City & Guilds Level 3 Diploma in Machining (1273-03)

Version 1.0 (March 2023)

Qualification Handbook

Qualification at a glance

Subject area	Manufacturing
City & Guilds number	1273
Age group approved	16+
Entry requirements	Centres must ensure that any pre-requisites stated in the learner entry requirements section are met
Assessment	Multiple-choice test / Short-answer test / Assignment / Portfolio of evidence
Grading	Pass / Merit / Distinction
Approvals	Fast track approval / Full approval for new centres
Support materials	Assessor and Candidate packs, SmartScreen
Registration and certification	Consult the Walled Garden/Online Catalogue for last dates

Title and level	City & Guilds qualification number	Regulatory reference number	GLH	TQT
City & Guilds Level 3 Diploma in Machining	1273-03	610/2166/0	750	811

Version and date	Change detail	Section
1.0 March 2023	Initial version	All

Contents

1 Introduction

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

Area	Description
Who is the qualification for?	This qualification is aimed at learners aged 16 and above who would like to gain the knowledge and skills required for the Level 3 Machining Technician apprenticeship. A learner can also take this qualification as a stand-alone option if they are self-employed or on short-term contracts that do not support the apprenticeship.
What does the qualification cover?	Learners will develop the knowledge and core skills needed to be an effective Machinist. They will also learn about how engineering businesses take account of health and safety, environmental and communication considerations. They will have the opportunity to learn how to carry out advanced operations using different manual and/or CNC machines as well as concepts related to engineering design, quality inspection, CAD/CAM, organisational efficiency and new technologies in the engineering sector.
What opportunities for progression are there?	Upon completion of this qualification, learners will have developed the knowledge and general machining skills required to progress to the end point assessment if all other requirements have been met.

Area	Description
Who did we develop the qualification with?	The qualification has been developed in collaboration with the Machining Employer Group. This consisted of employers, large and small from across the UK along with awarding organisations, EPAOs and training providers including GTA England.
Is it part of an apprenticeship standard or initiative?	Yes, this qualification has been developed to be included as the mandated on-programme component of the Machining Technician apprenticeship standard (England only).

Structure

To achieve the City & Guilds Level 3 Diploma in Machining, learners must achieve all mandatory units and six optional units as stated in the table below:

City & Guilds unit number	Unit title	GLH
Mandatory units:		
Learners must achieve all **5** mandatory units.		
248	General machining, fitting and assembly applications	120
301	Engineering and environmental health and safety	60
302	Communication for machinists/engineers	60
303	Properties and applications of engineering materials	60
304	Engineering maths	90
Optional units:		
Group A - Learners must achieve **3** optional units		
305	Advanced turning techniques	60
306	Advanced milling techniques	60
*307	Advanced milling and turning techniques	90
308	Advanced manufacturing CNC turning techniques	60
309	Advanced manufacturing CNC milling techniques	60
*310	Advanced manufacturing techniques Computer Numerical Control (CNC)	90
311	CNC programming	60
312	Specialist machining	60
314	Precision grinding techniques	60
317	Engineering inspection and quality control	60

Group B - Learners must achieve **2** optional units		
313	CAD/CAM	60
315	Further maths	60
316	Engineering organisational efficiency and improvement	60
318	Engineering design process	60
Group C - Learners must achieve **1** optional unit		
319	Additive manufacturing processes	60
320	Industry 4.0	60
321	Environmental engineering and sustainability	60
322	Simulation and digital twinning	60
323	Cyber security for engineers	60
324	Data analytics/Big data	60
325	Autonomous systems	60

*Please note the following **barred** unit combinations:

307 with either 305 or 306

310 with either 308 or 309

Learners may take an additional optional unit but only 6 optional units will count towards achievement of their qualification.

Total Qualification Time (TQT)

Total Qualification Time (TQT) is the number of notional hours which represents an estimate of the total amount of time that could reasonably be expected for a learner to demonstrate the achievement of the level of attainment necessary for the award of a qualification.

TQT is comprised of the following two elements:

1) The number of hours that an awarding organisation has assigned to a qualification for Guided Learning, and
2) An estimate of the number of hours a learner will reasonably be likely to spend in preparation, study or any other form of participation in education or training, including assessment, which takes place as directed by - but, unlike Guided Learning, not under the immediate guidance or supervision of - a lecturer, supervisor, tutor or other appropriate provider of education or training.

Title and level	GLH	TQT
City & Guilds Level 3 Diploma in Machining	750	811

2 Centre requirements

Approval

Full approval for new centres

To offer this qualification new centres will need to gain both centre and qualification approval. Please refer to the document **Quality Assurance Standards: Centre Approval Process** for further information.

Centre staff should familiarise themselves with the structure, content and assessment requirements of the qualification before designing a course programme.

Fast-track approval

If your centre is approved to offer the 1271-03 Level 3 Diploma in Advanced Manufacturing Engineering (Development Competence) or 1272-03 Level 3 Diploma in Machining - (Development Knowledge) then you can apply for fast track approval for the new 1273-03 Level 3 Diploma in Machining using the fast track approval form, available from the City & Guilds website.

Centres should use the fast track form if:

- there have been no changes to the way the qualifications are delivered, and
- they meet all of the approval criteria in the fast track form guidance notes.

Fast track approval is available for 12 months from the launch of the qualification. After 12 months, centres will have to go through the standard Qualification Approval Process. The centre is responsible for checking that fast track approval is still current at the time of application.

Please refer to the document **Quality Assurance Standards: Centre Approval Process** for further information.

Centre staff should familiarise themselves with the structure, content and assessment requirements of the qualifications before designing a course programme.

Resource requirements

Centre staffing

Staff delivering this qualification must be able to demonstrate that they meet the following occupational expertise requirements. They should:

- be occupationally competent or technically knowledgeable in the area(s) for which they are delivering training and/or have experience of providing training. This knowledge must be to the same level as the training being delivered
- have recent relevant experience in the specific area they will be assessing
- have credible experience of providing training.

Assessor requirements for Unit 248

- Assessment must be carried out by competent Assessors that as a minimum must hold the Level 3 Award in Assessing Competence in the Work Environment.

- Current and operational Assessors that hold units D32 and/or D33 or A1 and/or A2 as appropriate to the assessment being carried out, will not be required to achieve the Level 3 Award as they are still appropriate for the assessment requirements set out in this unit assessment strategy. However, they will be expected to regularly review their skills, knowledge and understanding and where applicable undertake continuing professional development to ensure that they are carrying out assessment to the most up to date assessor standards.

Assessor technical requirements:

- Assessors must be able to demonstrate that they have verifiable, relevant, and sufficient technical competence to evaluate and judge performance and knowledge evidence requirements as set out in the relevant outcomes in Unit 248.

- This will be demonstrated either by holding a relevant technical qualification or by proven industrial experience of the technical areas to be assessed. The assessor's competence must, at the very least, be at the same level as that required of the learner in the unit being assessed.

Continuing professional development (CPD)

Centres are expected to support their staff in ensuring that their knowledge remains current of the occupational area and of best practice in delivery, mentoring, training, assessment and quality assurance, and that it takes account of any national or legislative developments.

Quality assurance

Approved centres must have effective quality assurance systems to ensure optimum delivery and assessment of qualifications. Quality assurance includes initial centre approval, qualification approval and the centre's own internal procedures for monitoring quality. Centres are responsible for internal quality assurance and City & Guilds is responsible for external

quality assurance. For more detail on this visit the Quality Assurance Standards documents on the City & Guilds website.

Standards and rigorous quality assurance are maintained by the use of:

- Internal quality assurance
- City & Guilds external quality assurance.

In order to carry out the quality assurance role, Internal Quality Assurers must

- have appropriate teaching and vocational knowledge and expertise
- have experience in quality management/internal quality assurance
- hold or be working towards an appropriate teaching/training/assessing qualification
- be familiar with the occupation and technical content covered within the qualification.

External quality assurance for the qualification will be provided by City & Guilds EQA process. EQAs are appointed by City & Guilds to approve centres, and to monitor the assessment and internal quality assurance carried out by centres. External quality assurance is carried out to ensure that assessment is valid and reliable, and that there is good assessment practice in centres.

The role of the EQA is to:

- provide advice and support to centre staff
- ensure the quality and consistency of assessments within and between centres by the use of systematic sampling
- provide feedback to centres and to City & Guilds.

Learner entry requirements

City & Guilds does not set entry requirements for this qualification. However, centres must ensure that learners have the potential and opportunity to gain the qualification successfully.

Age restrictions

This qualification is approved for learners aged 16 or above.

Access to assessment and special consideration

For information on how to apply for access arrangements please refer to ***How and when to apply for access arrangements and special consideration (cityandguilds.com)***

3 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:

Description	How to access
Assessor and candidate assessment packs	www.cityandguilds.com
SmartScreen	www.smartscreen.co.uk

4 Assessment

Assessment of the qualification

Candidates must:

- have a completed portfolio of evidence for unit 248
- successfully complete an online multiple-choice test for mandatory unit 301
- successfully complete a short-answer test for each mandatory unit 302-304
- successfully complete a short-answer test for each chosen optional unit with the exception of units 312, 316, 319-325 for which the learner must complete an assignment

Assessment Types			
Unit	**Title**	**Assessment method**	**Where to obtain assessment materials**
248	General machining, fitting and assembly applications	**Portfolio of evidence** Centre devised, internally set and marked assessment	**n/a**
301	Engineering and environmental health and safety	**Online multiple-choice test 301** Externally set and externally marked	**City & Guilds e-volve system**
302	Communication for machinists/engineers	**Short-answer test 302** Externally set and internally marked	**www.cityandguilds.com**
303	Properties and applications of engineering materials	**Short-answer test 303** Externally set and internally marked	**www.cityandguilds.com**
304	Engineering maths	**Short-answer test 304** Externally set and internally marked	**www.cityandguilds.com**
305	Advanced turning techniques	**Short-answer test 305** Externally set and internally marked	**www.cityandguilds.com**
306	Advanced milling techniques	**Short-answer test 306** Externally set and internally marked	**www.cityandguilds.com**
307	Advanced milling and turning techniques	**Short-answer test 307** Externally set and internally marked	**www.cityandguilds.com**
308	Advanced manufacturing CNC turning techniques	**Short-answer test 308** Externally set and internally marked	**www.cityandguilds.com**

