</tr>
<tr>
<td>Methods</td>
<td>Token passing; CSMA/CD data control flow; TDMA; CDMA</td>
</tr>
<tr>
<td>Types</td>
<td>Parity checking; checksum; CRC</td>
</tr>
<tr>
<td>Main hardware</td>
<td>Server; PCs; terminals; peripherals</td>
</tr>
<tr>
<td>Network components</td>
<td>Hubs; repeaters; regenerators; bridges; routers; switches including typical features</td>
</tr>
<tr>
<td>Protocols</td>
<td>TCP/IP; UDP; ARP; ICMP; IPv6</td>
</tr>
<tr>
<td>International standards</td>
<td>CCITT; ISO; ANSI; IEEE; EIA</td>
</tr>
<tr>
<td>Communication network technologies</td>
<td>ISDN; ASDL; HDSL; VDSL; SDSL including typical data rates</td>
</tr>
</tbody>
</table>

**Learning outcome**

The learner will:
6. be able to install a functioning data network interface card in local area networks (LAN)

**Assessment criteria**

The learner can:
6.1 describe the operation of LANs
6.2 explain the purpose of different types of network interface cards (NIC)
6.3 describe security issues of externally connected networks
6.4 explain **problems** that may prevent networks from operating correctly
6.5 install appropriate network interface card
6.6 use software and **hardware resources** to connect devices
6.7 explain the purpose of **software resources** for network hardware operation
6.8 install network **software resources** using appropriate operating systems
6.9 create **user access** rights to resources on devices.
## Range

### Problems
Loose socket connection; break in cable; incompatible protocols installed

### Installation
IRQ; port address; memory address

### Hardware resources
Cables; cable connectors; components

### Software resources
Drivers; protocols; services

### User access
Client logon and directory/folder facilities

## Learning outcome

The learner will:

7. be able to commission local area network (LAN) operation

## Assessment criteria

The learner can:

7.1 produce network implementation documents
7.2 Test network installation and configuration
7.3 evaluate network installation and configuration.

## Range

### Network implementation documents
Configuration; protocol(s) used; type of network interface cards used; whether passwords are required for shared resources and specification of which resources are shared

### Installation and configuration
Testing of functionality; benefit to users; security of data; speed of data transfer for files and printed output and any problems which may have occurred

## Learning outcome

The learner will:

8. understand data network services maintenance and management

## Assessment criteria

The learner can:

8.1 explain tasks involved in the management of networks
8.2 explain the process for managing individual and group accounts on networks
8.3 evaluate network security techniques to prevent unauthorised access to data
8.4 assess the importance of security software.
<table>
<thead>
<tr>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tasks</strong></td>
</tr>
<tr>
<td>System configuration; management of users; management of workstations; activity log reporting; error log reporting; traffic analysis; performance analysis; regular backup of data</td>
</tr>
<tr>
<td><strong>Managing</strong></td>
</tr>
<tr>
<td>Creating; disabling; deleting</td>
</tr>
<tr>
<td><strong>Network security techniques</strong></td>
</tr>
<tr>
<td>Physical access; user identification code; password; access rights; proxy server; encryption</td>
</tr>
<tr>
<td><strong>Security software</strong></td>
</tr>
<tr>
<td>Antivirus; firewall; antispyware; desktop; network.</td>
</tr>
</tbody>
</table>
## Unit 409  Principles and operation of electrical machines

<table>
<thead>
<tr>
<th>Level:</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAN:</td>
<td>J/506/9274</td>
</tr>
<tr>
<td>GLH:</td>
<td>50</td>
</tr>
<tr>
<td>NLH:</td>
<td>150</td>
</tr>
<tr>
<td>Assessment method:</td>
<td>Dated written paper</td>
</tr>
<tr>
<td>Aim:</td>
<td>The purpose of this unit is to enable learners to develop an understanding of the principles and operations of electrical machines in engineering operations.</td>
</tr>
</tbody>
</table>

### Learning outcome
The learner will:
1. understand the principles and operation of dc machines

### Assessment criteria
The learner can:
1.1 describe components of dc machines
1.2 explain the operating principles of dc machines
1.3 describe types of winding arrangements and their effects on operation
1.4 solve problems involving dc machine parameters.

### Range
**Operating principles**
Torque, speed and rotation for shunt, series and compound wound machines

**Types**
Shunt; series; compound

**Effects**
Armature reaction (effects and minimisation)

**Parameters**
Voltage, current, power/horse-power, speed, starting torque
Learning outcome

The learner will:
2. understand the principles and operation of three-phase induction motors

Assessment criteria

The learner can:
2.1 evaluate features of different types of motors
2.2 outline parameters of induction motors
2.3 describe the load characteristic of three-phase induction motors
2.4 illustrate the equivalent circuit of three phase induction motors
2.5 assess types of induction motor starter systems
2.6 solve problems involving induction motor parameters.

Range

Types of motors
Wound rotor and squirrel cage induction

Types of induction motor starter systems
Direct on-line; Star-delta; Auto-transformer; Rotor resistance

Learning outcome

The learner will:
3. understand the principles and operation of synchronous machines

Assessment criteria

The learner can:
3.1 describe the operating principles of synchronous machines
3.2 analyse the operation of synchronous machines for different rotor types
3.3 describe the wound rotor synchronous induction motor
3.4 illustrate the equivalent circuit of a synchronous motor
3.5 solve problems involving synchronous induction motor parameters.

Range

Machines
Motors; generators

Types
Salient pole; cylindrical

Parameters
Power input; power output; efficiency and power factor correction
Learning outcome
The learner will:
4. understand the principles and operation of power transformers

Assessment criteria
The learner can:
4.1 explain the operating principles of a power transformer
4.2 assess the suitability of three phase transformers for different applications
4.3 outline standards for power transformer terminal markings
4.4 assess the functions of transformer winding vector groups
4.5 evaluate transformer types according to properties
4.6 analyse the consequences of incompatible transformers connected in parallel
4.7 explain faults that can occur with power transformers
4.8 solve problems involving transformer parameters.

Range

**Principles**
Ratios for voltage, current and turns; regulation and efficiency

**Applications**
Transmission systems; distribution systems

**Standards**
Current BS, EN or ISO equivalent

**Markings**
HV; LV; potential; phase shift and winding method

**Groups**
Including phasor diagrams (Star-star; delta-delta; star-delta; delta-star)

**Properties**
Winding type; low voltage displacement; high voltage displacement and methods of cooling

**Incompatible**
Polarity; phase sequence; phase difference; voltage ratio; per-unit impedance
**Unit 410 Using electrical protection techniques for engineering operations**

<table>
<thead>
<tr>
<th>Level:</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAN:</td>
<td>L/506/9275</td>
</tr>
<tr>
<td>GLH:</td>
<td>45</td>
</tr>
<tr>
<td>NLH:</td>
<td>150</td>
</tr>
<tr>
<td>Assessment method:</td>
<td>Assignment</td>
</tr>
</tbody>
</table>

**Aim:**
The purpose of this unit is to enable learners to develop an understanding of how to use electrical protection techniques for engineering operations.

### Learning outcome
The learner will:
1. be able to solve cable fault location problems using the bridge method

### Assessment criteria
The learner can:
1.1 explain the bridge method of cable fault location
1.2 use algebraic expressions for cable fault location
1.3 solve cable fault location problems.

### Learning outcome
The learner will:
2. understand how to simplify power systems into one-line impedance circuits

### Assessment criteria
The learner can:
2.1 explain fault level, base MVA and per unit impedance
2.2 explain the construction of supply system one-line impedance diagrams
2.3 evaluate electrical supply system parameters to simplify electrical supply system networks to one-line impedance diagrams.

### Range
**Parameters**
Sbase; Vbase; Zbase
### Learning outcome
The learner will:
3. understand current transformer application in electrical system protection

### Assessment criteria
The learner can:
3.1 explain current transformer principles of operation
3.2 evaluate current transformer parameters
3.3 evaluate classes of current transformer for particular applications.

#### Range
**Parameters**
Magnetic field strength; flux density; total flux; reluctance

### Learning outcome
The learner will:
4. be able to specify electrical protection relays for electrical systems

### Assessment criteria
The learner can:
4.1 describe relay time relationships
4.2 evaluate advantages and disadvantages of unit differential protection
4.3 solve relay problems.

#### Range
**Time**
Desired operating time; time setting multiplier and the British Standard IDMT characteristic time for full travel

**Problems**
IDMT relay setting from maximum load current for different system voltages; fault current as a multiple of relay setting; time for full travel of an IDMT relay from the BS characteristic (ISO equivalent); desired operating time of an IDMT relay; TMS of an IDMT relay and setting times of graded relays; fault clearance time

### Learning outcome
The learner will:
5. understand the principles of earthing and circuit protection of electrical plant

### Assessment criteria
The learner can:
5.1 explain earthing system arrangements
5.2 evaluate earth fault current in electrical circuits
5.3 describe circuit protection against various fault types.
<table>
<thead>
<tr>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arrangements</strong></td>
</tr>
<tr>
<td>TN; TT; IT; TN-C-S, TN-S</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overload; short-circuit; earth fault</td>
</tr>
</tbody>
</table>
Unit 411  Electrical services and installation

Level: 4
UAN: Y/506/9277
GLH: 41
NLH: 100
Assessment method: Assignment

Aim: The purpose of this unit is to enable learners to develop an understanding of electrical services and installation. Learners will look at regulations that apply, materials and equipment used and types of earthing systems and circuits.

The unit also enables learners to practically apply skills and knowledge to design aspects of low voltage electrical installations.

Learning outcome
The learner will:
1. understand the regulations applicable to electrical installations and services

Assessment criteria
The learner can:
1.1 outline regulations for safe electrical installation practice and equipment
1.2 interpret International Code of Protection ratings for electrical equipment
1.3 explain international standards for the use of electrical equipment in hazardous areas.

Range
Regulations
National (BS7671); European and international (IEC)
International standards
CENELEC; ATEX; IEC
### Learning outcome

The learner will:

2. understand materials and equipment used in electrical services and installations

### Assessment criteria

The learner can:

2.1 define types of **wiring systems** by their **properties**
2.2 evaluate types of **electrical equipment** according to installation method and location
2.3 evaluate types of **wiring enclosure** according to installation method and location
2.4 evaluate electrical switchgear in respect of **purpose** and operation.
2.5 evaluate **circuit protective devices** according to the type of fault protection required.

### Range

<table>
<thead>
<tr>
<th><strong>Wiring systems</strong></th>
<th>Wiring systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermosetting insulated cables including flexes; single and multicore thermoplastic (PVC) and thermosetting insulated cables; PVC/PVC flat profile cable; MIIC (with and without PVC sheath); SWA cables (PILC, XLPE, PVC); armoured/braided flexible cables and cords; data cables; fibre optic cables and fire resistant cables</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Properties</strong></th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of construction; voltage rating; material of construction; size and compatibility for installation method/location</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Electrical equipment</strong></th>
<th>Electrical equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolators and switches; socket-outlets; distribution-boards; consumer units; earthing fault and over current protective devices; luminaries; control equipment; data socket outlets; auxiliary equipment (eg heating/water system components)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Wiring enclosure</strong></th>
<th>Wiring enclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduit (PVC and metallic); trunking (PVC and metallic); cable tray; cable basket; ladder systems; ducting; modular wiring systems and Busbar systems/Powertrack</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Purpose</strong></th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection; isolation; switching</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Circuit protective devices</strong></th>
<th>Circuit protective devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCB; RCBO; RCD; Fuses (BS1361, BS3036 and BS88 or national equivalent)</td>
<td></td>
</tr>
</tbody>
</table>
### Learning outcome

The learner will:

3. understand earthing systems and circuits

### Assessment criteria

The learner can:

3.1 define types of permitted **earthing systems**
3.2 analyse electrical circuit earth fault loop **parameters**
3.3 explain the operation of residual current devices (RCDs)
3.4 analyse earth electrode resistance and soil resistivity using **standard** techniques
3.5 evaluate earthing installation testing methods according to **standards**.

### Range

**Earthing systems**

- TN-C; TN-S; TN-C-S; TT; IT

**Parameters**

- Earth fault loop impedance; external loop impedance; fault current; protective conductor size; circuit protective devices

**Standard**

- IET GN3 methodology (or international equivalent)

**Standards**

- National (BS7671); International

### Learning outcome

The learner will:

4. understand the requirements of special electrical installations or locations

### Assessment criteria

The learner can:

4.1 outline prescribed **locations** or **installations** with particular electrical installation requirements
4.2 analyse electrical installation requirements in relation to special **locations** or **installations**.

### Range

**Locations or installations**

- As per BS7671 – Part 7 definition; or international equivalent
<table>
<thead>
<tr>
<th><strong>Learning outcome</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The learner will:</td>
<td>5. understand the requirements of electrical equipment for protection against other hazards</td>
</tr>
<tr>
<td><strong>Assessment criteria</strong></td>
<td></td>
</tr>
<tr>
<td>The learner can:</td>
<td></td>
</tr>
<tr>
<td>5.1</td>
<td>describe hazards associated with static charge</td>
</tr>
<tr>
<td>5.2</td>
<td>evaluate methods of minimising hazards associated with high resistivity hydrocarbons and other flammable sources</td>
</tr>
<tr>
<td>5.3</td>
<td>evaluate the use of Zener diode barrier circuits</td>
</tr>
<tr>
<td>5.4</td>
<td>assess the suitability of different types of fire system installations</td>
</tr>
<tr>
<td>5.5</td>
<td>evaluate electrical equipment for use in hazardous areas according to regulations</td>
</tr>
<tr>
<td>5.6</td>
<td>evaluate international regulations to establish equivalence to national classifications and equipment classes</td>
</tr>
<tr>
<td>5.7</td>
<td>assess types of hazardous area electrical equipment appropriate to various industrial and commercial locations</td>
</tr>
<tr>
<td>5.8</td>
<td>analyse certification authority requirements for electrical equipment for use in hazardous areas.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Learning outcome</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The learner will:</td>
<td>6. be able to design aspects of low voltage electrical installations</td>
</tr>
<tr>
<td><strong>Assessment criteria</strong></td>
<td></td>
</tr>
<tr>
<td>The learner can:</td>
<td></td>
</tr>
<tr>
<td>6.1</td>
<td>explain the relationship between electrical installation design and statutory/non-statutory regulations</td>
</tr>
<tr>
<td>6.2</td>
<td>describe considerations for designing final circuits</td>
</tr>
<tr>
<td>6.3</td>
<td>explain the requirements for the assessment of general characteristics of electrical installations</td>
</tr>
<tr>
<td>6.4</td>
<td>use design calculations relevant to electrical installation design parameters</td>
</tr>
<tr>
<td>6.5</td>
<td>assess how the use of associated protective systems affects the design of electrical installations.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Range</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Statutory/non-statutory regulations</strong></td>
<td></td>
</tr>
<tr>
<td>BS 7671; IET Guidance Notes; Electricity at Work Regulations; Electricity Safety Quality and Continuity Regulations; The Building Regulations (England &amp; Wales) (Scotland) and Construction (Design Management) Regulations; international equivalence</td>
<td></td>
</tr>
<tr>
<td><strong>Final circuits</strong></td>
<td></td>
</tr>
<tr>
<td>Ring final; radial; powertrack and bus bar trunking; circuit loading.</td>
<td></td>
</tr>
<tr>
<td><strong>Requirements</strong></td>
<td></td>
</tr>
<tr>
<td>Purpose of supplies and structure; maximum demand and diversity; arrangements of live conductors and earthing arrangements; supplies; division of installation; compatibility; maintainability and continuity of service</td>
<td></td>
</tr>
</tbody>
</table>
**Parameters**
Cable sizes; protective device ratings; cable grouping; input power; line and phase current loads; earth fault loop impedance; diversity; prospective fault current

**Associated protective systems**
Lightning protection systems using zones of protection; lightning protection systems component parts; methods of protection against corrosion and erosion; manual fire detection systems; automatic fire detection systems; standby lighting systems; self-contained emergency lighting systems; centrally supplied emergency lighting systems; generator systems for alternative supplies; UPS systems for alternative supplies
Unit 412  Electrical supply and distribution

**Learning outcome**
The learner will:
1. understand principles, components and economic factors of electrical transmission and distribution systems

**Assessment criteria**
The learner can:
1.1 explain the principles of ac power generation
1.2 explain the methods of ac power generation
1.3 explain the principles of ac power transmission
1.4 explain the functions of local distribution system components
1.5 evaluate advantages and disadvantages of network systems for use in engineering supply connections
1.6 analyse costs involved with electricity supply systems for selection of use.

**Range**

**Power generation**
3-phase generators; frequency; phase displacement; voltage

**Methods**
Fossil fuel; nuclear; renewable

**Power transmission**
Transmission voltages; National grid; sub-stations; transformers

**Components**
Isolating switches; contactors; fuses and circuit breakers, switch-fuses and fuse-switches; oil switches

**Network systems**
Radial; parallel and open and closed ring; feeder

**Costs**
Fixed and variable (tariffs – using system values: load, demand, maximum demand, diversity factor, load factor and power factor)
### Learning outcome
The learner will:

2. be able to analyse the characteristics of three-phase power transformers in parallel operation

### Assessment criteria
The learner can:

2.1 explain the conditions for transformers to successfully and safely operate in parallel
2.2 explain the operation of voltage control of transmission lines using tap changing transformers
2.3 assess the kVA load of transformers operating in parallel using impedance based schematics
2.4 assess transformer impedances connected in parallel referred to primary or secondary windings
2.5 assess the properties of system configurations of transformers connected in parallel.

### Range
**Load**
Product of total load being shared and the ratio of transformer impedances

**Properties**
Load distribution; current circulation; phase regulation; in groupings; (using phasor diagrams where appropriate)

**System configurations**
Involving different complex impedances; supplying different loads over short transmission lines and connected in various configurations

### Learning outcome
The learner will:

3. be able to apply short transmission line theory for electrical supply configurations

### Assessment criteria
The learner can:

3.1 assess the configuration of supply systems using equivalent circuits
3.2 assess the configuration of systems using schematic diagrams and complex reactances
3.3 illustrate series equivalent circuits representing transmission lines
3.4 evaluate the performance of short line receiving end line systems
3.5 assess short line system parameters using complex notation from given data.
Range

Supply systems
Consisting of generators; transformers; motors; lines; loads

Systems
Radial supply; parallel; ring

Equivalent circuits (in the form of phasor diagrams)
Using load current as a reference and using the receiving end voltage as the reference

Performance
For different power factors, from given data, for control of real and reactive power by transmission angle and sending voltage and for demonstrating the effects of variation in real power and power factor on the sending end voltage

Parameters
The sending end voltage; line voltage drop; load angle

Learning outcome
The learner will:
4. understand operating characteristics of three-phase generators on infinite busbars

Assessment criteria
The learner can:
4.1 explain the relationships between generator parameters
4.2 assess the operation of synchronous machines using equivalent circuits
4.3 assess the relationship between generator parameters
4.4 illustrate generator load diagrams using given data
4.5 evaluate generator load diagrams to measure operational performance and limits
4.6 assess generator performance limitations with respect to operating characteristics.

Range

Parameters
Stator phase voltage; stator phase current; generated voltage and synchronous reactance and impedance

Parameters
Stator phase voltage; stator phase current; generated voltage; load angle; stator voltage drop; power factor; constant power; constant VAR control mode; terminal voltage

Given data
Stator phase current; power; reactive power; load angle; power factor; active power lines; rotor current limit; unity power factor line; areas of lagging and leading power factor; power output limit; generated voltage; terminal voltage

Limits
Prime mover limit (MW or turbine power limit); theoretical and practical stability limits; excitation; stator heat limits
Operating characteristics
Real power output; reactive power output; the p.u. excitation; operating power factor and apparent power output; short circuit ratio (SCR)

Learning outcome
The learner will:
5. be able to solve fault levels on electrical supply system configurations

Assessment criteria
The learner can:
5.1 explain terms used in electrical supply system configurations
5.2 illustrate supply systems using one-line diagrams
5.3 describe principles used in high voltage circuit breakers
5.4 assess the construction and operation of high voltage protection devices for use in different applications
5.5 assess the operation of circuit breakers using equivalent circuits
5.6 evaluate techniques for reducing fault levels to specified values
5.7 assess the magnitude of fault levels at various points using system parameters
5.8 evaluate the effects of system switching transients on electrical supply system operation
5.9 solve system fault level problems involving star/delta circuit transformations.

Range
Terms
Fault level; per unit impedance; grid in-feed; source fault VA
Supply systems
Appropriate symbols for generators, transformers and lines, units represented as voltages
Principles
Arc suppression; control; interruption and closing of circuits
High voltage protection devices
Bulk and minimum oil circuit breakers; air blast circuit breakers; vacuum interrupters; sulphur hexafluoride circuit breakers; HRC, liquid and expulsion fuses; high voltage fuses; switch fuses and fuse switches
Techniques
In accordance to industry standards (UK and International)
Parameters
Circuit p.u. impedance; base VA and impedance circuit reduction
### Learning outcome

The learner will:

6. understand protection systems used in electrical supply systems

### Assessment criteria

The learner can:

6.1 explain elements used in overcurrent protection systems

6.2 explain the operation of overcurrent protection equipment on contactors and circuit breakers

6.3 explain the operation of overcurrent and differential protection systems

6.4 explain over-voltage protection methods

6.5 evaluate circuit breaker operations relative to fault positions

6.6 assess advantages of IDMT relays, Directional Overcurrent relays and unit protection for use in supply systems

6.7 assess the operation of time setting multipliers and plug setting multipliers for IDMT relays in electrical supply systems.

### Range

**Protection systems**

Inverse definite minimum time (IDMT) relays; supply system unit circulating current differential protection schemes (as applied to a large generator and to protect a star/delta transformer)

**Methods**

Overhead earth wires on EHV lines; surge diverters; non-linear surge diverters

**IDMT relays**

With reference to BS142 (BS EN 60255) IDMT characteristic curve and to give the required discrimination in radial feeder circuits with various load take off points
Unit 413  Testing and measurement of electronic and electrical systems

Level: 4
UAN: L/506/9289
GLH: 66
NLH: 100
Assessment method: Assignment

Aim: The purpose of this unit is to enable learners to develop an understanding of testing and measurements of electrical and electronic systems. The unit also enables learners to practically apply skills and knowledge to given testing and measurement applications.

Learning outcome
The learner will:
1. understand the selection of equipment used to measure electrical and electronic values

Assessment criteria
The learner can:
1.1 explain the operation of test equipment
1.2 describe types of signal transmission systems used for measurement
1.3 evaluate the selection of test equipment used to measure differing values.