309	Advanced manufacturing CNC milling techniques	**Short-answer test 309** Externally set and internally marked	**www.cityandguilds.com**
310	Advanced manufacturing techniques Computer Numerical Control (CNC)	**Short-answer test 310** Externally set and internally marked	**www.cityandguilds.com**
311	CNC programming	**Short-answer test 311** Externally set and internally marked	**www.cityandguilds.com**
312	Specialist machining	**Assignment 312** Externally set and internally marked	**www.cityandguilds.com**
313	CAD/CAM	**Short-answer test 313** Externally set and internally marked	**www.cityandguilds.com**
314	Precision grinding techniques	**Short-answer test 314** Externally set and internally marked	**www.cityandguilds.com**
315	Further maths	**Short-answer test 315** Externally set and internally marked	**www.cityandguilds.com**
316	Engineering organisational efficiency and improvement	**Assignment 316** Externally set and internally marked	**www.cityandguilds.com**
317	Engineering inspection and quality control	**Short-answer test 317** Externally set and internally marked	**www.cityandguilds.com**
318	Engineering design process	**Short-answer test 318** Externally set and internally marked	**www.cityandguilds.com**

319	Additive manufacturing processes	**Assignment 319** Externally set and internally marked	**www.cityandguilds.com**
320	Industry 4.0	**Assignment 320** Externally set and internally marked	**www.cityandguilds.com**
321	Environmental engineering and sustainability	**Assignment 321** Externally set and internally marked	**www.cityandguilds.com**
322	Simulation and digital twinning	**Assignment 322** Externally set and internally marked	**www.cityandguilds.com**
323	Cyber security for engineers	**Assignment 323** Externally set and internally marked	**www.cityandguilds.com**
324	Data analytics/Big data	**Assignment 324** Externally set and internally marked	**www.cityandguilds.com**
325	Autonomous systems	**Assignment 325** Externally set and internally marked	**www.cityandguilds.com**

Assessment strategy

City & Guilds has written the following assessments to use with this qualification:

- short-answer tests, which can be downloaded from the City & Guilds website
- live assignments, which can be downloaded from the City & Guilds website

Portfolio of evidence

Unit 248 General Machining is based on an Employer Unit of Competence (EUC) and will be assessed via a Portfolio of Evidence. All evidence in the portfolio for the learning outcomes must be generated in the workplace or in a sheltered but realistic working environment such as in a Training Centre or College where the environment replicates that expected in industry.

This is due to an on-going emphasis on safety critical work activities and the need to ensure flexibility of assessment opportunities to both maintain and enhance the provision of competent personnel within the Advanced Manufacturing and Engineering sector. This assessment method will allow a minimum safe level of skills, knowledge and understanding to be achieved and demonstrated by the learner prior to being exposed to the hazards of the industrial environment, thus minimising the risk of injury to themselves and other employees.

Where applicable, the machinery, tools, materials, equipment, and resources used must be representative of industry standards and there must be sufficient equipment/resources available for each learner to demonstrate their competence on an individual basis. Workpieces or work outcomes assessed must be the learner's own work and should be actual work examples that combine the skills and techniques required by the Employer Units of Competence so that achievement will properly reflect the learner's capabilities.

Assessors must therefore ensure that the competency for this unit is fully transferable to the workplace.

Other aspects that should be considered could include:

- Environmental conditions such as lighting conditions, noise levels and the presence of
- hazards
- Pressure of work, including time constraints and repetitive activities
- Producing actual workpieces or work outcomes, the consequence of making mistakes, and the effect this has on customer, supplier, and departmental relationships

Candidates and centres may decide to use a paper-based or electronic method of recording evidence.

City & Guilds endorses several ePortfolio systems, including our own, **Learning Assistant**, an easy-to-use and secure online tool to support and evidence learners' progress towards achieving qualifications. Further details are available at **www.cityandguilds.com/eportfolios**.

City & Guilds has developed a set of *Recording forms* including examples of completed forms, for new and existing centres to use as appropriate. *Recording forms* are available on the City & Guilds website.

Although new centres are expected to use these forms, centres may devise or customise alternative forms, which must be approved for use by the External Quality Assurers, before they are used by candidates and assessors at the centre. Amendable (MS Word) versions of the forms are available on the City & Guilds website.

Evidence sources

A Portfolio of Evidence will typically include several pieces of evidence - it must contain sufficient evidence to demonstrate the knowledge and skills required in Unit 248.

Evidence sources may include:

- training logbooks
- centre produced worksheets and activities
- annotated photographs
- video clips (maximum duration in total 10-minutes)
- workplace documentation/records, for example job cards/job sheets, equipment check/maintenance/service records, parts order records.

This is not a definitive list; other evidence sources are permitted.

The evidence provided must be valid and attributable to the learner; the Portfolio of Evidence must contain a statement from the centre confirming this.

Evidence **must not** include any methods of self-assessment.

Any employer contributions should focus on direct observation of evidence (for example witness statements) of competence rather than opinions.

Time constraints

The following must be applied to the assessment of this qualification:

Candidates must finish their assessment within the candidate's period of registration.

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.

The following RPL is allowed for this qualification:

1272-03 Level 3 Diploma in Machining (Development Knowledge) – a candidate's prior achievement of units and assessments 1272-302 to 318 can be used to claim the equivalent unit within the 1273-03 Level 3 Diploma in Machining. However, candidates must successfully complete the multiple-choice online test for unit 301 Engineering and environmental health and safety.

Assessment objectives

The theory tests (301-311, 313-315, 317-318) for this qualification are set against a set of assessment objectives (AOs), see below for detail. They are designed to allow judgement of the candidate to be made across a number of different categories of performance. Each theory test for the qualification has been allocated a set number of marks against these AOs based on weightings recommended by stakeholders of the qualification, in addition to the Learning Outcome weightings specified in the test specifications. This mark allocation remains the same for all versions of the tests, ensuring consistency across versions and over time.

AO1 - Recall of knowledge relating to the unit LOs

Security of factual knowledge base that is available to the candidate when presented with a problem. The candidate's ability to recall the specific knowledge that is important in relation to the context is what is being assessed – the breadth of knowledge seen may be limited by the context ie have they recalled the breadth expected given the context.

AO2 - **Understanding of concepts/ theories/ processes relating to the unit LOs**

Security of understanding of the theories, concepts and processes that underpin the unit – the ability of the candidate to correctly apply or explain understanding in the specific context or make plausible adjustments to thinking that demonstrates understanding rather than recall or mimicry. This is about quality of understanding of individual concepts rather than recall of facts.

Test specifications

The way the knowledge is covered by each test, by learning outcome and by assessment objective (AO) is laid out in the tables below:

Assessment title: 1273-301 Engineering and environmental health and safety

Assessment type: Online multiple-choice test

Assessment conditions: Invigilated exam conditions

Graded: Pass/Fail

Pass mark: The pass mark for this test will be approximately 60%

This pass mark may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-301	**Duration: 60 minutes**		
Unit	**Outcome**	**Number of marks**	**Percentage %**
301	01 Understand workplace health and safety responsibilities	12	40
	02 Understand how to maintain a safe and healthy workplace	9	30
	03 Understand environmental management requirements of engineering businesses	9	30
	Total	30	100%

Test: 1273-301	**Duration: 60 minutes**	**AO1**	**AO2**
Unit	**Outcome**	**Approx %**	**Approx %**
301	01 Understand workplace health and safety responsibilities	30	10
	02 Understand how to maintain a safe and healthy workplace	20	10
	03 Understand environmental management requirements of engineering businesses	23	7
	Total	73%	27%

Assessment title: 1273-302 Communication for machinists/engineers

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 65%
Distinction: 80%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-302	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**Percentage %**
302	01 Understand how to communicate technical information	26	52
	02 Understand how to communicate general information	24	48
	Total	50	100%

Test: 1273-302	Duration: 90 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
302	01 Understand how to communicate technical information	20	32
	02 Understand how to communicate general information	16	32
	Total	36%	64%

Assessment title: 1273-303 Properties and applications of engineering materials

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 44%
Merit: 60%
Distinction: 75%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-303	Duration: 75 minutes		
Unit	**Outcome**	**Number of marks**	**Percentage %**
303	01 Understand the properties of materials	16	36
	02 Understand why engineering materials fail	16	36
	03 Understand the suitability of engineering materials	13	28
	Total	45	100%

Test: 1273-303	Duration: 75 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
303	01 Understand the properties of materials	9	27
	02 Understand why engineering materials fail	9	27
	03 Understand the suitability of engineering materials	0	28
	Total	18%	82%

Assessment title: 1273-304 Engineering maths

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 65%
Distinction: 80%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-304	**Duration: 75 minutes**		
Unit	**Outcome**	**Number of marks**	**Percentage %**
304	01 Solve engineering problems using arithmetic	9	22.5
	02 Solve engineering problems using algebraic methods	10	25
	03 Solve engineering problems using trigonometric methods	9	22.5
	04 Solve engineering problems using calculus	8	20
	05 Solve engineering problems using statistics	4	10
	Total	40	100%

Test: 1273-304	Duration: 75 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
304	01 Solve engineering problems using arithmetic	0	22.5
	02 Solve engineering problems using algebraic methods	0	25
	03 Solve engineering problems using trigonometric methods	0	22.5
	04 Solve engineering problems using calculus	0	20
	05 Solve engineering problems using statistics	0	10
	Total	**n/a**	100%

Assessment title: 1273-305 Advanced turning techniques

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 65%
Distinction: 80%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-305	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**Percentage %**
305	01 Understand equipment required for advanced turning operations	16	32
	02 Understand how to produce complex turned components on a lathe	26	52
	03 Understand how to meet quality requirements for advanced turning operations	8	16
	Total	50	100%

Test: 1273-305	Duration: 90 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
305	01 Understand equipment required for advanced turning operations	4	28
	02 Understand how to produce complex turned components on a lathe	4	48
	03 Understand how to meet quality requirements for advanced turning operations	0	16
	Total	8%	92%

Assessment title: 1273-306 Advanced milling techniques

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 65%
Distinction: 80%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-306	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**Percentage %**
306	01 Understand equipment required for advanced milling operations	16	32
	02 Understand how to produce complex components on a milling machine	26	52
	03 Understand how to meet quality requirements for advanced milling operations	8	16
	Total	50	100%