Range
Test equipment
Explain with the aid of block diagrams as appropriate: oscilloscopes; meters; signal generators; counters; logic analysers; spectrum analysers; low resistance ohmmeters; insulation resistance testers; voltage indicating devices; earth fault loop impedance testers; prospective fault current testers; RCD testers; earth electrode testers and phase rotation meters

Transmission systems
Coaxial; twisted pair; flat cable; single cable; clamp; fibre-optic; attenuation; phase change and frequency response; noise and noise reduction where appropriate; accounting for; response of the systems; transfer function; impulse response; frequency response and dynamic range

Selection
The correct equipment to measure signals based on; signal characteristics (continuous signals, discrete signals, frequency and period, peak, average; effective value, phase shift, amplitude, attenuated. Magnitude, peak to peak, time domain, frequency Domain, Fourier series of signals), actual or emulated, transmission system, environment, cost, availability, accuracy and required outcome.

**Values**
Electronic and low voltage electrical

<table>
<thead>
<tr>
<th>Learning outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>The learner will:</td>
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<table>
<thead>
<tr>
<th>Assessment criteria</th>
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<tbody>
<tr>
<td>The learner can:</td>
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</table>

<table>
<thead>
<tr>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signal characteristics</strong></td>
</tr>
<tr>
<td>Continuous signals; discrete signals; frequency and period; peak; average; effective value; phase shift; amplitude; peak to peak; time domain; frequency domain; Fourier series of signals</td>
</tr>
<tr>
<td>** Appropriateness of use**</td>
</tr>
<tr>
<td>Errors; accuracy; significant digits; rounding numbers; statistical analysis; error rates. Including potential solutions to problems relating to values measured</td>
</tr>
<tr>
<td><strong>Methods</strong></td>
</tr>
<tr>
<td>Graphs (linear, polar and logarithmic – including line of best fit), tables and use of spreadsheets</td>
</tr>
<tr>
<td><strong>Techniques</strong></td>
</tr>
<tr>
<td>Graphical analytical techniques to illustrate outcomes including: system/component performance, fault diagnosis, compliance to design/operational parameters</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Learning outcome</th>
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<th>Assessment criteria</th>
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<td>The learner can:</td>
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</table>
**Range**

**Internal architecture**
Using block diagrams as appropriate: input section (eg transducers), signal conditioning and multiplexer, sampling methods, output filtering and corrections (sin x/x), errors, A/D conversion, CPU and I/O devices, data recording methods (eg graphic and magnetic), operation of bus structures and control of data lines.

**Test**
As appropriate to range included within 3.1

---

**Learning outcome**

The learner will:
4. understand procedures for the inspection of electrical systems

**Assessment criteria**

The learner can:
4.1 outline the regulatory requirements for inspection, testing and commissioning of electrical systems
4.2 outline the procedures to prepare for inspection of electrical systems
4.3 explain how human senses could be used during the inspection process
4.4 assess items that would form part of inspection checklists for electrical systems.

---

**Range**

**Regulatory requirements**
UK current or international equivalents of: IET wiring regulations and IET Guidance Note 3 Electricity at Work Regulations 1989

**Electrical systems**
Low voltage - new, existing, three phase, single phase

**Procedures**
Contact with client; arrange isolation timings; range and limitations of inspection; gather information (client, test results, certificates); risk assessment; prepare method statements

**Human senses**
Sight, touch, hearing, smell

**Inspection**
Initial installation, periodic review, minor works

**Electrical systems**
Low voltage - new, existing, three phase, single phase

---

**Learning outcome**

The learner will:
5. understand procedures used for testing of electrical systems

**Assessment criteria**

The learner can:
5.1 explain the purpose and procedures for conducting regulatory tests on electrical systems
5.2 explain the preparation requirements for testing
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5.3</td>
<td>explain the <strong>implications</strong> of test values that are non-compliant with regulatory standards</td>
</tr>
<tr>
<td>5.4</td>
<td>explain the requirements for the safe and correct <strong>use</strong> of <strong>instruments</strong> to be utilised for testing.</td>
</tr>
</tbody>
</table>
Range

Regulatory tests
Verify continuity of conductors (circuit protective, earthing, bonding, ring final); insulation resistance; polarity; earth electrode resistance; earth fault loop impedance; prospective fault current; correct operation of RCDs; functional testing; phase rotation (to include explanation of sequence of tests)

Electrical systems
Low voltage - new, existing, three phase, single phase

Preparation requirements
Risk assessment; safe system of work; precautions to be taken when carrying out tests; safe isolation; instrumentation fit for purpose; communication with clients; range and limitations

Implications
Shock; fire; burns; injury

Use
Correct scale/settings of the instrument; safety checks; functioning correctly; calibrated in accordance with regulatory requirements

Instruments
In accordance with UK current or international equivalents of: HSE guidance document GS 38; low resistance ohmmeter; insulation resistance tester; voltage and current indicating devices; earth fault loop impedance tester; prospective fault current tester; RCD tester; earth electrode tester; phase rotation meter

Learning outcome
The learner will:
6. understand the requirements for documenting installed electrical systems

Assessment criteria
The learner can:
6.1 explain the purpose of certification documentation
6.2 explain the responsibilities of personnel involved in the completion of certification documentation
6.3 explain the regulatory requirements for documenting electrical systems.

Range
Certification
Electrical installation certificate; electrical installation condition report; minor works certificate; schedule of inspections; schedule of test results
Personnel
Designer; installer; tester
Documentation
Regulatory requirements; UK current or international equivalents of: IET wiring regulations; IET Guidance Note 3; recording; retention
Regulatory requirements
UK current or international equivalents of: IET wiring regulations; IET Guidance Note 3; recording; retention
<table>
<thead>
<tr>
<th>Learning outcome</th>
<th>The learner will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>be able to inspect electrical wiring systems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>The learner can:</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1</td>
<td>use <strong>safe systems</strong> of work for inspection of electrical systems</td>
</tr>
<tr>
<td>7.2</td>
<td>carry out electrical system <strong>inspections</strong>.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
<th>Safe systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design; apply; document; safe isolation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inspection</th>
<th>UK current or international equivalents of: IET Wiring Regulations, IET Guidance Note 3, specifications</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Learning outcome</th>
<th>The learner will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>be able to test the safety of electrical systems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>The learner can:</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1</td>
<td>use <strong>safe systems</strong> of work for testing electrical systems</td>
</tr>
<tr>
<td>8.2</td>
<td>carry out <strong>regulatory tests</strong> of electrical systems</td>
</tr>
<tr>
<td>8.3</td>
<td>carry out <strong>commissioning</strong> of electrical systems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
<th>Safe systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design; apply; document; safe isolation</td>
</tr>
</tbody>
</table>

| Regulatory tests | Verify continuity of conductors (circuit protective, earthing, bonding, ring final); insulation resistance; polarity; earth electrode resistance; earth fault loop impedance; prospective fault current; correct operation of RCDs; functional testing; phase rotation (to include explanation of sequence of tests) |

| Commissioning | Functionality; fitness for purpose; safety in accordance with the installation specification and complete documentation (electrical installation certificates, schedules of inspections, schedules of test results) |
Unit 414  Programmable logic controllers

Level: 4  
UAN: F/506/9290  
GLH: 60  
Assessment method: Assignment  
NLH: 100  

Aim: The purpose of this unit is to enable learners to develop an understanding of programmable controller systems. Learners will understand features, PLC information and communication techniques, programming methods and methods of diagnosing faults in programmable controlled environments.

The unit also enables learners to practically apply skills and knowledge to create operational programs to drive PLCs in industrial related tasks.

**Learning outcome**

The learner will:
1. understand features of programmable controller systems

**Assessment criteria**

The learner can:
1.1 explain the advantages of processor controlled logic systems over relay logic systems
1.2 explain the *internal architecture* of Programmable Logic Controllers (PLCs)
1.3 explain the *operational characteristics* of PLCs
1.4 explain the operational requirements for input and output *devices* used by PLCs
1.5 evaluate *types* of communication link used in programmable logic control systems and controllers.
## Internal architecture
- Storage devices
- Memory
- Central processing unit (CPU)
- Address bus
- Data bus
- Control bus
- Arithmetic logic unit (ALU)
- Opto-isolators
- Flags
- Shift registers

## Operational characteristics
- Scanning
- Performing logic operations
- Continuous updating
- Mass input/output (I/O) copying

## Devices
- Mechanical switches
- Non-mechanical digital sources
- Transducers
- Relays

## Learning outcome
The learner will:
2. Understand PLC information and communication techniques

### Assessment criteria
The learner can:
2.1 Describe the forms of signal interface used by PLCs
2.2 Explain the significance of digital resolution
2.3 Calculate the resolution of analogue-to-digital converters
2.4 Assess the uses of number systems in PLCs
2.5 Evaluate network topologies used by PLCs
2.6 Explain the use of logic functions in PLC programming
2.7 Explain how to write ladder logic programs using logic functions.

## Forms
- Analogue (0-10 V dc, 4-20 mA)
- Digital

## Resolution
- 9-bit
- 10-bit
- 12-bit

## Number systems
- Decimal
- Binary
- Octal
- Hexadecimal
- Binary-Coded Decimal (BCD)

## Network topologies
- Master to slave
- Peer to peer
- ISO
- IEE
- MAP

## Logic functions
- AND
- OR
- EXCLUSIVE OR
- NAND
- NOR

## Learning outcome
The learner will:
3. Understand PLC programming methods

### Assessment criteria
The learner can:
3.1 Explain the relationship between source codes and object codes
3.2 Identify methods of using text in PLCs
3.3 Assess the operation of PLC software functions
3.4 Explain the application of different PLC programming methods
3.5 Evaluate PLC advanced functions.
Methods of using text in PLCs
Contact labels; rung labels; programming lists; cross-referencing.

Functions
Contacts; coils; timers; counters; override facilities; flip-flops; shift registers; sequencers.

PLC programming methods
Ladder and logic diagrams; flow charts; statement lists; Boolean algebra; function diagrams; graphical programming languages.

Advanced functions
Less than; greater than; binary to BCD conversion; proportional feedback control.

Learning outcome
The learner will:
4. be able to create operational programs to drive PLCs in industrial related tasks

Assessment criteria
The learner can:
4.1 design operational PLC programs
4.2 produce operational PLC programs
4.3 test - debug PLC programs.

Range

Produce
Enter suitable PLC programs

Test – Debug
Run program and test for correct operation.
Forcing inputs, forcing outputs; changing data; comparing files (tapes, EPROM, disc); displayed error analysis.

Learning outcome
The learner will:
5. understand how to diagnose faults in programmable controller environments

Assessment criteria
The learner can:
5.1 describe methods of communicating symptoms of faults
5.2 evaluate types of fault finding techniques
5.3 assess the relationship between cause and effects of faults
5.4 recommend remedial action for the correction of system faults.

Range

Methods
Verbal; written (job sheets, fault reports, production rejects)

Types
Safety; software (built in fault analysis, watchdog, disaster recovery); physical (power/battery, system indicators, half-split)
Unit 415  Principles of analogue circuits

Level: 4  
UAN: D/506/9295  
GLH: 97  
NLH: 150  
Assessment method: Assignment

Aim: The purpose of this unit is to enable learners to develop an understanding of the principles and simple design of analogue circuits. Learners will understand the properties and applications of semiconductor diodes; characteristics, operation and applications of transistors; principles of gain and loss, related to the function of amplifiers in analogue circuits; feedback on amplifier performance.

On completion of this unit, learners will be able to design simple linear and non-linear operational amplifier circuits; and design, and simulate oscillators and filters using the operational-amplifier.

Learning outcome
The learner will:
1. understand the properties, principles and applications of semiconductor diodes

Assessment criteria
The learner can:
1.1 explain the principles of semiconductor operation
1.2 evaluate the characteristics of diode types
1.3 calculate diode resistance using the diode equation
1.4 evaluate the use of diodes for different applications.