Test: 1273-306	Duration: 90 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
306	01 Understand equipment required for advanced milling operations	4	28
	02 Understand how to produce complex components on a milling machine	4	48
	03 Understand how to meet quality requirements for advanced milling operations	0	16
	Total	8%	92%

Assessment title: 1273-307 Advanced milling and turning techniques

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 65%
Distinction: 80%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-307	Duration: 100 minutes		
Unit	**Outcome**	**Number of marks**	**Percentage %**
307	01 Understand equipment required for advanced machining operations	26	43
	02 Understand how to produce complex machined components	26	43
	03 Understand how to meet quality requirements for advanced machining operations	8	14
	Total	60	100%

Test: 1273-307	Duration: 100 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
307	01 Understand equipment required for advanced machining operations	3.5	40
	02 Understand how to produce complex machined components	3.5	40
	03 Understand how to meet quality requirements for advanced machining operations	0	13
	Total	7%	93%

Assessment title: 1273-308 Advanced manufacturing CNC turning techniques

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 60%
Distinction: 70%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-308	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**Percentage %**
308	01 Understand equipment required for CNC operations on multi-axis CNC machines	16	32
	02 Understand how to produce complex components on multi-axis CNC lathes	26	52
	03 Understand how to meet quality requirements for advanced CNC turning operations	8	16
	Total	50	100%

Test: 1273-308	Duration: 90 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
308	01 Understand equipment required for CNC operations on multi-axis CNC machines	4	28
	02 Understand how to produce complex components on multi-axis CNC lathes	4	48
	03 Understand how to meet quality requirements for advanced CNC turning operations	0	16
	Total	8%	92%

Assessment title: 1273-309 Advanced manufacturing CNC milling techniques

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 60%
Distinction: 70%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-309	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**Percentage %**
309	01 Understand equipment required for CNC operations on multi-axis CNC milling machines	16	32
	02 Understand how to produce complex components on multi-axis CNC milling machines	26	52
	03 Understand how to meet quality requirements for advanced CNC milling operations	8	16
	Total	50	100%

Test: 1273-309	Duration: 90 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
309	01 Understand equipment required for CNC operations on multi-axis CNC milling machines	4	28
	02 Understand how to produce complex components on multi-axis CNC milling machines	4	48
	03 Understand how to meet quality requirements for advanced CNC milling operations	0	16
	Total	8%	92%

Assessment title: 1273-310 Advanced manufacturing techniques Computer Numerical Control (CNC)

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 60%
Distinction: 70%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-310	**Duration: 90 minutes**		
Unit	**Outcome**	**Number of marks**	**Percentage %**
310	01 Understand equipment required for CNC operations on multi-axis CNC machines	16	32
	02 Understand how to produce complex components on multi-axis CNC machines	26	52
	03 Understand how to meet quality requirements for advanced CNC operations	8	16
	Total	50	100%

Test: 1273-310	**Duration: 90 minutes**	**AO1**	**AO2**
Unit	**Outcome**	**Approx %**	**Approx %**
310	01 Understand equipment required for CNC operations on multi-axis CNC machines	4	28
	02 Understand how to produce complex components on multi-axis CNC machines	4	48
	03 Understand how to meet quality requirements for advanced CNC operations	0	16
	Total	8%	92%

Assessment title: 1273-311 CNC programming

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 65%
Distinction: 80%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-311	**Duration: 75 minutes**		
Unit	**Outcome**	**Number of marks**	**Percentage %**
311	01 Understand equipment required for CNC machining	8	20
	02 Understand how to produce programs for CNC machining	32	80
	Total	40	100%

Test: 1273-311	**Duration: 75 minutes**	**AO1**	**AO2**
Unit	**Outcome**	**Approx %**	**Approx %**
311	01 Understand equipment required for CNC machining	0	20
	02 Understand how to produce programs for CNC machining	0	80
	Total	n/a	100%

Assessment title: 1273-313 CAD/CAM

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 65%
Distinction: 80%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-313	**Duration: 90 minutes**		
Unit	**Outcome**	**Number of marks**	**Percentage %**
313	01 Understand the application of Computer Aided Engineering (CAE)	14	28
	02 Understand how to operate CAD software to produce complex designs	22	44
	03 Understand the use of CAD/CAM in machining	14	28
	Total	50	100%

Test: 1273-313	**Duration: 90 minutes**	**AO1**	**AO2**
Unit	**Outcome**	**Approx %**	**Approx %**
313	01 Understand the application of Computer Aided Engineering (CAE)	12	16
	02 Understand how to operate CAD software to produce complex designs	12	32
	03 Understand the use of CAD/CAM in machining	4	24
	Total	28%	72%

Assessment title: 1273-314 Precision grinding techniques

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 65%
Distinction: 80%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-314	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**Percentage %**
314	01 Understand equipment needed for precision grinding	16	32
	02 Understand how to produce complex components with grinding machines	26	52
	03 Understand how to meet quality requirements for precision grinding operations	8	16
	Total	50	100%

Test: 1273-314	Duration: 90 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
314	01 Understand equipment needed for precision grinding	4	28
	02 Understand how to produce complex components with grinding machines	4	48
	03 Understand how to meet quality requirements for precision grinding operations	0	16
	Total	8%	92%

Assessment title: 1273-315 Further maths

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 40%
Merit: 58%
Distinction: 75%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-315	**Duration: 90 minutes**		
Unit	**Outcome**	**Number of marks**	**Percentage %**
315	01 Solve engineering problems using algebraic methods	19	38
	02 Solve engineering problems using trigonometric methods	15	30
	03 Solve engineering problems using calculus	16	32
	Total	50	100%

Test: 1273-315	**Duration: 90 minutes**	**AO1**	**AO2**
Unit	**Outcome**	**Approx %**	**Approx %**
315	01 Solve engineering problems using algebraic methods	0	38
	02 Solve engineering problems using trigonometric methods	0	30
	03 Solve engineering problems using calculus	0	32
	Total	n/a	100%

Assessment title: 1273-317 Engineering inspection and quality control

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 63%
Distinction: 75%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-317	Duration: 100 minutes		
Unit	**Outcome**	**Number of marks**	**Percentage %**
317	01 Understand the principles and applications of quality management systems	18	30
	02 Understand the application of measurement techniques	22	37
	03 Understand the application of Statistical Process Control (SPC) to manage product quality	20	33
	Total	60	100%

Test: 1273-317	Duration: 100 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
317	01 Understand the principles and applications of quality management systems	20	10
	02 Understand the application of measurement techniques	0	37
	03 Understand the application of Statistical Process Control (SPC) to manage product quality	0	33
	Total	20%	80%

Assessment title: 1273-318 Engineering design process

Assessment type: Short-answer test

Assessment conditions: Supervised exam conditions

Graded: Pass/Merit/Distinction

Grade boundaries: The grade boundaries for this test will be approximately:
Pass: 50%
Merit: 60%
Distinction: 70%

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

Test: 1273-318	Duration: 90 minutes		
Unit	**Outcome**	**Number of marks**	**Percentage %**
318	01 Understand the design process	18	36
	02 Understand the factors considered when designing a product	15	30
	03 Understand how manufacturing processes influence design	17	34
	Total	50	100%

Test: 1273-318	Duration: 90 minutes	AO1	AO2
Unit	**Outcome**	**Approx %**	**Approx %**
318	01 Understand the design process	16	20
	02 Understand the factors considered when designing a product	8	22
	03 Understand how manufacturing processes influence design	18	16
	Total	42%	58%

5 Grading

Grading of individual assessments

Units 248 is graded Pass only.

Assessment for unit 301 is graded Pass only.

Individual assessments for units 302-325 are graded Pass/Merit/Distinction.

For a unit to be achieved, candidates must achieve a minimum Pass in the assessment, as per the marking scheme provided.

A Pass reflects the minimum requirements that are expressed in the unit, with Merit and Distinction showing progression in the depth and breadth of the learner's knowledge, as well as in the type of cognitive operations they demonstrate.

Grading of the qualification

The grade boundaries for Pass, Merit and Distinction for individual assessments for units 301-325 have been set through a judgemental process using technical experts, aimed at defining what the grades for each assessment should mean in practice. The following descriptors are based on that process.

For the units to be achieved, candidates must achieve a minimum of Pass in the assessments. The descriptors given here simply provide a baseline against which Merit and Distinction grades can be understood and should **not** be used for grading/marking the assessments.

Pass

The candidate has a solid understanding of the unit key concepts. Some understanding may be simplistic, narrow or shallow. Individual topics are dealt with separately but understanding is clear. Recall of the unit content is generally accurate, without serious misapprehensions or gaps. Recall may be slow or show signs of difficulty/uncertainty and minor misapprehensions may occur.

Indicators:

- explanations may be a little incoherent or incomplete but the meaning is on the whole accurate
- the use of illustrations/examples are mostly relevant to the explanation
- relationships between concepts are missing
- reasoning shows comprehension of the main facts
- analyses or evaluations are simplistic but relevant
- sources, when used, are limited but relevant

- main facts are stated accurately
- definitions and descriptions are accurate, but somewhat limited
- diagrams, when used, are mostly correctly annotated, with some minor errors eg spelling.

Merit

The candidate has a sound understanding of the breadth/depth of the relevant concepts. Topics are dealt with in relation to each other and communicated clearly. The breadth and depth of the unit content are recalled in an accurate and complete manner. Recall is confident.

Indicators:

- explanations are coherent, complete and accurate
- use of illustrations/examples which accurately and clearly add to/support the explanation
- relationships are made between concepts
- reasoning is plausible and conventional
- analyses and evaluations are methodical and plausible
- information is drawn from a range of appropriate sources and used appropriately
- facts are accurate and cover the breadth and depth of the unit
- definitions and descriptions are clear
- technical language is accurate

Distinction

The candidate has a well-developed understanding of the relevant concepts. Relationships between topics are highly developed and may be set in context; interactions between topics are clearly expressed. There is evidence of understanding of some facts/knowledge which go beyond the requirements of the unit. Recall is automatic and can be brought together making useful connections.

Indicators:

- explanations are well thought out, thorough and well-argued/justified
- well-chosen illustrations/ examples, which accurately and precisely clarify explanations
- relationships are brought together to show an understanding of the bigger picture
- reasoning is justified, well-argued and may be creative
- analyses and evaluations are thorough, well-developed
- sourced information is critically evaluated, showing awareness of its importance or relevance
- evidence of interest beyond the scope of the unit
- descriptions and definitions are detailed
- use of knowledge is consistently high and second nature.