Range
Semiconductor
Materials (Silicon, Germanium); P and N-type doping; PN junction; forward and reverse bias characteristics.
Types
Schottky; Zener; tunnel
Resistance
Static; dynamic
Applications
Power rectification; voltage reference; signal processing; light emitting; photosensitive diodes; variable capacitance; high voltage.

### Learning outcome

The learner will:

2. understand the characteristics, operation and applications of transistors

### Assessment criteria

The learner can:

2.1 analyse the operation of bipolar junction transistors in terms of their construction
2.2 explain the operation of a common emitter amplifier using **hybrid parameters**
2.3 analyse Common Emitter transistor amplifier **characteristics**
2.4 analyse the quiescent conditions of transistor amplifiers using different **methods**
2.5 analyse the operation of **field effect transistors** (FET) in terms of their construction
2.6 evaluate the application of transistor amplifier **biasing** against parameters
2.7 compare actual FET output transfer characteristics against manufactures data to assess component fidelity.

### Range

<table>
<thead>
<tr>
<th>Hybrid parameters</th>
<th>hfe; hie; hoe; hre.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristics</strong></td>
<td>Static; dynamic resistance; gain</td>
</tr>
<tr>
<td><strong>Methods</strong></td>
<td>Load-line; algebraic</td>
</tr>
<tr>
<td><strong>Field effect transistors</strong></td>
<td>JFETs; IGFETs; MOSFET; NOMFET; CNTFET</td>
</tr>
<tr>
<td><strong>Biasing</strong></td>
<td>Common emitter; emitter follower; common source;</td>
</tr>
<tr>
<td><strong>Parameters</strong></td>
<td>Input impedance; output impedance; gain; stability.</td>
</tr>
<tr>
<td><strong>Output transfer characteristics</strong></td>
<td>Static (VDS; VGS; IG; ID; saturation, pinch-off; ohmic region); Dynamic (quiescent values and voltage gain)</td>
</tr>
</tbody>
</table>

### Learning outcome

The learner will:

3. understand the operational properties, related to the function of amplifiers in analogue circuits

### Assessment criteria

The learner can:

3.1 explain the use of the decibel (dB)
3.2 explain the **operating properties** of an amplifier
3.3 assess the principles of **noise** affecting components and circuits
3.4 evaluate the application of different **classes** of transistor amplifiers.
### Range

**Operating properties**
Gain; attenuation; input impedance; output impedance

**Noise**
Thermal; cross-talk; Avalanche; burst noise; shot; calculation of signal-to-noise ratio

**Classes**
A; B; AB; C

### Learning outcome
The learner will:
4. understand the effects of feedback on amplifier performance

### Assessment criteria
The learner can:
4.1 explain types of feedback applied to amplifiers
4.2 explain the terms associated with amplifier feedback
4.3 analyse the effect of loop gain on amplifiers
4.4 explain the effects of feedback variables on amplifiers
4.5 assess the relationship between gain and bandwidth on amplifier performance
4.6 solve loop gain using different measures.

### Range

**Types**
Positive; negative; voltage; current

**Terms**
Open loop; closed loop; stability; distortion; bandwidth.

**Amplifiers**
When under gain conditions $G >> 1$; $G<<1$; using classic amplifier feedback equation

**Feedback variables**
Input and output impedances; series; shunt fed; voltage and current derived; frequency and phase; noise and distortion.

**Measures**
Decibels, power, voltage, current

### Learning outcome
The learner will:
5. be able to design simple linear and non-linear operational amplifier circuits

### Assessment criteria
The learner can:
5.1 explain the operation of an ideal operational amplifier
5.2 calculate the transfer functions in feedback circuit under different conditions
5.3 carry out circuit design calculations, including simulation for specified applications.
### Range

**Operation**
Including ‘virtual earth’ concept

**Conditions**
Linear; non-linear

**Circuit**
Linear (summing, difference, inverting and non-inverting amplifier circuits); non-linear (precision rectifier, precision voltage regulator).

**Application**
Level shifter; current-to-voltage converter; voltage-to-current converter

---

### Learning outcome

The learner will:

6. be able to design and simulate oscillators using the operational-amplifier

### Assessment criteria

The learner can:

6.1 state the feedback conditions required for an amplifier to give sustained oscillations
6.2 evaluate the operation of different oscillator circuits
6.3 carry out oscillator circuit design calculations at given frequencies
6.4 simulate the design parameters for oscillator operation.

---

### Range

**Oscillator**
R/C oscillator; phase-shift oscillator; Wien bridge oscillator

**Design parameters**
At given operating frequency

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### Learning outcome

The learner will:

7. be able to design and simulate simple filters using operational-amplifiers

### Assessment criteria

The learner can:

7.1 explain the parameters of first and second order filters
7.2 use transfer functions to calculate mid-band gain and Q-factor
7.3 carry out filter design calculations
7.4 simulate the design parameters for filter operation.

---

### Range

**Parameters**
Transfer function (from first principles); asymptotic gain-frequency response

**Filter**
Low-pass, Sallen Key
### Learning outcome

The learner will:

8. understand properties of data converters

### Assessment criteria

The learner can:

8.1 explain terms associated with data conversion

8.2 explain the operational properties of analogue /digital (converters).

### Range

**Terms**

Conversion time; conversion rate; conversion code; resolution; settling time; quantization error; nominal full-scale output; missing code; aliasing; oversampling

**converters**

'R-2R' ladder; slope; successive approximation and flash
Unit 416  Sequential and combinational logic circuits

Level: 4
UAN: T/506/9299
GLH: 66
NLH: 100

Assessment method: Assignment

Aim: The purpose of this unit is to enable learners to develop an understanding of designing simple sequential and combinational logic circuits. Learners will understand the function and features of logic device circuits.

The unit also enables learners to practically apply skills and knowledge to design sequential and combinational logic circuits.

Learning outcome
The learner will:
1. understand the function and features of logic device circuits

Assessment criteria
The learner can:
1.1 evaluate the function of logic gates
1.2 evaluate the principal characteristics of different logic families.

Range
Function
Symbols; truth tables; logic gate equivalence.

Logic gates
AND; OR; NOT; EXOR; NAND; NOR

Principal characteristics
Speed; power; cost; interface requirements (propagation delay).

Families
Complementary metal oxide – semiconductor (CMOS); transistor-transistor logic (TTL); ECL; BiCMOS
Learning outcome
The learner will:
2. be able to design simple combinational logic circuits

Assessment criteria
The learner can:
2.1 explain the operation of combinational logic circuits
2.2 produce minimised Boolean expressions using the laws of Boolean algebra
2.3 use methods to simplify Boolean functions
2.4 illustrate minimised Boolean expressions using universal gates
2.5 design minimised circuits using simulation to test against specifications.

Range
Operation
Using Boolean expressions; truth tables
Logic circuits
Half adder; full adders; multiplexers and demultiplexers; code converters; comparators, decoders and encoders, parity checkers.
Laws
Commutative; associative; distributive; duality; de Morgan
Methods
Algebraic methods; graphical methods (Karnaugh Mapping)
Universal gates
NAND; NOR - Illustrate using logic diagrams; or other

Learning outcome
The learner will:
3. be able to design simple sequential logic circuits

Assessment criteria
The learner can:
3.1 assess types of sequential logic circuit
3.2 outline standards of graphical symbols for binary logic elements
3.3 describe the function of sequential logic devices
3.4 explain the operation of sequential circuits using state diagrams
3.5 produce state-transition and output tables from state diagrams
3.6 evaluate the minimum number of binary elements required to implement a sequential circuit from the number of internal system states
3.7 design minimised circuits using simulation to test against specifications.
<table>
<thead>
<tr>
<th><strong>Range</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Types</strong></td>
<td>Synchronous; Asynchronous working</td>
</tr>
<tr>
<td><strong>Standards</strong></td>
<td>ANSI/IEE Std 91a-1991; BS EN 60617-12:1999; dependency notation; international equivalent</td>
</tr>
<tr>
<td><strong>Logic devices</strong></td>
<td>S-R; J-K; T-type and D-Type bistables (element in terms of a truth table, steering table, Karnaugh map; timing diagram); data latch; counter; shift register</td>
</tr>
<tr>
<td><strong>State diagrams</strong></td>
<td>Mealy or Moore model</td>
</tr>
<tr>
<td><strong>State</strong></td>
<td>Previous; next</td>
</tr>
</tbody>
</table>
Unit 417  Microprocessor based systems

Level: 4  
UAN: D/506/9300  
GLH: 60  
NLH: 100  
Assessment method: Assignment

Aim: The purpose of this unit is to enable learners to develop an understanding of microprocessor based systems. Learners will understand the structure of microprocessor based systems.

The unit also enables learners to practically apply skills and knowledge to
- develop software for microprocessor-based systems
- develop simple control software for programmable interface devices.

Learning outcome
The learner will:
1. understand the structure of microprocessor based systems

Assessment criteria
The learner can:
1.1 analyse characteristics of microprocessor based families
1.2 describe the features commonly found in a Centre Processing Unit (CPU)
1.3 describe the properties of memory components
1.4 explain common applications of embedded microprocessor based systems.

Range
Characteristics
Speed; cost; input/output (I/O) facilities; instruction set; physical size; bus structure (address, data and control); word size

Features
Program Counter; Stack pointer; Status Register; General Purpose Registers; Arithmetic and Logic Unit (ALU); Instruction Set

Memory
SRAM; DRAM; flash memory

**Applications**
- **Control systems**: Engine management systems (EMU); robotics; distributed control systems; coin-operated machines; printers
- **Instrumentation systems**: data acquisition systems; data logging systems; indicator display systems; ‘intelligent’ panel instruments; test equipment
- **Communication systems**: modems; radio transmitters; radar systems
- **Commercial systems**: electronic funds transfer at point of sale systems (EFTPOS); electronic bank teller machines; hand-held stock loggers

**Learning outcome**
The learner will:
2. be able to develop software for microprocessor-based systems

**Assessment criteria**
The learner can:
2.1 design software to given specifications using software design techniques
2.2 use computer language to develop programs for simple operations
2.3 use software debugging tools to test software against specifications.

**Range**

**Techniques**
Algorithms in the form of a structure chart showing actions and conditions; pseudo code

**Language**
Assemblers; high-level language compilers (C++, Visual BASIC, Java, Pascal (Delphi))

**Operations**
Interface to external devices: lights; switches; motors; heaters; keypads; liquid crystal displays (LCD); light emitting diode (LED) displays; printers; analogue to digital converters (ADC); digital to analogue converters (DAC)

**Software debugging tools**
Integrated Development Environment (IDE); In-Circuit Emulation (ICE); simulators

**Test**
Data (inputs and expected outputs) should be prepared prior to running programs and results of the tests should be documented

**Learning outcome**
The learner will:
3. be able to develop simple control software for programmable interface devices

**Assessment criteria**
The learner can:
3.1 evaluate programmable interface devices in terms of
<table>
<thead>
<tr>
<th><strong>functionality</strong></th>
<th>3.2 develop simple control software against given specifications.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Range</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interfaces</strong></td>
<td>Universal asynchronous receiver transmitter (UART); programmable peripheral interface (PPI); I/O mapped devices, memory-mapped devices</td>
</tr>
<tr>
<td><strong>Functionality</strong></td>
<td>Control signals; interrupts; polling; handshaking; port current rating; (interfaces can be in parallel or serial form in terms of performance or distance respectively). Programmable/configurable features</td>
</tr>
<tr>
<td><strong>Specifications</strong></td>
<td>Testing; control; monitoring</td>
</tr>
</tbody>
</table>
Unit 418  

Maintenance of engineering systems and equipment

**Level:** 4  
**UAN:** H/506/9301  
**GLH:** 56  
**NLH:** 150  
**Assessment method:** Assignment

**Aim:** The purpose of this unit is to enable learners to develop an understanding of how to plan for and carry out maintenance work on systems and equipment used in manufacturing operations.

**Learning outcome**
The learner will:
1. understand maintenance planning in engineering

**Assessment criteria**
The learner can:
1.1 outline regulations required to be used for the maintenance of equipment and systems
1.2 evaluate maintenance strategies used for different systems and equipment
1.3 assess factors in determining maintenance plans.

**Range**

**Regulations**
UK current or international equivalents of: (statutory and non-statutory including Codes of Practice) - Electricity at Work Regulations (1989), BS7671, GS 38 or international equivalents, Health & Safety Act (1974), Building Regulations (2000), Management of Health & Safety at Work Regulations, Reporting of Injuries, Diseases & Dangerous Occurrences Regulations, Provision & Use of Work Equipment Regulations, Manual Handling Operations Regulations, Personal Protective Equipment at Work Regulations, Work at Height Regulations, Control of Substances Hazardous to Health Regulations, Control of Asbestos at Work Regulations

**Maintenance strategies**
Breakdown; preventative; periodic; predictive; corrective Maintenance Prevention – as part of Total Productive Maintenance (TPM)

**Factors**
System functions; system failures; failure consequences; failure processes
<table>
<thead>
<tr>
<th>Learning outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>The learner will:</td>
</tr>
<tr>
<td>2. understand mechatronics in industrial systems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
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</thead>
<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>2.1 explain <strong>key components</strong> of industrial systems</td>
</tr>
<tr>
<td>2.2 outline the <strong>architecture</strong> of various types of industrial systems</td>
</tr>
<tr>
<td>2.3 evaluate the <strong>features</strong> of conventional and mechatronic systems</td>
</tr>
<tr>
<td>2.4 evaluate the <strong>use of fieldbus networks</strong> in industrial network systems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Key components</strong></td>
</tr>
<tr>
<td>Input devices; prime movers; gearing; controllers; output devices</td>
</tr>
</tbody>
</table>

| **Architecture** |
| Controller; correction element; process; outputs; logical sequence of events; construct block diagrams |

| **Features** |
| Centralised control or distributed control; hard wiring or networks; sequence control or intelligent individual control; relay logic or software programming; plant maintenance or predictive maintenance |

| **Use of fieldbus networks** |
| Requirement for multiple devices in a process control system to communicate with each other without conflict; cost, complexity, competing fieldbus standards – compatibility between components (eg sensors and actuators); Ethernet based systems |

<table>
<thead>
<tr>
<th>Learning outcome</th>
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<tbody>
<tr>
<td>The learner will:</td>
</tr>
<tr>
<td>3. understand the principles of sensors in mechatronics</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
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</thead>
<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>3.1 evaluate the operation and application of <strong>sensors</strong> in control systems</td>
</tr>
<tr>
<td>3.2 evaluate the operation of <strong>signal conditioning systems</strong> for use in mechatronics</td>
</tr>
<tr>
<td>3.3 explain the <strong>terms</strong> applied to sensors used in mechatronics.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td><strong>Sensors</strong></td>
</tr>
<tr>
<td>Contact: micro switch, snap action limit switch, wobble stick, pressure mat, positively guided safety switch, level switch</td>
</tr>
</tbody>
</table>

| Non-contact: inductive proximity, capacitive proximity, optical proximity, light curtain, thermocouple, strain gauge, differential |
pressure, impeller flow, encoder (incremental and absolute), resolver, vibration transducer, motion sensor

**Signal conditioning systems**
Purpose: isolation; amplification; excitation; monitoring; conversion (voltage to current, current to voltage, pressure to voltage, pressure to current, analogue to digital, digital to analogue, frequency to voltage, frequency to current, sink to source, source to sink)

**Terms**
Sensitivity; repeatability; resolution; dead band; alignment; compatibility; cross talk; grounding; calibration; noise; discrimination; linearity; dynamic error

**Learning outcome**
The learner will:
4. understand the principles of actuation systems

**Assessment criteria**
The learner can:
4.1 evaluate the use of control and actuation systems in mechatronics
4.2 assess the operation of pneumatic power systems and their components
4.3 assess the operation of hydraulic power systems and their components
4.4 assess the operation of electrical actuation systems and their components
4.5 assess the operation of mechanical systems
4.6 describe the symbols used in actuation systems.

**Range**

**Control and actuation systems**
Pneumatic, hydraulic, electrical

**Pneumatic power systems**
Prime mover (ie motor); compressor (ie two stage reciprocating); silencer; filter; pressure relief valve; cooler; filter and water trap; air receiver; pipe work distribution system

**Components**
Valves (directional control valves (DCV) – spool, 3/2, 4/2, 5/2, directly operated, pilot operated, solenoid operated, poppet)

Directional valves (one way, one way restrictor return)

Pressure control valves (pressure regulating, pressure limiting, pressure sequence)

Proportional process control valves (pneumatic diaphragm actuator, linear contoured, equal)

Actuators (Linear actuators – single acting, double acting, fluid muscle, tandem, multi position, stick slip phenomenon; Rotary actuators – use of linear actuator to produce rotation, vane-type semi-rotary, vane motor)

Hydraulic power system
Components

Valves (directional control valves (DCV) – spool, 3/2, 4/2, 5/2, directly operated, pilot operated, solenoid operated, poppet)  
Directional valves (one way, one way restrictor return)  
Pressure control valves (pressure regulating, pressure limiting, pressure sequence, proportional)  
Electrical actuation systems:  
Switching devices (push buttons, relays, thyristor, TRIAC, solid state relay, solenoid devices)

Motors (series dc, shunt dc, separately excited dc, stepper, servo, single phase induction, three phase induction)

Motor control (basic dc motor speed control (ie, inverter drive), basic induction motor speed control (ie, inverter drive), basic stepper motor controllers, basic servo motor controllers)

Components

Benefits over hard wired systems; communications interface to control system; basic requirements of wiring medium (ie CAT 5, screening, grounding); types of distributed input /output modules (ie digital, analogue) terminations (insulation displacement connection (IDC), RJ-45, DIN, BNC)

Mechanical system

Comprising of: prismatic motion; revolute motion; sliding joints; revolving joints; force amplification (ie levers); change of speed (ie gears); transfer of rotation (ie belts and chains); types of motion (ie quick return mechanism); cams and cam followers; change of direction (ie bevel and worm gear); linear to revolute / revolute to linear (ie rack and pinion); bearings (ie plain roller needle and ball)

Symbols

Flow path; flow shut-off; initial connections; push button operation; lever operation; roller operation; plunger operation; spring operation; solenoid operation; pedal operation; pilot operation; 2/2 valve; 3/2 valve; 4/2 valve; 5/2 valve; non return valve; pressure limiting valve; regulator; pressure source; exhaust; filter; single acting cylinder; double acting cylinder; rotary actuator

Systems

Pneumatic; hydraulic; electrical

Learning outcome

The learner will:
5. be able to plan for maintenance operations

Assessment criteria

The learner can:
5.1 evaluate the safety factors affecting maintenance operations
5.2 evaluate sources of information used to facilitate maintenance of systems and equipment
5.3 produce operational maintenance documentation
5.4 assess physical and human resources required to carry out maintenance of systems and equipment.
Range

**Safety factors**
Area; safety requirements; equipment; barriers and enclosures; safe isolation procedures; selection of safe isolation methods for: electrical systems and pressurised systems (ie hydraulic; compressed air; water; gas); notification of personnel and other workers; Personal Protective Equipment (PPE); switchgear requirements; Environmental considerations; provision for safe storage of tools; equipment and materials; arrangements for working at height and in confined spaces

**Sources of information**
Component data; availability of materials; e-diagnostics; drawings; diagrams (circuit and wiring); maintenance schedules/specifications; data charts; manufacturer’s manuals; servicing records/running logs; flow charts; standard maintenance time records

**Documentation**
Risk assessments; method statements; maintenance reports; safe isolation procedures; Permits to work; work plan (including definition of tasks, planned shut downs/isolations, safety precautions (provision for release of stored and latent energy), communication with relevant stakeholders, time/cost effectiveness, work over-run notification procedures)

**Physical and human resources**

*Physical*: tools and equipment (power tools, hand tools, lighting, power supplies, diagnostic equipment, temporary services, access equipment, safety equipment (fall-arrest gear, gas tester, breathing apparatus), mechanical handling equipment); works orders; requisitions; contracts; tendering

*Human*: company-based maintenance staff; sub-contractor involvement; skills and competence of involved personnel; training needs; licence / authority to work

Learning outcome
The learner will:
6. be able to carry out maintenance procedures on systems and equipment

Assessment criteria
The learner can:
6.1 assess the safety of systems prior to undertaking maintenance operations
6.2 apply maintenance procedures to systems and equipment
6.3 evaluate the performance of maintained systems and equipment
6.4 apply re-commissioning processes on completion of maintenance activities.
### Range

### Safety
Safe isolation procedures in accordance with regulatory requirements for systems and equipment; the Health and Safety of personnel within the work location

### Systems
Mechanical; electrical; pneumatic; hydraulic

### Maintenance
Planned preventative (periodic, predictive); breakdown/corrective (including fault diagnosis/rectification)

### Procedures
Complying with manufacturer's instructions, industry approved practices, maintenance schedules and specifications

*Electrical, Hydraulic and Pneumatic*: loss of supply; overload; short circuit and earth fault; transient voltage; loss of phase/line; incorrect phase rotation; high resistance joints

*Mechanical*: component; accessory or equipment faults

### Systems
Pneumatic radial, Pneumatic ring, Hydraulic, components and accessories

*Electrical*: Three-line four wire distribution systems; ELV and LV single and multiphase circuits; lighting systems heating and ventilating systems; air conditioning and refrigeration systems; drive systems, security systems; earthing systems and data communication systems

### Equipment
Electrical plant; components and accessories; motors and starters; switchgear and distribution panels; control systems and components; contactors; power transmission mechanisms; luminaires and lamps

### Performance
Using suitable test methods

### Re-commissioning
Safety before re-energising; check all systems in place and re-set; prescribed start up procedures; electrical; mechanical and pneumatic/hydraulic checks.

*Dispose of hazardous substances*: oils; greases; cleaning agents; solvents; insulation; adhesives; fillers; packing; lagging.

*Complete reports*: maintenance schedules; clear permits to work and sign off; diaries; materials used; record likely future requirements; update maintenance schedule; complete hand over
### Unit 419  Engineering design

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<thead>
<tr>
<th>Level:</th>
<th>4</th>
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<tbody>
<tr>
<td>UAN:</td>
<td>M/506/9334</td>
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<tr>
<td>GLH:</td>
<td>60</td>
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<tr>
<td>NLH:</td>
<td>150</td>
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<tr>
<td>Assessment method:</td>
<td>Assignment</td>
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</tbody>
</table>

#### Aim:
The purpose of this unit is to enable learners to develop an understanding of the principles and processes involved in engineering design.

On completion of this unit, learners will be able to
- use computer software to develop design drawings or schemes
- develop design specifications to meet customer requirements.

### Learning outcome
The learner will:
1. understand how to select and justify design solutions required to meet given specifications

### Assessment criteria
The learner can:
1.1 analyse possible design solutions
1.2 evaluate conceptual designs
1.3 justify selected design solution
1.4 assess compliance of design solution.