Grading of qualification

The Employer Group has taken the decision to grade this qualification Pass/Merit/Distinction, through the aggregation of the individual assessments graded Pass/Merit/Distinction.

Grading can be of use both as a motivational tool within the learning environment and also to learners presenting evidence of their knowledge to prospective employers.

All assessments must be achieved at a minimum of Pass for the qualification to be awarded. Assessments graded Pass/Merit/Distinction (units 302-325 only) contribute equally to the overall qualification grade.

Centres will need to calculate the qualification grade as follows:

- The grade achieved by a learner will need to be converted into points as follows:

Individual assessment grade (units 302-325)	Grade points
Pass	2
Merit	3
Distinction	4

- Grade points for each of the **nine** graded assessments achieved need to be added together in line with the qualification structure, and the overall qualification grade determined, using the following conversion table:

Total grade points	Overall qualification grade
18 – 22	Pass
23 - 31	Merit
32 – 36	Distinction

Overall grade calculation must include the graded mandatory units (302-304) and six optional units only, as shown in the example below. If any additional optional units are taken the six highest scoring optional units must be used in the overall grade calculation.

Example
Learner A has achieved the following:

Assessment	Grade achieved	Grade points
Mandatory		
1273-248	Pass	No grade points, as Pass/Fail only
1273-301	Pass	No grade points, as Pass/Fail only
1273-302	Pass	2
1273-303	Pass	2
1273-304	Merit	3
Optional		
1273-3xx	Distinction	4
1273-3xx	Pass	2
1273-3xx	Merit	3
1273-3xx	Merit	3
1273-3xx	Distinction	4
1273-3xx	Pass	2
	Total grade points	**25**
	Overall qualification grade	**Merit**

- Overall qualification grades must be entered using **one** of the following overall grading modules on the Walled Garden:

  901 Pass
  902 Merit
  903 Distinction

6 Units

Structure of the units

Unit 248 has the following:

- City & Guilds reference number
- Title
- Level
- Guided learning hours (GLH)
- Performance requirements and related scope/range, and knowledge and understanding content

Units 301-325 each have the following:

- City & Guilds reference number
- Title
- Level
- Guided learning hours (GLH)
- Learning outcomes, which are comprised of a number of topics and associated range content

Guidance for delivery of the units

This qualification is comprised of a number of **units**. A unit describes what is expected of a competent person in particular aspects of his/her job.

Unit 248 is based on an Employer Unit of Competence (EUC) and comprises of the Performance requirements and related scope/range, and knowledge and understanding criteria that must be satisfied before an individual can be said to have performed to the agreed standard.

Units 301-325
Each **unit** is divided into **learning outcomes** which describe in further detail the knowledge that a candidate should possess.

Each **learning outcome** has a set of **topics** (knowledge and understanding) which specify the desired criteria that must be satisfied before an individual can be said to have performed to the agreed standard.

Topic statements define the breadth or scope of a learning outcome and its topics by setting out the various circumstances in which they are to be applied.

Supporting information provides guidance of the evidence requirement for the unit and specific guidance on delivery and topic statements. Centres are advised to review this information carefully before delivering the unit.

Unit 248 General machining, fitting and assembly applications

Level:	2
GLH:	120
Assessment type:	Portfolio of evidence
Aim:	This unit covers a broad range of basic machining, fitting and assembly competences that will prepare learners for entry into the engineering or manufacturing sectors, creating a progression between education and employment, or that will provide a basis for the development of additional skills and occupational competences in the working environment. Learners will be expected to carry out practical exercises in order to gain an understanding of how these machining, fitting and assembly activities are undertaken, the types of equipment used, the manufacturing techniques, and the operating and safety procedures that are required. In carrying out the activities, learners will use appropriate tools and equipment to mark out the material for the features to be produced, and then to use hand tools, portable power tools, machine tools and shaping, fitting and assembly techniques appropriate to the operations being performed. These activities will include sawing, filing, drilling, turning, milling and assembly. During, and on completion of, the operations, learners will be expected to check the quality of the workpiece, using measuring equipment appropriate to the aspects being checked and the tolerances to be achieved. Learners will need to be able to recognise when the activities are not meeting the required specification, and to discuss/determine what action needs to be taken to remedy any faults that occur, in order to ensure that the finished workpiece is within the specification requirements. On completion of the activities, learners will be expected to return all tools and equipment that learners have used to the correct location, and to leave the work area in a safe and tidy condition. Learner responsibilities will require them to comply with health and safety requirements and organisational policy and procedures for the activities undertaken. Learners will need to take account of any potential difficulties or problems that may arise with the activities, and to seek

appropriate help and advice in determining and implementing a suitable solution. Learners will work under a high level of supervision, whilst taking responsibility for their own actions and for the quality and accuracy of the work that learner carry out.

Learner underpinning knowledge will provide an understanding of their work, and will enable learners to apply appropriate machining, fitting and assembly techniques and procedures safely. Learners will understand the machining, fitting and assembly processes, and their application, and will know about the equipment, materials and consumables, to the required depth to provide a sound basis for carrying out the activities to the required specification.

Learners will understand the safety precautions required when carrying out the various machining, fitting and assembly techniques, and when using hand tools and machinery. Learners will be required to demonstrate safe working practices throughout, and will understand the responsibility learners owe to themselves and others in the workplace.

They will be able to apply the appropriate behaviours required in the workplace to meet the job profile and overall company objectives, such as strong work ethic, positive attitude, team player, dependability, responsibility, honesty, integrity, motivation and commitment.

Performance requirements

The learner will:

P1 work safely at all times, complying with health and safety legislation, regulations, directives and other relevant guidelines
P2 demonstrate the required behaviours in line with the job role and company objectives
P3 determine what has to be done and how they are going to do it
P4 obtain the appropriate tools and equipment for the manufacturing operations
P5 mark out the components for the required operations, using appropriate tools and techniques
P6 cut and shape the materials to the required specification, using appropriate tools and techniques
P7 use appropriate methods and techniques to assemble and secure the components in their correct positions
P8 measure and check that all dimensional and geometrical aspects of the component are to the specification

P9 deal promptly and effectively with problems within their control, and seek help and guidance from the relevant people if they have problems that they cannot resolve

P10 leave the work area in a safe and tidy condition on completion of the manufacturing activities

Knowledge and understanding

The learner will know and understand:

K1 the health and safety requirements, and safe working practices and procedures required for the machining, fitting and assembly activities undertaken (such as wearing appropriate protective clothing and equipment (PPE), using machine guards, and of keeping the work area safe and tidy

K2 the hazards associated with the activities (such as use of power tools, trailing leads or hoses, damaged or badly maintained tools and equipment, using files with damaged or poor fitting handles, using machine tools), and how they can be minimised

K3 how to extract and use information from engineering drawings and related specifications (to include symbols and conventions to appropriate BS or ISO standards) in relation to work undertaken

K4 the importance of applying the appropriate behaviours in the workplace and the implications for both the apprentice and the business if these are not adhered to

K5 how to interpret first and third angle drawings, imperial and metric systems of measurement, workpiece reference points and system of tolerancing

K6 how to prepare the materials in readiness for the marking out activities, in order to enhance clarity, accuracy and safety (such as visually checking for defects, cleaning the materials, removing burrs and sharp edges, applying a marking-out medium)

K7 how to select and establish a suitable datum; the importance of ensuring that marking out is undertaken from the selected datum, and the possible effects of working from a different datum

K8 use of marking-out conventions when marking out the workpiece (such as datum lines, cutting guidelines, square and rectangular profiles, circular and radial profiles, angles, holes linearly positioned, boxed and on pitch circles)

K9 the various fitting activities to be carried out (such as how to file flat, square and curved surfaces and achieve a smooth surface finish; how to select saw blades for different materials, and how to set the saw blades for different operations; how to produce screw threads on workpieces using hand dies; how to determine the drill size for tapped holes, and the importance of using the taps in the correct sequence)

K10 how to prepare drilling machines for operations (such as adjustment of table height and position; mounting and securing drills, in chucks or Morse taper sockets; setting and adjusting spindle speeds; setting and adjusting guards/safety devices)

K11 methods of holding the workpiece for the hand fitting, turning and milling activities (such as in a bench vice, machine vice, chuck, collets or clamped directly to the machine table)

K12 the assembly methods, techniques and procedures to be used; how the components are to be aligned, adjusted and positioned prior to securing them, and the tools and equipment that is used

K13 the various mechanical fastening devices that are used (such as nuts, bolts, machine screws, cap screws, clips, pins, locking and retaining devices)

K14 the various turning operations that can be performed (such as parallel, stepped and tapered external diameters, drilled, bored and reamed holes, internal and external screw threads, special profiles)

K15 the various milling operations that can be performed (such as flat, parallel, square and angled surfaces; open ended and enclosed slots, special forms, drilled and bored holes)

K16 how to mount and secure the cutting tools in the tool holding devices (such as front or rear tools posts; mounting cutters on long or stub arbors; mounting drills in chucks or by the use of morse taper sockets; the need to ensure that the tool is sharp and secure)

K17 the techniques of taking trial cuts and checking dimensional accuracy; the application of roughing and finishing cuts, and the effect on tool life, surface finish and dimensional accuracy

K18 factors that affect the selection of cutting feeds and speeds, and the depth of cut that can be taken (such as type of material, size of material, operations being performed, workholding method/security of workpiece, condition of machine, finish and tolerance required)

K19 the application of cutting fluids and compounds with regard to a range of different materials, and why some materials do not require cutting fluids to be used

K20 how to check the workpiece and the measuring equipment that is used (such as rules, micrometers, Verniers, gauges and surface finish comparison equipment)

K21 the need to check that the measuring equipment is within current calibration dates, and that the instruments are correctly zeroed; measuring internal and external dimensions (such as lengths, diameters, depths, slots, hole positions, angles, profiles); measuring geometric features (such flatness, squareness, parallelism, concentricity, ovality); how to check surface finish (such as by using comparison blocks or instruments)

K22 when to act on own initiative and when to seek help and advice from others

K23 the importance of leaving the work area and equipment in a safe and clean condition on completion of the machining and fitting activities (such as isolating machines, removing and returning cutting tools, cleaning the equipment, and removing and disposing of waste)

Scope/range related to performance criteria

The learner will be able to:

1. carry out **all** of the following during the machining, fitting and assembly activities:

- 1.1 adhere to procedures or systems in place for risk assessment, COSHH, personal protective equipment (PPE) and other relevant safety regulations
- 1.2 ensure that all hand tools and equipment used are in a safe and serviceable condition (such as cables to hand tools and extension leads, file handles, hammer striking faces)
- 1.3 ensure that all machine tools are correctly guarded at all times
- 1.4 check that all measuring equipment is within calibration date
- 1.5 return all tools and equipment to the correct location on completion of the fitting activities

2. cut and shape **two** different types of material from the following:

- 2.1 low carbon/mild steel
- 2.2 stainless steel
- 2.3 plastic/nylon/synthetic
- 2.4 high carbon steel
- 2.5 aluminium/aluminium alloys
- 2.6 composite
- 2.7 cast iron
- 2.8 brass/brass alloys
- 2.9 other specific material

3. use **three** of the following workholding devices:

- 3.1 bench vice
- 3.2 three-jaw chuck
- 3.3 collet chuck
- 3.4 machine vice
- 3.5 four-jaw chuck
- 3.6 drive plate and centres
- 3.7 clamps (such as toolmaker's)

4. use marking out methods and techniques which include **all** of the following:

- 4.1 preparing/determining suitable datums from which to mark out (such as choosing a machine face or filing a flat face as a datum)
- 4.2 applying a marking medium to enhance clarity of the marking out
- 4.3 using an appropriate method of marking out (such as direct marking using instruments, use of templates or tracing/transfer methods)
- 4.4 using a range of marking out equipment (such as rules, squares, scribers, Vernier instruments)
- 4.5 marking out a range of features (such as datum/centre lines, square/rectangular profiles, circles/radial profiles, hole positions)

5. use a range of hand fitting methods, to include **all** of the following:

5.1 cutting out the rough profile using saws (such as hacksaw, band saw)
5.2 filing flat and square
5.3 filing a curved profile
5.4 drilling holes
5.5 cutting a screw thread (such as by tapping or dieing)

6. produce mechanical assemblies, using **six** of the following methods and techniques:

6.1 assembling components having interference fits (such as by pressure, expansion or contraction)
6.2 securing components using threaded fasteners (such as nuts, bolts, machine screws, cap screws)
6.3 securing components using spring clips (such as external circlips, internal circlips, special clips)
6.4 using locking and retaining devices (such as tab washers, locking nuts, wire locks, special purpose types)
6.5 securing components using rivets (such as countersunk, roundhead, blind, special purpose types)
6.6 applying sealing compounds or adhesives
6.7 electrical bonding of components
6.8 setting and adjusting components to give correct working parameters (such as shimming and packing)
6.9 torque setting of nuts and bolts

7. carry out turning operations to include **all** of the following:

7.1 mounting the workpiece in an appropriate workholding device
7.2 mounting cutting tools in tool holders to give the correct centre height
7.3 selecting and setting appropriate feeds and speeds
7.4 facing off
7.5 producing tapered diameters
7.6 producing parallel diameters
7.7 centre drilling and drilling a hole
7.8 producing stepped diameters
7.9 reaming or boring a hole

8. carry out milling operations, to include **all** of the following:

8.1 mounting the workpiece in an appropriate workholding device
8.2 mounting cutting tools on appropriate arbors or direct to the machine spindle
8.3 selecting and setting appropriate feeds and speeds
8.4 producing flat and square faces
8.5 producing an enclosed slot
8.6 producing parallel faces
8.7 producing an open ended slot
8.8 producing angular faces

9. carry out the necessary checks for accuracy, to include **all** of the following:

9.1 linear dimensions (such as lengths, depths)
9.2 profiles
9.3 diameters (such as external, internal)
9.4 hole size and position
9.5 flatness
9.6 thread size and fit
9.7 squareness
9.8 surface finish
9.9 angles

10. use the following measuring equipment during the checking activities:

10.1 external micrometers
10.2 surface finish equipment (such as comparison plates, machines)
10.3 Vernier/digital/dial calliper

Plus **four** more of the following:

10.4 rules
10.5 bore/hole gauges
10.6 squares
10.7 slip gauges
10.8 protractors
10.9 radius/profile gauges
10.10 depth micrometers
10.11 thread gauges
10.12 depth Verniers
10.13 dial test indicators (DTI)
10.14 feeler gauges
10.15 coordinate measuring machine (CMM)

11. produce components within **all** of the following standards, as applicable to the process:

11.1 components to be free from false tool cuts, burrs and sharp edges
11.2 dimensional tolerance +/- 0.25mm or +/- 0.010”
11.3 flatness and squareness 0.05mm per 25mm or 0.002″ per inch
11.4 angles within +/- 1 degree
11.5 screw threads to BS Medium fit
11.6 reamed holes within H8
11.7 surface finish 63µin or 1.6 µm

Unit 248 General machining, fitting and assembly applications

Supporting Information

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Unit ref	KSB(s)
P1	S1, S2, S5, S7, S22, B1
P2	S23, S24, B1-B6
P3	S3, S8, S10
P4	S3, S6, S12, S13, S17
P5	S9
P6	S4, S9, S14, S15
P7	S9, S13
P8	S9, S11, S16, S19
P9	S18, S19, S21, S23, S25
P10	S1, S20, S24, B1
K1	K1, B1
K2	K2, B1
K3	K4, K8, K16
K4	B1-B6
K5	K4, K16
K6	K7
K7	K10, K11
K8	K10, K11
K9	K10, K11
K10	K10, K11
K11	K10, K11
K12	K10, K11
K13	K7
K14	K10, K11
K15	K10, K11
K16	K9, K10, K11
K17	K12, K13
K18	K7, K10, K11

K19	K7, K10, K11
K20	K12, K13, K14
K21	K12, K13, K14
K22	B3, B4
K23	K1, B1

Unit 301 Engineering and environmental health and safety

Level:	3
GLH:	60
Assessment type:	Multiple-choice online test
Aim:	The aim of this unit is for learners to develop knowledge of their health and safety responsibilities when working in an engineering business. They will learn about health and safety legislation and how the business' activities could impact on the environment. They will also learn about the types of documentation required to adhere to Health and Safety policies.

Learning outcome

The learner will:

LO1 understand workplace health and safety responsibilities

Topics

1.1 Responsibilities under legislation
1.2 Roles of key people involved in workplace health and safety
1.3 Roles of organisations involved in workplace health and safety

Topic 1.1

Key responsibilities of employers and employees under legislation:

- Health and Safety at Work Act (HASWA)
- Management of Health and Safety at Work Regulations
- Control of Substances Hazardous to Health (COSHH)
- Provision and Use of Work Equipment Regulations (PUWER)
- Personal Protective Equipment (PPE) Regulations
- Manual Handling Operations Regulations
- Lifting Operations and Lifting Equipment Regulations (LOLER)
- Noise at Work Regulations
- Vibration at Work Regulations
- Electricity at Work Regulations
- Health and Safety (Display Screen Equipment) Regulations

- Reportable Diseases and Dangerous Occurrences Regulations (RIDDOR).

Topic 1.2

Roles of key health and safety personnel in a workplace and how they may differ depending on the type and size of organisation:

- Health and safety representatives
- Environmental health officers
- Health and Safety Executive Inspectors
- First aiders
- Fire marshals/wardens.

Topic 1.3

Roles of organisations involved in workplace health and safety and actions that can be taken in specific situations:

- Health and Safety Executive (HSE)
- Local authorities
- Environmental Health Agency (EHA)
- Fire authority
- Trade unions.

Learning outcome

The learner will:

LO2 understand how to maintain a safe and healthy workplace

Topics

2.1 Organisational safety requirements
2.2 Risk assessment

Topic 2.1

Procedures and supporting documentation for workplace health and safety for:

- Fire prevention
- Emergency evacuation
- Near misses
- Accidents
- Machining operations
- Maintenance
- Storage of materials
- Movement of materials.

Topic 2.2
Requirements and procedures involved in producing a risk assessment:

- Hierarchy of control and how it is applied in different situations (elimination, substitution, controls, safe systems of work, personal protective equipment)
- Hazard, likelihood, severity, risk rating, who affected and how
- Review process.

Learning outcome

The learner will:

LO3 understand environmental management requirements of engineering businesses

Topics

3.1 Key requirements of environmental legislation and standards
3.2 Human and environmental conditions in the workplace
3.3 Energy and waste

Topic 3.1
Key requirements of environmental legislation and standards:

- Environmental Protection Act
- Pollution Prevention and Control Act
- Clean Air Act
- Radioactive Substances Act
- Waste Regulations
- Dangerous Substances and Preparations and Chemicals Regulations
- ISO 14001.

Topic 3.2
Human and environmental conditions in the workplace, their impact and how they are controlled:

- Human conditions (lack of management control, carelessness, improper behaviour and dress, lack of training, supervision and experience, fatigue, drug-taking, alcohol)
- Environmental conditions (unguarded or faulty machinery, equipment and tools, inadequate ventilation, untidy, dirty, overcrowded workplace, inadequate lighting).

Topic 3.3

- Sources of energy and their environmental impact (fossil, renewable, nuclear)
- Types and likely causes of industrial emissions and methods used for mitigation
- Requirements for the safe disposal and recycling of waste
- Procedures required for energy audits and implications of findings.

Unit 301 Engineering and environmental health and safety

Supporting Information

Unit guidance

This is a theory unit that provides opportunities for learners to input on their own experiences when working in an engineering environment. The use of case studies from a range of different types of business would enable learners to grasp the scale and scope that health and safety has on the industry. Case studies can also be used to consider the impact of an engineering activities on the environment.

Gaining an understanding of health, safety and the environment can be developed through practical activities where learners complete documentation related to real machining tasks.

There are opportunities to work with employers who can provide case studies of how policies and procedures have prevented incidents. They can also provide examples of real documentation used in their business.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K1, K2
	1.2	K1
	1.3	K1
2	2.2	K1
3	3.1	K2, K3, K8

Unit 302 Communication for machinists/engineers

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	The aim of this unit is for learners to develop their understanding of how to communicate with an engineering business. They will learn about communicating with both general and technical information. This will include research methodologies and understanding engineering drawings. They will also learn about the types of documentation required to effectively communicate within their business.