### Learning outcome
The learner will:
2. be able to use computer software to develop design drawings or schemes to meet design specifications

### Assessment criteria
The learner can:
2.1 explain the key features of **computer software** in the design for manufacture process
2.2 use computer software to produce design drawings or schemes
2.3 review available computer software that can assist the design process.
### Range

**Computer software**

CAD; CAM

---

### Learning outcome

The learner will:

3. understand how to justify selected product designs for economic manufacture

### Assessment criteria

The learner can:

3.1 explain the advantages and disadvantages of **standardisation**
3.2 describe the **elements** involved in the total cost of manufacture
3.3 review manufacturing processes and material requirements for components.

---

### Range

**Standardisation**

Product; components; manufacturing process

**Elements**

eg materials; labour; overheads; compliance fees; development and testing; marketing

---

### Learning outcome

The learner will:

4. be able to develop design specifications to meet customer requirements

### Assessment criteria

The learner can:

4.1 research customer requirements including **design parameters**
4.2 use design information from appropriate **sources** to prepare design specifications
4.3 assess customer requirements against **design limitations**.

---

### Range

**Design parameters**

eg off the shelf solution; safety standards; national, international industry standards (eg BSI, CE); compatibility with existing/emerging technologies

**Sources**

eg client; designer; stress engineer; production designer; procurement; marketing; regulatory authorities; legal/patent team; business case

**Design limitations**

eg cost; practicality; available technology; materials; production process; reliability of product; manufacturing type (mass, batch, bespoke)
Unit 420 Programming using C

Level: 4
UAN: K/506/9302
GLH: 60
NLH: 150
Assessment method: Assignment

Aim: The purpose of this unit is to enable learners to develop problem solving and software programming skills to build C programs for specific engineering problems using appropriate abstractions to represent problems, requirements, algorithms and data structures; and to understand the role of documentation for improving software design, usability and maintenance.

Learning outcome

The learner will:
1. be able to apply knowledge of the software development life cycle and tools to build programs

Assessment criteria

The learner can:
1.1 explain characteristics of popular software development models
1.2 explain the purpose and the outcome of the stages in the Waterfall software development model
1.3 explain the purpose and usage of software development tools
1.4 use software development tools to edit, compile, and execute programs
1.5 construct pre-processor directives to manage compilation of programs
1.6 apply a program debugger to step through a program and to inspect values of program variables at different stages of execution

Range

Models
Waterfall; Spiral; Iterative and incremental development; Agile programming; Rapid application development

Stages
System requirements; Software requirements; Analysis; Program design; Implementation; Testing; Operation and maintenance

Tools
Editor; Pre-processor; Compiler; Linker; Debugger; Integrated Development Environment (IDE)

Directives
#include; #define; #ifdef/#ifndef

<table>
<thead>
<tr>
<th>Learning outcome</th>
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<tbody>
<tr>
<td>The learner will:</td>
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<tr>
<td>2. understand software requirements, designs and quality metrics</td>
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<table>
<thead>
<tr>
<th>Assessment criteria</th>
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</thead>
<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>2.1 explain processes for requirements identification and methods for requirements specification</td>
</tr>
<tr>
<td>2.2 distinguish between different types of software requirements</td>
</tr>
<tr>
<td>2.3 produce use cases and requirements lists for a given engineering problem</td>
</tr>
<tr>
<td>2.4 explain commonly used software quality characteristics and relationships between those characteristics and measurable software attributes</td>
</tr>
<tr>
<td>2.5 compare quality characteristics of programs based on measurable software attributes</td>
</tr>
<tr>
<td>2.6 produce requirements specification and software design documents according to the relevant documentation standards</td>
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<tr>
<th>Range</th>
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<tbody>
<tr>
<td>Processes</td>
</tr>
<tr>
<td>Stakeholder identification; Stakeholder interviews; Facilitation and joint sessions</td>
</tr>
<tr>
<td>Methods</td>
</tr>
<tr>
<td>Contract-style lists; Use cases; Measurable goals</td>
</tr>
<tr>
<td>Types</td>
</tr>
<tr>
<td>Structural; Behavioural; Functional; Non-functional</td>
</tr>
<tr>
<td>Characteristics</td>
</tr>
<tr>
<td>Reliability, Security, Efficiency, Maintainability, Size</td>
</tr>
<tr>
<td>Standards</td>
</tr>
<tr>
<td>IEEE 1016-2009; IEEE 29148-2011</td>
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<tr>
<th>Learning outcome</th>
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<tbody>
<tr>
<td>The learner will:</td>
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<tr>
<td>3. be able to use problem solving to develop software programs which reflect considerations for usability and hardware portability</td>
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<thead>
<tr>
<th>Assessment criteria</th>
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<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>3.1 identify and select appropriate data types to represent information pertaining to a given engineering problem</td>
</tr>
<tr>
<td>3.2 explain representation of symbolic (character) and logical (Boolean) values using appropriate encoding standards</td>
</tr>
<tr>
<td>3.3 explain encoding of numeric data in different hardware architectures and analyse how this may affect software portability</td>
</tr>
</tbody>
</table>
3.4 use appropriate C language expressions, control structures, and functions to construct a program to solve a given engineering problem

3.5 apply the best practice in coding conventions and facilitate re-use of frequently used code, ease of maintenance, and collaborative development

**Range**

**Data types**
Void; Integer (char, short, int, long); Floating point (float, double, long double)

**Encoding standards**
ASCII

**Hardware architectures**
Big-endian; Little-endian

**Expressions**
Algebraic; Boolean

**Control structures**
Decision; selection; iteration (for, do/while, while)

**Functions**
Input/output (scanf(), printf()); user defined

**Coding conventions**
Code indentation; comments; naming

**Learning outcome**
The learner will:
4. be able to apply data structures and algorithms for software

**Assessment criteria**
The learner can:
4.1 declare and use appropriate data structures to represent information pertaining to a given engineering problem
4.2 distinguish between common types of algorithms
4.3 explain the concept of recursion and its theoretical and practical benefits
4.4 produce representations of algorithms with commonly used abstract methods
4.5 select and implement suitable algorithms to solve a given engineering problem
4.6 compare performance characteristics of different algorithms

**Range**

**Data structures**
Arrays; records (struct)

**Types**
Deterministic; Heuristic; Recursive

**Methods**
Flow charts; Pseudo code

**Algorithms**
| Characteristics | Iterative; recursive; sorting; search  
<table>
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<tbody>
<tr>
<td>Time; memory</td>
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</table>

**Learning outcome**

The learner will:

5. be able to use information provided with software development tools and libraries

**Assessment criteria**

The learner can:

5.1 use built-in help sub-systems within software development **tools**
5.2 interpret information provided in reference manuals for software libraries to determine the purpose and **usage** for library functions
5.3 investigate online sources, including the use of Web search engines, to locate information about specific software development **topics**

**Range**

**Tools**

Compiler; Linker; Debugger; Integrated Development Environment

**Usage**

Acceptable input parameter ranges; meaning of output values

**Topics**

Tools; functions; algorithms
Unit 421  Planning and implementing change within businesses

Level: 4
UAN: T/506/9304
GLH: 30
NLH: 150
Assessment method: Assignment

Aim: The purpose of this unit is to enable learners to develop an understanding of the need to plan, manage and implement organisational change in a positive way to ensure that the organisation and its employees benefit from the change.

Learners will also gain an understanding of how to evaluate the change process and how to use various tools and techniques for evaluation.

Learning outcome
The learner will:
1. understand the need for managing organisational change

Assessment criteria
The learner can:
1.1 describe the internal and external factors that contribute to the need for change in organisations
1.2 analyse different types of organisational change
1.3 explain the benefits of planning organisational change.

Range
Internal factors
Strategic; organisational; sector led objectives; resources eg human; financial; physical; technological.

External factors
Environmental; political; legal; economic; technological.

Types
Strategic; structural; process orientated; people centred.

Benefits
Change is planned and managed; reduces stress levels on individuals; maximise efficiency of existing resources; more opportunities for development; increased skills.
<table>
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<tr>
<th>Learning outcome</th>
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<tbody>
<tr>
<td>The learner will:</td>
<td></td>
</tr>
<tr>
<td>2. understand the change process within business environments</td>
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</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
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<tbody>
<tr>
<td>The learner can:</td>
<td></td>
</tr>
<tr>
<td>2.1 explain <strong>processes</strong> for managing change</td>
<td></td>
</tr>
<tr>
<td>2.2 explain why <strong>organisational culture</strong> has a <strong>role</strong> in the management of change.</td>
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<table>
<thead>
<tr>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>Processes</td>
<td>Learners should be encouraged to refer to current theories and processes eg Kotter’s 8 Steps, Dunphy and Stace.</td>
</tr>
<tr>
<td><strong>Organisational culture</strong></td>
<td>Learners should be encouraged to refer to specific theories on organisational culture eg Thomas Handy: power culture, role culture, task culture, person culture.</td>
</tr>
<tr>
<td><strong>Role</strong></td>
<td>In terms of ensuring clear communication, committed managers, modelling cultures through actions, recognition, change in physical environment.</td>
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<thead>
<tr>
<th>Learning outcome</th>
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<tbody>
<tr>
<td>The learner will:</td>
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<tr>
<td>3. understand the importance of effective leadership and management in the change process</td>
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<tbody>
<tr>
<td>The learner can:</td>
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</tr>
<tr>
<td>3.1 explain the <strong>skills</strong> needed to manage people through organisational change</td>
<td></td>
</tr>
<tr>
<td>3.2 describe <strong>reasons</strong> for individuals to resist change</td>
<td></td>
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<tr>
<td>3.3 explain how leaders and managers can <strong>overcome</strong> resistance to change.</td>
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<tr>
<th>Range</th>
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<tbody>
<tr>
<td><strong>Skills</strong></td>
<td>Use of effective communication; giving feedback; understanding behaviours/styles; managing performance; team working.</td>
</tr>
<tr>
<td><strong>Reasons</strong></td>
<td>Disbelief/anxiety; failure to understand problem; mistrust; demotivation; frustration.</td>
</tr>
<tr>
<td><strong>Overcome</strong></td>
<td>Resistance to change eg how organisations encourage participation, empathy, feedback, trust, be open to revision of plans. Learners should refer to specific theories such as Tannenbaum and Schmidt.</td>
</tr>
<tr>
<td>Learning outcome</td>
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<td>------------------</td>
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<tr>
<td>The learner will:</td>
<td></td>
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<tr>
<td>4. be able to evaluate the change process in organisations</td>
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<thead>
<tr>
<th>Assessment criteria</th>
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<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>4.1 describe how to <strong>monitor</strong> the implementation of change</td>
</tr>
<tr>
<td>4.2 explain the importance of evaluating the efficiency and effectiveness of the implementation process</td>
</tr>
<tr>
<td>4.3 use <strong>techniques</strong> to evaluate the change process</td>
</tr>
<tr>
<td>4.4 recommend procedures by which the change process can be continually improved.</td>
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<th>Range</th>
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<tbody>
<tr>
<td><strong>Monitor</strong></td>
</tr>
<tr>
<td>Use of planning tools to monitor cost, quality, adherence to change programme, timescales eg how it can be used for continuous improvement.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Techniques</th>
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<tbody>
<tr>
<td>Learners should be given an understanding of the following techniques before applying them:</td>
</tr>
<tr>
<td>• identifying the benefits of change through SWOT analysis</td>
</tr>
<tr>
<td>• force field analysis</td>
</tr>
<tr>
<td>• measuring against standards.</td>
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</table>
Unit 422  Personal and professional development

Level: 4
UAN: A/506/9305
GLH: 25
NLH: 100
Assessment method: Assignment

Aim: The purpose of this unit is to enable learners to develop an understanding of the different methods and resources available to them for planning their personal and professional development. They will learn how to identify factors that may affect targets or goals, prioritise actions and how feedback from others can be utilised to aid their development and career progression. They will be able to develop a plan which can either be used during progress of a course of study or as a tool for their future or current career path.