Learning outcome

The learner will:

LO1 understand how to communicate technical information

Topics

1.1 Research methods
1.2 Sources of technical information
1.3 Diagrammatic representation of technical information

Topic 1.1

Process for obtaining primary and secondary information:

- Identify requirements
- Gather
- Record sources
- Collate
- Evaluate
- Synthesise.

Types of information:

- Qualitative
- Quantitative.

Criteria for evaluating information:

- Credibility
- Bias
- Assumptions
- Validity
- Sufficiency
- Currency.

Topic 1.2

Characteristics of sources of technical information:

- Characteristics (information provided, location)
- Types of technical information (manufacturers' specifications, technical manuals, engineering drawings, schematics, reference books, standard operating procedures (SOPs), method statements, job cards).

Suitability of sources for different engineering problems:

- Technical problems (materials, processes, equipment, skills)
- Commercial problems (finance, time, risk/reward).

Topic 1.3

Interpretation of different types of diagrammatic representation:

- Types of diagrammatic representation (sketches, drawings, models, graphs)
- Interpret (symbols, geometric dimensioning and tolerancing (GDT), dimensions, tolerances, different views, imperial and metric systems of measurement, labels, data, axes, lines).

Creation of diagrammatic representation:

- Use conventions and standards (sketches, drawings, models, graphs)
- Views and layouts.

Learning outcome

The learner will:

LO2 understand how to communicate general information

Topics

2.1 Principles of communication
2.2 Business documentation
2.3 Barriers to communication
2.4 Information Communication Technology (ICT) applications
2.5 Information security

Topic 2.1

Principles of communication:

- Two-way process
- Content (language, structure, organisation, legal requirements/constraints, relevance)

- Presentation (house style, tone, style)
- Context (audience, location, purpose, timescale)
- Types (oral, non-verbal, written).

Topic 2.2

Conventions and suitability of different types of communication records:

- Conventions (layout, format, structure, content)
- Types of communication records (policies, protocols, contracts, notes, minutes, emails, letters, websites, social media, images, texts).

Topic 2.3

Characteristics of barriers to communication and how these can be overcome:

- Physical
- Technical
- Emotional
- Attitude.

Topic 2.4

Characteristics of ICT applications and their suitability for communicating different types of information:

- Word-processing
- Spreadsheets
- Databases
- Presentation.

Topic 2.5

Security of information records:

- Threats to security of information records (digital, physical)
- Procedures used to minimise security risks
- Commercial and personal consequences of non-compliance
- Key requirements of data protection legislation.

Procedures for managing information records and their application:

- Storage
- Retrieval
- Archiving
- Retention
- Classification
- Labelling/indexing
- Version control
- Internal controls.

Unit 302 Communication for machinists/engineers

Supporting Information

Unit guidance

This is a theory unit that provides opportunities for learners to input on their own experiences when communicating in an engineering environment. The use of case studies from a range of different types of business would enable learners to understand the uses of different types of communication. Case studies can also be used to demonstrate best practice of communication by machinists.

Gaining an understanding of technical information can be developed through practical activities where learners research and interpret engineering information from a range of sources related to real machining tasks.

There are opportunities to work with employers who can provide case studies and examples of engineering technical information. They can also provide examples of real documentation used in their business communications.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K16, K19
	1.2	K4, K6, K8, K15, K16
	1.3	K4, K8, K15, K16
2	2.1	K4, K16
	2.2	K4, K16
	2.3	K18, K22, B6
	2.4	K6, K16
	2.5	K12, K16

Unit 303 Properties and applications of engineering materials

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	The purpose of this unit is for learners to understand the behaviours and properties of materials that are important wherever they work in engineering. By learning these topics, they will better understand their importance in the process that allows engineers to design and manufacture complex components for a range of specific situations. This also supports the learner in selecting and testing the most appropriate materials to satisfy the requirements for different types of application.

Learning outcome

The learner will:

LO1 understand the properties of materials

Topics

1.1 Properties of materials
1.2 Structure of materials
1.3 Effects of processing on the properties of materials

Topic 1.1

Properties of materials:

- Mechanical (strength (compressive, shear, tensile), hardness, toughness, ductility, durability, malleability, elasticity, plasticity)
- Physical (conductivity (thermal, electrical), density, melting temperature, permeability, thermal expansion, corrosion resistance).

Classification of materials:

- Metals (cast iron, aluminium alloys, titanium, steels, copper)
- Natural (natural polymers, rubber, wood, stone)
- Synthetic (neoprene, thermoplastics, thermosets, composites)
- Engineering ceramics (tungsten carbide, silicon carbide, alumina).

Topic 1.2

Relationship between material structures and properties:

- Periodic table
- Atomic structure
- Molecular structure
- Bonding mechanisms
- Structure (lattice, grain, crystals)
- Cross linking of polymers.

Topic 1.3

Effects of processing on material properties:

- Cutting
- Forming (rolling, forging, moulding)
- Welding
- Sintering
- Coating
- Heat treatments (case hardening, annealing, quenching, tempering, precipitation hardening)
- Hot working
- Cold working.

Learning outcome

The learner will:

LO2 understand why engineering materials fail

Topics

2.1 Causes of engineering materials failure
2.2 Symptoms of engineering materials failure
2.3 Methods of testing for engineering materials failure

Topic 2.1

Causes of engineering materials failure:

- Chemical
- Physical
- Design
- Manufacture.

Topic 2.2

Symptoms of engineering materials failure:

- Fracture
- Fatigue
- Creep.

Topic 2.3

Methods of testing:

- Destructive (tensile, shear, hardness, corrosion, wear resistance, impact)
- Non-destructive (visual, penetrant, radiographic, magnetic powder, ultrasonic).

Learning outcome

The learner will:

LO3 understand the suitability of engineering materials

Topics

3.1 Factors affecting selection of engineering materials
3.2 Criteria from engineering information

Topic 3.1

Factors affecting selection of engineering materials:

- Application
- Properties
- Environment
- Availability
- Sustainability
- Costs.

Topic 3.2

Use engineering information to determine criteria for suitability of engineering materials:

- Standard (British Standards (BS), European Standards (EN), International Standards (ISO))
- Manufacturers' information (data sheets, catalogues, websites).
- Specifications.

Unit 303 Properties and applications of engineering materials

Supporting Information

Unit guidance

This is a theoretical unit that is best taught through applied activities related to engineering contexts.

There are many opportunities to link the learning in this unit with practical machining activities. For example, selecting appropriate materials for machining based on their mechanical properties. Practical activities involving machining different types of materials can be used to discuss the atomic structure of these materials, as learners experience the ease and/or difficulty of working with them in different applications.

Employers can be engaged to support delivery with examples of activities where the theory can be applied eg costing materials for specific applications.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K5, K7
	1.2	K5, K7
	1.3	K7
2	2.1	K5, K13
	2.2	K13
	2.3	K12, K13, K14, K19
3	3.1	K3, K7, K23
	3.2	K8, K16

Unit 304 Engineering maths

Level:	3
GLH:	90
Assessment type:	Short-answer test
Aim:	The purpose of this unit is for learners to understand the principles of mathematics and apply these to solve engineering problems. They will learn the principles of arithmetic, trigonometry, calculus, algebraic methods and statistics and how these can be applied in a range of engineering contexts.

Learning outcome

The learner will:

LO1 understand how to solve engineering problems using arithmetic

Topics

1.1 Apply arithmetic methods
1.2 Apply standard formulae

Topic 1.1

Apply arithmetic methods

- Addition, subtraction, multiplication, division
- Order of operation
- Decimal places
- Significant figures
- SI units (metric) and prefixes
- Ratio, proportions
- Transposition
- Fractions.

Topic 1.2

Apply standard formulae:

- Area of simple and compound 2D shapes
- Surface area and volume of simple and compound 3D shapes
- Calculating density and mass.

Learning outcome

The learner will:

LO2 solve engineering problems using algebraic methods

Topics

2.1 Solve problems using equations
2.2 Solve problems using rules of indices
2.3 Solve problems using logarithms

Topic 2.1

Solve problems using equations:

- Simplifying equations and functions
- Manipulating equations to change the subject.

Topic 2.2

Solve problems using rules of indices.

Topic 2.3

Solve problems with logarithms:

- Laws of logarithms
- Use of natural logarithms
- Changing the base.

Learning outcome

The learner will:

LO3 solve engineering problems using trigonometric methods

Topics

3.1 Use trigonometry on right angled triangles
3.2 Apply sine and cosine rules to engineering problems
3.3 Radian measure

Topic 3.1

Use trigonometry on right angled triangles, calculate:

- Length of unknown side from two other sides
- Length of unknown side from a known angle and length
- Unknown angle from two lengths.

Topic 3.2

Apply sine and cosine rules to solve engineering problems:

- Solution of triangles, by applying sine and cosine rules.

Topic 3.3
Radian measure:
- Using radians
- Convert angles between radians and degrees.

Learning outcome

The learner will:

LO4 solve engineering problems using calculus

Topics

4.1 Solving problems relating to graphs
4.2 Solving problems using differentiation and integration

Topic 4.1
Solving problems relating to graphs:
- Interpret changes in an engineering system from a graph
- Express equations of a straight line using a graph.

Topic 4.2
Solving problems using differentiation and integration:
- Standard integrals
- Calculation of turning points maximum, minimum and optimal values.

Learning outcome

The learner will:

LO5 solve engineering problems using statistics

Topics

5.1 Calculation of averages
5.2 Central tendency and dispersion

Topic 5.1
Calculation of averages:
- Mean
- Median
- Mode.

Topic 5.2
Central tendency and dispersion:
- Cumulative frequency and variance
- Standard deviation.

Unit 304 Engineering maths

Supporting Information

Unit guidance

This is a theoretical unit that is best taught through applied activities related to engineering contexts.

There are many opportunities to link the learning in this unit with practical machining activities. For example, calculating polar coordinates for machining operations. Gear ratios can be applied when setting up speeds and feeds on machines. Statistical methods can be used to produce an SPC analysis.