Learning outcome
The learner will:
1. understand how to plan for personal and professional development

Assessment criteria
The learner can:
1.1 describe the benefits of personal and professional development
1.2 identify development opportunities for career and personal progression
1.3 analyse development opportunities that may support career and personal progression.

Range
Benefits
personal - update skills, gain new skills, increase motivation, confidence
professional - career progression, meeting organisation goals, how role fits into organisation

Development opportunities
• internal and external
- **skills**: inter-personal, enterprise, self-management and leadership
- **knowledge**: qualifications

### Learning outcome
The learner will:
2. understand how people learn

### Assessment criteria
The learner can:
2.1 explain the **principles** of how people learn
2.2 describe different **learning styles**
2.3 evaluate **learning resources** to support development
2.4 analyse the use of different **learning strategies**.

### Range
**Principles**
relevant theories, methodologies, pedagogies, codes of ethics

**Learning styles**
General:
visual, aural, physical, logical, social, solitary
Applications:
awareness of personal style eg Kolb, Honey and Mumford theories

**Learning resources**
libraries; organisation’s resources, IT, internet, progress files, portfolio development

**Learning strategies**
interactions with others, taking responsibility for own development, effective time-management, structured reflection, self-directed learning

### Learning outcome
The learner will:
3. be able to produce personal and professional development plans

### Assessment criteria
The learner can:
3.1 carry out **self-audit** of skills and experience
3.2 identify **targets** for personal and professional development
3.3 use **methods** to track personal development
3.4 create a personal and professional development plan.

### Range
**Self-audit**
personal reflections, feedback from others; skills scan; revisiting job role

**Targets**
SMART target setting, responding to feedback, realigning targets, addressing strengths and weaknesses
### Methods
- task manager, blog, project management tools, diaries, performance review/plan, objectives, monitoring, reflecting and planning

### Learning outcome
The learner will:
4. be able to make recommendations for personal and professional development

### Assessment criteria
The learner can:
4.1 explain the **benefits** of reflective practice
4.2 evaluate **progress** against development plan
4.3 recommend opportunities for further development.

### Range
**Benefits**
extent to which targets have been met/not met, recognise any changes in expectations; suggest further support required, identify barriers to progress

**Progress**
the learner should regularly identify progress against original plan and refine plan accordingly
## Unit 423  Managing information and knowledge

**Level:** 4  
**UAN:** F/506/9306  
**GLH:** 60  
**NLH:** 150  
**Assessment method:** Assignment

**Aim:**  
The purpose of this unit is to enable learners to develop an understanding of the relationship between data, information and knowledge, and the contribution, information and knowledge management makes to the success of organisations.

### Learning outcome

The learner will:

1. understand the need to manage information and knowledge within organisations

### Assessment criteria

The learner can:

1.1 outline the main features of information management  
1.2 explain the relationship between data, information and knowledge  
1.3 analyse the concept of knowledge management  
1.4 analyse the benefits information and knowledge management brings to organisations.

### Range

#### Features of information management  
Database management; compiling reports; success/security.

#### Relationship between data, information and knowledge  
Definitions and attributes of data and information, eg  
Types of data (qualitive and quantative)  
Data: one off event  
Information: when data is added to data  
Knowledge: the ability to use the information.

#### Knowledge Management  
Gather; organise; share; analyse.

#### Benefits  
Efficient processing of data; positive impact on organisation goals; improved productivity; improved customer service.
Learning outcome
The learner will:
2. understand the role of ICT in managing information and knowledge

Assessment criteria
The learner can:
2.1 outline the types and nature of organisational information systems
2.2 explain how information and communication technology (ICT) affects organisational communication
2.3 evaluate how ICT can be used to disseminate knowledge throughout the organisation.

Range
Types
Accounting; financial; human resources; marketing; operational.
Organisational communication
Formal and informal,
Computer Misuse Act.
Disseminate knowledge
Through written reports, networks, intranet, emails, to a wide audience.

Learning outcome
The learner will:
3. understand the links between knowledge management strategy and competitive advantage

Assessment criteria
The learner can:
3.1 explain the role and importance of knowledge for organisations
3.2 justify the need for maintaining a learning culture in a changing environment
3.3 demonstrate how knowledge management strategies and processes support and facilitate organisational learning
3.4 evaluate the relationship between organisational learning and competitive advantage.

Range
Role
Organisational culture; organisational knowledge; individual knowledge; wider cultural context.
Need for maintaining a learning culture
Improved performance; increased customer satisfaction; committed workforce; ability to deal with change.
Knowledge management strategies
In relation to culture; internal/external networks; support/change structures; monitoring
Organisational learning
Peter Senge model of organisational learning.
Competitive advantage
Increases profits; less resistance to change.
## Unit 424  Engineering Procurement

<table>
<thead>
<tr>
<th>Level:</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAN:</td>
<td>T/506/9335</td>
</tr>
<tr>
<td>GLH:</td>
<td>60</td>
</tr>
<tr>
<td>NLH:</td>
<td>150</td>
</tr>
<tr>
<td>Assessment method:</td>
<td>Assignment</td>
</tr>
<tr>
<td>Aim:</td>
<td>The purpose of this unit is to enable learners to develop an understanding of procurement for engineering operations.</td>
</tr>
</tbody>
</table>

### Learning outcome

The learner will:

1. understand the principles of resource management and its application to an engineering operation

### Assessment criteria

The learner can:

1.1 assess the methods available for managing materials
1.2 explain the principles involved when procuring equipment and the ongoing requirements over the life of that equipment.

### Range

**Methods**

Selection; acquisition; maintenance; replacement criteria; storage; handling logistics

**Principles**

Procurement strategy; specification; supplier identification; selection criteria; working with specialist suppliers; stock control; maintenance strategy

### Learning outcome

The learner will:

2. understand how the procurement strategy contributes to the achievement of an engineering operation’s objectives

### Assessment criteria

The learner can:

2.1 recommend procurement systems and processes with related performance indicators and benchmarking for an engineering operation
2.2 analyse the risks involved in a procurement strategy
2.3 examine the role of the procurement officer within an engineering operation.
### Range

**Systems and processes**
Standard specification; tendering; estimating/quoting; methods of procurement (centralised, contract, lease) Pareto analysis; ‘just in time’ (JIT); services; terms and conditions; risk register

**Risks**
Financial; physical; task duplication; direct and indirect costs; effect on the internal and external customer (quality assurance and control, legal implications); effect on process and outcome activities of organisations; assessing operational needs; selecting suppliers; timing; company policies; budgetary restrictions (discounts, receipt and control of purchases, wastage factors)

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### Learning outcome

The learner will:

3. understand the importance of the procurement contract and its application to engineering operations

### Assessment criteria

The learner can:

3.1 **explain the importance of a procurement contract**
3.2 **evaluate the sourcing issues** for a procurement situation using a range of suppliers
3.3 **review the management techniques** used to appraise and evaluate the suppliers of an engineering management operation.

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### Range

**Sourcing issues**
Method of supply (buying products/services, tendering, subcontracting/outsourcing); value for money; hygiene factors; choice; service guarantee; legal and contractual compliance; trace origin data; methods of payment; credit and price; volume of product; negotiating skills

**Management techniques include review of**
Communication; attitude to customers; compliance with procurement specification (cost, size, quantity); sample testing and defect elimination; delivery

---

### Learning outcome

The learner will:

4. understand procurement pricing and management strategies within an engineering organisation

### Assessment criteria

The learner can:

4.1 **explain the management strategies** that can be used to maximise the purchasing power of the procurement officer
4.2 **compare pricing management techniques** used in an engineering procurement situation
### Range

**Management strategies**
Competition between suppliers; developing profit margins to increase financial returns; releasing cash and capital by minimising stock; negotiating extended credit; determining the right quality for the right application; negotiating and developing delivery schedules

**Pricing management techniques**
Negotiating price reductions; controlling or resisting price increases; quantity discounts; prompt payment discounts

### Learning outcome

The learner will:
5. be able to review and evaluate procurement strategies within an engineering organisation

### Assessment criteria

The learner can:
5.1 plan a review and evaluation to measure the success of a company’s procurement strategy
5.2 conduct a review and evaluation for a procurement scenario in an engineering operation.

### Range

**Review**
Standard specifications; terms and conditions; monitoring; redeveloping strategy; contemporary developments; comparing and contrasting purchasing options

**Evaluation**
Cost models (return on investment); productivity gain; human resource benefits; value added analysis
The purpose of this unit is to enable learners to develop an understanding of the principles of composite materials.

Learners will understand the different structures of composite materials, the fundamentals of polymer chemistry and will look in detail at the materials and techniques used with pre-preg, pre-form materials and in dry fibre moulding. Learners will also gain an understanding of the preparation and assembly methods used for composite components in the manufacture of composite structures.

### Learning outcome

The learner will:

1. understand the principles and structure of composite materials

### Assessment criteria

The learner can:

1.1 explain different types and applications of composite materials
1.2 explain the concept of reinforcement embedded within a matrix and evaluate the resultant global properties
1.3 describe properties of reinforcement
1.4 explain reinforcement types and their selection for particular applications
1.5 explain the purpose and concept of core materials and their selection for particular applications
1.6 describe the composition of commonly used composite matrix materials
1.7 analyse mechanical properties of composite materials
1.8 explain the concept and principles of laminate characteristics
1.9 describe the application of composites
1.10 review the advantages and disadvantages of composites
1.11 describe health and safety requirements for handling and using composite materials.
### Range

**Types**  
PMC; MMC; CMC

**Reinforcement**  
Stiffness; strength; materials

**Matrix**  
Mechanical, chemical and adhesive properties

**Reinforcement**  
Glass; carbon; aramid; thermoplastic fibres; ceramic; metal; natural fibres

**Types**  
Uni-directional; Multi-directional; bonded; particulate; stitched; braids; roving; woven

**Core materials**  
Honeycombs; woods; foams; inserts

**Composition**  
Thermosetting polymers; thermoplastic polymers; metal; ceramic; bio-resins

**Mechanical properties**  
Load transfer; rule of mixtures; axial and transverse stiffness; long and short fibres; anisotropic and isotropic strength; creep; wear; toughness; thermal stability; composite classification

**Principles**  
Ply direction; direction of stiffness; rule of mixtures; use of cores

**Application**  
Sector-specific (e.g. aircraft, automotive, marine, power generation, construction, civil engineering, rail)

**Advantages and disadvantages**  
Material performance; weight; embedded defects; cost; lifespan; degradation; repair; assembly; bespoke properties

**Requirements**  
Bulk storage; ventilation and temperature control of work areas; protection of respiratory system; skin; fire protection; long- and short-term exposure to fibres; solvents and matrix materials

### Learning outcome

The learner will:

2. understand elementary polymer chemistry

### Assessment criteria

The learner can:

2.1 describe the chemistry of the **main classes of resin systems**

2.2 compare the **properties** of thermoplastics and thermosets

2.3 analyse the **performance** of resin systems in different applications

2.4 evaluate the use of **additive materials** in resin systems

2.5 assess the curing cycle for different resin systems

2.6 explain how composites are recycled or disposed of.
Range

**Main classes of resin systems**
Thermoplastics; thermosets

**Properties**
Physical; chemical

**Performance**
Eg strength; corrosion resistance; UV resistance; toughness

**Additive materials**
Additives; fillers; pigments; fire retardants

Learning outcome

The learner will:
3. Understand the materials and techniques used with pre-impregnated (pre-preg) and pre-formed (pre-forms) materials

Assessment criteria

The learner can:
3.1 Explain the **benefits** of pre-preg and pre-form materials
3.2 Describe **pre-preg materials** and their use
3.3 Describe **pre-form materials** and their use
3.4 Explain **storage requirements** for pre-preg materials
3.5 Explain laminate **preparation** and efficient use of consumables
3.6 Explain **techniques** for manufacturing components from pre-preg materials.