Employers can be engaged to support delivery with examples of activities where the theory can be applied eg with engineering drawings or case studies.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K5, S9
	1.2	K5, S9
2	2.1	K5, S9
	2.2	K5, S9
	2.3	K5, S9
3	3.1	K5, S9
	3.2	K5, S9
	3.3	K5, S9
4	4.1	K4, K5, S8, S9
	4.2	K5, S9
5	5.1	K5, S9
	5.2	K5, S9

Unit 305 Advanced turning techniques

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	This unit enables the learner to acquire the essential knowledge and understanding needed to develop advanced turning skills. This unit provides the learner with knowledge of the tools, equipment and machinery used to create complex turned components. They will learn how to set up, operate and plan the use of machinery to create complex turned components safely and efficiently. Learners will develop an understanding of quality requirements and how they can evaluate the quality of a complex turned component against a specification.

Scope of content

Complex turned components require the combination of a number of different types of features.

Learning outcome

The learner will:

LO1 understand equipment required for advanced turning operations

Topics

1.1 Parts of a lathe
1.2 Workholding devices
1.3 Cutting tools

Topic 1.1

Characteristics, function and considerations of parts of a lathe and how they interact to achieve machining operations:

- Safety features
- Tool holding devices
- Mechanical parts
- Electrical/electromechanical parts (controls, digital readout).

Topic 1.2

Characteristics, function and considerations for the use of workholding devices:

- Chucks (3 jaw, 4 jaw, collet)
- Face plates
- Between centres
- Steadies (travelling steadies, fixed steadies, self-centring steadies).

Topic 1.3

Characteristics, functions and limitations of cutting tools:

- Tool types (roughing and finishing, turning, boring, grooving, undercutting, parting, forming, chamfering, reaming, tapping, threading, drilling)
- Characteristics (tool angles (rake and clearance, approach), materials, ISO Coding for indexable inserts)
- Tool posts (fixed, indexable)
- Materials (tungsten carbide, ceramic coatings)
- Effects of cutting fluids and compounds.

Learning outcome

The learner will:

LO2 understand how to produce complex turned components on lathes

Topics

2.1 Safety issues
2.2 Information required to produce turned features
2.3 Techniques for the use of workholding devices
2.4 Techniques for mounting cutting tools
2.5 Calculations required for turning operations
2.6 Principles of planning turning operations

Topic 2.1

Safety issues associated with the use of lathes and how they are controlled:

- Hazards (flying debris, entanglement, ejected workpieces, moving parts, sharp edges, heat)
- Controls (safety checks, PPE, safe working practices).

Topic 2.2

Information required to create different types of features:

Types of features:

- Faces (datum, flat, perpendicular, parallel, tapered)
- Diameters (internal, external, bored, tapered, concentric, eccentric)
- Shoulders
- Grooves/undercuts
- Holes (drilled, reamed, blind, through, counterbored, countersunk, flat-bottomed)
- Threads (internal, external, multi-start, square).

Information:
- Datum
- Sizes
- Material
- Tooling
- Measuring instruments
- Speeds and feeds.

Information sources:
- Engineering drawings
- Tables and charts
- International standards
- Calculations.

Topic 2.3
Techniques for the use of workholding devices:
- Mounting and removal of workholding device into/from machine
- How to mount, secure and align.

Topic 2.4
Techniques for mounting cutting tools:
- Checking tools are fit for purpose
- Securing cutting tools in tool holding devices
- Aligning tool to centre height
- Orientating tool to workpiece.

Topic 2.5
Calculations required for turning operations in different machining conditions:
- Speeds
- Feeds
- Counterweight position
- Power requirements
- Tapers using precision balls.

Topic 2.6
Principles of planning turning operations:
- Critical path
- Sequence of operations.

Learning outcome

The learner will:

LO3 understand how to meet quality requirements for advanced turning operations

Topics

3.1 Monitoring machine performance

Topic 3.1

Monitoring machine performance

- Potential defects (symptoms, causes, resolution)
- In-process checks (Coordinate Measuring Machine (CMM), trial cuts, dimensions and tolerances of workpiece, surface finish, condition of tools, time, effects of temperature, cost).

Topic 3.2

Evaluating turned components against specification:

- Identify quality criteria (tolerance, surface finish, concentricity, parallelism) from engineering information (drawings, standards)
- Application of inspection techniques (measurement, visual).

Unit 305 Advanced turning techniques

Supporting Information

Unit guidance

This is a theory unit intended to underpin the development of practical skills. It is beneficial for learners to have prior knowledge of the use of lathes. If this is not the case it may be advantageous for learners to undertake introductory sessions related to basic turning techniques.

This unit is designed to be delivered alongside practical workshop or real work activities. The combination of theory and practice is more likely to reinforce the learning required.

It is recommended that learning is based on engineering information such as engineering drawings. From this, learners can interpret the information presented and consider the appropriate tools, equipment and machinery required to create the components. Learners can then consider the operational requirements and processes that will deliver the complex turned component presented in the engineering information.

Working with employers would enhance the delivery of the unit. This could be through the presentation of engineering information or presentations on the types of machinery and components.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K1, K10, B1
	1.2	K9
	1.3	K9, K10
2	2.1	K1, B1
	2.2	K4, K5, K11, K16
	2.3	K9
	2.4	K9, K10
	2.5	K5, S9
	2.6	K6
3	3.1	K12, K13, K19
	3.2	K4, K8, K12, K13, K14, K19

Unit 306 Advanced milling techniques

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	This unit provides the learner with knowledge of the tools, equipment and machinery used to create complex milled components. They will learn how machinery is set up and operated safely and the processes to be followed to create complex milled components. Learners will develop an understanding of quality requirements and how they can evaluate the quality of a complex milled component against a specification.

Scope of content

Complex machined components require the combination of a number of different types of features.

Learning outcome

The learner will:

LO1 understand equipment required for advanced milling operations

Topics

1.1 Parts of a milling machine
1.2 Workholding devices
1.3 Cutting tools

Topic 1.1

Characteristics, function and considerations of parts of a vertical and horizontal milling machine and how they interact to achieve machining operations:

- Safety features
- Tool holding devices
- Mechanical parts (slides, lead screws, spindles, arbours)
- Electrical/electromechanical parts (drives, pumps, motors, controls).

Topic 1.2
Characteristics, function and considerations for the use of workholding devices:

- Machine vice (fixed, swivel, hydraulic)
- T slot and clamps
- Angle plate
- V block and clamps
- Dividing head
- Fixtures.

Topic 1.3
Characteristics, functions and limitations of cutting tools:

- Tool types (end mill, slot drill, shell cutter, bullnose cutter, face mill, fly cutter, dovetail cutter, drills, reamers, taps, woodruff cutter)
- Characteristics (tool angles, materials, ISO Coding for indexable inserts)
- Materials (Tungsten carbide, ceramic, high speed steel, coatings)
- Effects of cutting fluids and compounds.

Learning outcome

The learner will:

LO2 understand how to produce complex machined components on a milling machine

Topics

2.1 Safety issues
2.2 Information required to produce machined features
2.3 Techniques for the use of workholding devices
2.4 Techniques for mounting cutting tools
2.5 Calculations required for milling operations
2.6 Principles of planning milling operations

Topic 2.1
Safety issues associated with the use of a milling machine and how they are controlled:

- Hazards (flying debris, entanglement, moving parts, sharp edges, heat)
- Controls (safety checks, PPE, safe working practices).

Topic 2.2
Information required to create different types of features:
Types of features:

- Faces (datum, flat, perpendicular, parallel, tapered)
- Steps
- Slots (enclosed, open ended, tee)
- Recesses
- Holes (drilled, reamed, blind, through, counterbored, countersunk, flat-bottomed, bored)
- Internal threads.

Information:
- Datum
- Sizes
- Material
- Tooling
- Measuring instruments
- Speeds and feeds.

Information sources:
- Engineering drawings
- Tables and charts
- International standards
- Calculations.

Topic 2.3
Techniques for the use of workholding devices:
- Mounting and removal of workholding devices into/from machine
- How to mount, secure and align.

Topic 2.4
Techniques for mounting cutting tools:
- Checking tools are fit for purpose
- Securing cutting tools in tool holding devices
- Align tools.

Topic 2.5
Calculations required for milling operations in different machining conditions:
- Speeds
- Feeds
- Power requirements
- Pitch Circle Diameters (PCDs)
- Dividing head (40:1).

Topic 2.6
Principles of planning milling operations**:**
- Critical path
- Sequence of operations.

Learning outcome

The learner will:

LO3 understand how to meet quality requirements for advanced milling operations

Topics

3.1 Monitoring machine performance
3.2 Evaluating components against specification requirements

Topic 3.1

Monitoring machine performance

- Potential defects (symptoms, causes, resolution)
- In-process checks (CMM, trial cuts, dimensions and tolerances of workpiece, surface finish, condition of tools, time, effects of temperature, cost).

Topic 3.2

Evaluating milled components against specification:

- Identify quality criteria (tolerance, surface finish, concentricity, parallelism) from engineering information (drawings, standards)
- Application of inspection techniques (measurement, visual).

Unit 306 Advanced milling techniques

Supporting Information

Unit guidance

This is a theory unit intended to underpin the development of practical skills. It can be delivered alongside practical workshop or real work activities. The combination of theory and practice is more likely to reinforce the learning required.

It is recommended that learning is based on engineering information such as engineering drawings. From this, learners can interpret the information presented and consider the appropriate tools, equipment and machinery required to create the complex components. Learners can then consider the operational requirements and processes that will deliver the complex milled component presented in the engineering information.

Working with employers would enhance the delivery of the unit. This could be through the presentation of engineering information or presentations on the types of machinery and complex components that are manufactured in the engineering environment.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K1, K10, B1
	1.2	K9
	1.3	K9, K10
2	2.1	K1, B1
	2.2	K4, K5, K11, K16
	2.3	K9
	2.4	K9, K10
	2.5	K5, S9
	2.6	K6
3	3.1	K12, K13, K19
	3.2	K4, K8, K12, K13, K14, K19

Unit 307 Advanced milling and turning techniques

Level:	3
GLH:	90
Assessment type:	Short-answer test
Aim:	This unit provides the learner with knowledge of the tools, equipment and machinery used to create complex machined components. They will learn how machinery is set up and operated safely and the processes to be followed to create complex machined components. Learners will develop an understanding of quality requirements and how they can evaluate the quality of a complex machined component against a specification.

Scope of content

The content of this unit relates to both milling and turning operations.

Complex machined components require the combination of a number of different types of features.