Range

**Benefits**
Quality control; productivity; cost effective

**Pre-preg materials**
Woven; uni-directional; B-stage material; filler

**Pre-form materials**
Eg 3D; cloths

**Storage requirements**
Refrigeration; humidity control

**Preparation**
Nesting; cutting; knitting; bagging materials; release films

**Techniques**
Manual (use of heat and pressure; autoclave, out of autoclave; vacuum bag); automated (automatic tape laying)
<table>
<thead>
<tr>
<th>Learning outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>The learner will:</td>
</tr>
<tr>
<td>4. understand preparation and assembly methods for composite components in the manufacture of composite structures</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment criteria</th>
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</thead>
<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>4.1 describe <strong>adhesive and bonding agents</strong> and their application in composite structures</td>
</tr>
<tr>
<td>4.2 describe <strong>mechanical fastening methods and fittings</strong> used for composite structures</td>
</tr>
<tr>
<td>4.3 evaluate the effectiveness of mechanical and chemical techniques in composite structures for different <strong>applications</strong></td>
</tr>
<tr>
<td>4.4 explain the importance of correct surface preparation, sealing and curing.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Range</th>
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<tbody>
<tr>
<td><strong>Adhesive and bonding agents</strong></td>
</tr>
<tr>
<td>Jigs; fixtures</td>
</tr>
<tr>
<td><strong>Mechanical fastening methods and fittings</strong></td>
</tr>
<tr>
<td>Shims; bolts</td>
</tr>
<tr>
<td><strong>Application</strong></td>
</tr>
<tr>
<td>Sector-specific (eg aircraft, automotive, marine, power generation, construction, civil engineering, rail)</td>
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</tbody>
</table>
Unit 426 Principles of composites manufacture

Level: 4
UAN: L/506/9308
GLH: 60
NLH: 150
Assessment method: Dated written paper

Aim: The purpose of this unit is to enable learners to develop an understanding of the principles of composites manufacture.

Learners will understand the different manufacturing processes used for thermoplastics and thermosets, implications of manufacturing processes on design for manufacture, types and sources of defects, different applications of NDT methods and the process and quality systems required for composite component and structure manufacture.

Learning outcome
The learner will:
1. understand the manufacturing processes used for composite components and structures

Assessment criteria
The learner can:
1.1 describe the range of processes used in the manufacture of thermoset composite materials
1.2 describe the range of processes used in the manufacture of thermoplastic composite materials
1.3 research the selection criteria for use of manufacturing processes.

Range
Range of processes used to manufacture thermoset composite materials
Hand layup; resin infusion systems; resin transfer; filament winding; pultrusion; automated tape and fibre placement; hot press

Range of processes used to manufacture thermoplastic composite materials
Hot pressing; RTM; compression moulding; pultrusion; auto-clave; rotational moulding
### Selection criteria
Cost; application; raw materials required; skill of labour force; quality assurance; defect tolerance; repeatability

### Learning outcome
The learner will:
2. understand the implications of manufacturing processes on design for manufacture

### Assessment criteria
The learner can:
2.1 investigate how manufacturing processes influence the **design for manufacture** of composite components and structures.

### Range
**Design for manufacture**
Shape; thickness; process sequence; assembly; bonding; surface finish; material selection; quality control

### Learning outcome
The learner will:
3. understand types and sources of manufacture defects of composite components and structures

### Assessment criteria
The learner can:
3.1 identify different **types** of manufacturing defects
3.2 explain **sources** of manufacture defects
3.3 analyse the **effects** of different types of manufacturing defects on component and structures fitness for purpose.

### Range
**Types**
eg cavities/voids; wrinkling; porosity; de-lamination; bridging; debonds; pre-release

**Sources**
eg contamination and cleanliness; incorrect process control; environmental; equipment failure; manufacturing damage

**Effects**
eg unsatisfactory properties; cost; rework; delivery; service life; premature failure
## Learning outcome

The learner will:

4. understand Non-Destructive Testing (NDT) methods of testing

## Assessment criteria

The learner can:

4.1 explain the principles of **NDT methods**
4.2 review **types**, functions and limitations of NDT systems
4.3 review the **selection criteria** of NDT type to suit manufacture processes and materials.

### Range

**NDT methods**
Visual; physical; penetrative

**Types**
- Tap test; visual surface; dye penetrant; thermography; x-ray;
- ultrasonic

**Selection criteria**
- eg costs; accuracy; repeatability; skill level available; effectiveness

---

## Learning outcome

The learner will:

5. understand process and quality systems required for composite component and structure manufacture

## Assessment criteria

The learner can:

5.1 analyse the need for materials' **life control and correct storage** of raw materials and finished product
5.2 analyse the need for **environmental controls** in composite manufacture and storage
5.3 explain the process of defect management and concessions (lower tolerance) for composite materials.

### Range

**Life control and correct storage**
- Refrigeration, Material Safety Data Sheets; shelf life of materials;
- inhibitors

**Environmental controls**
- Room ventilation; push-pull ventilation; on-tool air extraction; personal protective equipment
Unit 427  Developing business improvement plans

Level: 4  
UAN: K/506/9333  
GLH: 35  
NLH: 100  
Assessment method: Assignment  

Aim: The purpose of this unit is to provide learners with the knowledge and understanding to be able to develop business plans to implement improvements in the workplace and communicate it appropriately to others.

Learning outcome
The learner will:  
1. understand the need for business improvement within organisations

Assessment criteria
The learner can:  
1.1 explain the application of performance measures used in business analysis  
1.2 explain the application of processing measures used in organisations  
1.3 explain types of tools used to improve business performance  
1.4 explain how to apply diagnostic tools  
1.5 explain the benefits of lean programmes to organisations.

Range
Performance measures  
Cost; OEE; manning; material savings; balanced scorecard

Processing measures  
Flow; takt time; pitch time

Tools  
Kaizen; 5S/5C analysis; visual management; VSM; TPM; SMED; SOPs; six sigma; line balancing; lead time analysis; process flow analysis

Apply diagnostic tools  
Manual; electronic; verbal

Benefits  
Cost; quality; productivity; efficiency; effectiveness
## Learning outcome

The learner will:

2. be able to create training plans to identify workplace requirements prior to the implementation of the improvement plan

### Assessment criteria

The learner can:

2.1 outline improvement plan **objectives**
2.2 explain the **terms of reference** of improvement plans
2.3 explain individual **roles** that will be responsible for improvement activities
2.4 assess **skill and knowledge gaps** in individuals who will be responsible for improvement activities
2.5 produce training plans to address skill gaps of individuals responsible for improvement activities.

### Range

**Objectives**
Short term; medium term; long term

**Terms of reference**
Scope; requirements; constraints

**Roles**
Colleagues; subordinates; line manager; department heads; managing director; chief executive

**Skill and knowledge gaps**
Skills matrix; diagnostics; skill scans, consultation with affected people

## Learning outcome

The learner will:

3. be able to produce business improvement plans

### Assessment criteria

The learner can:

3.1 identify **resources** required for improvement activities
3.2 predict **time scales** for completion of improvement activities
3.3 **communicate** role responsibilities for improvement activities including required actions
3.4 evaluate the impact of improvement activities on organisational performance
3.5 identify **performance measures** to be used
3.6 state review dates for improvement activities.

### Range

**Resources**
Physical; HR; financial

**Time scales**
Short-term; medium term; long term

**Communicate**
eg verbal; non-verbal; formal; informal; electronic, importance of consultation process

**Performance measures**
<table>
<thead>
<tr>
<th>Vision; objectives; stakeholders; financial and quality; cost benefit analysis</th>
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<table>
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<tr>
<th><strong>Learning outcome</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The learner will:</td>
</tr>
<tr>
<td>4. be able to communicate business improvement plans to stakeholders</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Assessment criteria</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The learner can:</td>
</tr>
<tr>
<td>4.1 explain who should be involved/consulted with at each stage of the plan</td>
</tr>
<tr>
<td>4.2 communicate potential changes to focus areas</td>
</tr>
<tr>
<td>4.3 explain how improvement and training plans will be communicated to the organisation</td>
</tr>
<tr>
<td>4.4 present results of planning activities to business stakeholders.</td>
</tr>
</tbody>
</table>
Appendix 1 Sources of general information

The following documents contain essential information for centres delivering City & Guilds qualifications. They should be referred to in conjunction with this handbook. To download the documents and to find other useful documents, go to the Centres and Training Providers homepage on www.cityandguilds.com.

Centre Guide – Delivering International Qualifications contains detailed information about the processes which must be followed and requirements which must be met for a centre to achieve ‘approved centre’ status, or to offer a particular qualification. Specifically, the document includes sections on:

- The centre and qualification approval process and forms
- Assessment, verification and examination roles at the centre
- Registration and certification of candidates
- Non-compliance
- Complaints and appeals
- Equal opportunities
- Data protection
- Frequently asked questions.
### Useful contacts

<table>
<thead>
<tr>
<th>UK learners</th>
<th>General qualification information</th>
<th>T: +44 (0)844 543 0033</th>
<th>E: <a href="mailto:learnersupport@cityandguilds.com">learnersupport@cityandguilds.com</a></th>
</tr>
</thead>
<tbody>
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<td>UK learners</td>
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<td>T: +44 (0)844 543 0033</td>
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</tr>
<tr>
<td>International learners</td>
<td>General qualification information</td>
<td>T: +44 (0)844 543 0033</td>
<td>F: +44 (0)20 7294 2413</td>
</tr>
<tr>
<td>Centres</td>
<td>Exam entries, Certificates, Registrations/enrolment, Invoices, Missing or late exam materials, Nominal roll reports, Results</td>
<td>T: +44 (0)844 543 0000</td>
<td>F: +44 (0)20 7294 2413</td>
</tr>
<tr>
<td>Single subject qualifications</td>
<td>Exam entries, Results, Certification, Missing or late exam materials, Incorrect exam papers, Forms request (BB, results entry), Exam date and time change</td>
<td>T: +44 (0)844 543 0000</td>
<td>F: +44 (0)20 7294 2413</td>
</tr>
<tr>
<td>International awards</td>
<td>Results, Entries, Enrolments, Invoices, Missing or late exam materials, Nominal roll reports</td>
<td>T: +44 (0)844 543 0000</td>
<td>F: +44 (0)20 7294 2413</td>
</tr>
<tr>
<td>Walled Garden</td>
<td>Re-issue of password or username, Technical problems, Entries, Results, e-assessment, Navigation, User/menu option, Problems</td>
<td>T: +44 (0)844 543 0000</td>
<td>F: +44 (0)20 7294 2413</td>
</tr>
<tr>
<td>Employer</td>
<td>Employer solutions, Mapping, Accreditation, Development Skills, Consultancy</td>
<td>T: +44 (0)121 503 8993</td>
<td>E: <a href="mailto:business@cityandguilds.com">business@cityandguilds.com</a></td>
</tr>
<tr>
<td>Publications</td>
<td>Logbooks, Centre documents, Forms, Free literature</td>
<td>T: +44 (0)844 543 0000</td>
<td>F: +44 (0)20 7294 2413</td>
</tr>
</tbody>
</table>

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