Learning outcome

The learner will:

LO1 understand equipment required for advanced machining operations

Topics

1.1 Parts of a milling machine
1.2 Parts of a lathe
1.3 Workholding devices
1.4 Cutting tools

Topic 1.1

Characteristics, function and considerations of parts of a milling machine and how they interact to achieve machining operations:

- Safety features
- Tool holding devices
- Mechanical parts
- Electrical/electromechanical parts (drives, pumps, motors, controls).

Topic 1.2
Characteristics, function and considerations of parts of a lathe and how they interact to achieve machining operations:

- Safety features
- Tool holding devices
- Mechanical parts
- Electrical/electromechanical parts (digital readouts, controls).

Topic 1.3
Characteristics, function and considerations for the use of workholding devices:

- Machine vice (fixed, swivel, hydraulic)
- Dividing head
- Between centres
- Steadies (travelling steadies, fixed steadies)
- Fixtures
- Chucks (3 jaw, 4 jaw, collet).

Topic 1.4
Characteristics, functions and limitations of cutting tools:

- Tool types (end mill, slot drill, shell cutter, bullnose cutter, drills, reamers, taps, roughing and finishing, parting, chamfering, reaming, threading, boring)
- Characteristics (tool angles (rake and clearance, approach), materials, ISO Coding for indexable inserts)
- Effects of cutting fluids and compounds.

Learning outcome

The learner will:

LO2 understand how to produce complex machined components

Topics

2.1 Safety issues
2.2 Information required to produce machined features
2.3 Techniques for the use of workholding devices
2.4 Techniques for mounting cutting tools
2.5 Calculations required for machining operations
2.6 Principles of planning machining operations

Topic 2.1
Safety issues associated with the use of a machine and how they are controlled:

- Hazards (flying debris, entanglement, moving parts, sharp edges, heat)
- Controls (safety checks, PPE, safe working practices).

Topic 2.2

Information required to create different types of features:

Types of features:

- Faces (datum, flat, perpendicular, parallel, tapered)
- Steps/shoulders
- Slots (enclosed, open ended)
- Grooves, undercuts
- Holes (drilled, reamed, blind, through, counterbored, countersunk, flat-bottomed, bored)
- Diameters (internal, external, tapered)
- Threads (internal, external).

Information:

- Datum
- Sizes
- Material
- Tooling
- Measuring instruments
- Speeds and feeds.

Information sources:

- Engineering drawings
- Tables and charts
- International standards
- Calculations.

Topic 2.3

Techniques for the use of workholding devices:

- Mounting and removal of workholding device into/from machine
- How to mount, secure and align.

Topic 2.4

Techniques for mounting cutting tools:

- Checking tools are fit for purpose
- Securing cutting tools in tool holding devices
- Align tools.

Topic 2.5

Calculations required for machining operations in different machining conditions:

- Speeds
- Feeds
- Tapers using precision balls
- Counterweight positions
- Pitch Circle Diameters (PCDs)
- Dividing head (40:1).

Topic 2.6
Principles of planning machining operations:

- Critical path
- Sequence of operations.

Learning outcome

The learner will:

LO3 understand how to meet quality requirements for advanced machining operations

Topics

3.1 Monitoring machine performance
3.2 Evaluating components against specification requirements

Topic 3.1
Monitoring machine performance:

- Potential defects (symptoms, causes, resolution)
- In-process checks (Coordinate Measuring Machine (CMM), trial cuts, dimensions and tolerances of workpiece, surface finish, condition of tools, time, effects of temperature, cost).

Topic 3.2
Evaluating machined components against specification:

- Identify quality criteria (tolerance, surface finish, concentricity, parallelism) from engineering information (drawings, standards)
- Application of inspection techniques (measurement, visual).

Unit 307 Advanced milling and turning techniques

Supporting Information

Unit guidance

This is a theory unit intended to underpin the development of practical skills for using milling machines and lathes. It can be delivered alongside practical workshop or real work activities. The combination of theory and practice is more likely to reinforce the learning required.

It is recommended that learning is based on engineering information such as engineering drawings. From this, learners can interpret the information presented and consider the appropriate tools, equipment and machinery required to create the complex components. Learners can then consider the operational requirements and processes that will deliver the complex machined component presented in the engineering information.

Working with employers would enhance the delivery of the unit. This could be through the presentation of engineering information or presentations on the types of machinery and complex components that are manufactured in the engineering environment.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K1, K10, B1
	1.2	K1, K9, K10, B1
	1.3	K9
	1.4	K9, K10
2	2.1	K1, B1
	2.2	K4, K5, K11, K16
	2.3	K9
	2.4	K9, K10
	2.5	K5, S9
	2.6	K6
3	3.1	K12, K13, K19
	3.2	K4, K8, K12, K13, K14, K19

Unit 308 Advanced manufacturing CNC turning techniques

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	This unit provides the learner with knowledge of the tools, equipment and machinery used to create complex components on multi-axis CNC lathes. They will learn how machinery is set up and operated safely and the processes to be followed to create complex components. Learners will develop an understanding of quality requirements and how they can evaluate the quality of a complex component against a specification.

Scope of content

Complex machined components require the combination of a number of different features.

Learning outcome

The learner will:

LO1 understand equipment required for CNC operations on multi-axis CNC machines

Topics

1.1 CNC lathe parts
1.2 Material loading and workholding devices
1.3 Tooling on multi-axis machines

Topic 1.1

Characteristics, function and considerations of multi-axis CNC lathe parts and how they interrelate to achieve machining operations:

- Safety devices
- Tool holding devices
- Mechanical parts
- Electrical/electronic parts (DC and AC drives, controls).

Topic 1.2
Characteristics, function and considerations for the use of material loading and workholding devices:

- Bar feeders/pullers
- Face drivers
- Robots
- Hydraulic chucks (hard jaw, soft jaw).

Topic 1.3
Function and limitations of different types of tooling used on multi-axis CNC lathes:

- Cutting tools
- Live tooling
- Sister tooling
- Preset tooling
- Qualified tooling
- Through coolant tooling.

Types of indexing:

- Materials
- Coding.

Learning outcome

The learner will:

LO2 understand how to produce complex components on multi-axis CNC lathes

Topics

2.1 Safety issues
2.2 Component features
2.3 Mounting tools
2.4 CNC programs
2.5 Planning CNC operations

Topic 2.1
Safety issues associated with the use of multi-axis CNC lathes and how they are controlled:

- Hazards (flying debris, entanglement, ejected workpieces, moving parts, sharp edges, heat, unscheduled cycle starts)
- Controls (safety checks, PPE, safe working practices, machine safety features).

Topic 2.2
Information required to create different types of complex component features:
Features:

- Faces (datum, flat, perpendicular, parallel, tapered)
- Diameters (internal, external, bored, tapered, concentric, eccentric)
- Holes (drilled, reamed, blind, through, counterbored, countersunk, flat-bottomed, tapered)
- Non-standard threads (multi-start, acme, square, non-standard pitch)

- Complex profiles.

Information:
- Datum (datum shift)
- Coordinates
- Tooling
- Order of indexing.

Information sources:
- Engineering drawings
- Tables and charts
- International standards
- Calculations.

Topic 2.3
Techniques for mounting tools:
- Checking tools are fit for purpose
- Securing cutting tools in tool holding devices
- Set tool offset.

Topic 2.4
Use machine codes:
- Rapid motion
- Linear motions
- Circular motions
- Coolant
- Tool change
- Spindle start
- Spindle stop
- Program stop.

Use preparatory function codes:
- Absolute programming
- Incremental programming
- Feed per revolution
- Feed per minute
- Speed per revolution
- Speed per minute
- Metric
- Imperial.

Determine machine axes:
- Primary
- Secondary
- Auxiliary.

Determine coordinates:

- Absolute
- Incremental
- Polar
- Cartesian.

Define terminology:
- Part programs
- Word address
- Conversational
- Lead in
- Lead out
- Sub-routine/labels
- Canned cycles/process pages.

Limitations of methods of inputting program:
- Manual
- USB flash drive
- Intranet
- Direct Numerical Control (DNC).

Suitability of methods of proving part programs:
- Proof read
- Graphic simulation
- Single block
- Rapid override.

Topic 2.5
Principles of planning CNC operations:
- Critical path
- Sequence of operations
- Tooling collision
- Optimisation.

Learning outcome

The learner will:

LO3 understand how to meet quality requirements for advanced CNC turning operations

Topics

3.1 Monitoring machine performance
3.2 Evaluating components against specification requirements

Topic 3.1
Monitoring machine performance:
- Potential defects (symptoms, causes, resolution)

- In-process checks (probing, trial cuts, dimensions and tolerances of workpiece, surface finish of workpiece, condition of tools, timing, repeatability, effects of temperature).

Topic 3.2

Evaluating turned components against specification:

- Identify quality criteria (tolerance, surface finish, concentricity, parallelism) from engineering information (drawings, standards)
- Application of inspection techniques (measurement, visual).

Unit 308 Advanced manufacturing CNC turning techniques

Supporting Information

Unit guidance

This is a theory unit intended to underpin the development of practical skills. It is beneficial for learners to have prior knowledge of the use of CNC machines and/or basic machining operations. If this is not the case, it may be advantageous for learners to undertake introductory sessions related to basic machining techniques.

This unit is designed to be delivered alongside practical workshop or real work activities. The combination of theory and practice is more likely to reinforce the learning required.

It is recommended that learning is based on engineering information such as engineering drawings. From this learners can interpret the information presented and consider the appropriate tools, equipment and machinery required to create complex components. Learners can then consider the operational requirements and processes that will deliver the component in the engineering information.

Working with employers would enhance the delivery of the unit. This could be through the presentation of engineering information or programs which can be reviewed.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K1, K9, K10, B1
	1.2	K9, K10
	1.3	K9, K10
2	2.1	K1, B1
	2.2	K10, K11, K16
	2.3	K9, K10
	2.4	K10
	2.5	K6
3	3.1	K12, K13, K19
	3.2	K8, K12, K13, K14, K19

Unit 309 Advanced manufacturing CNC milling techniques

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	This unit provides the learner with knowledge of the tools, equipment and machinery used to create complex components on multi-axis CNC milling machines. They will learn how machinery is set up and operated safely and the processes to be followed to create complex components. Learners will develop an understanding of quality requirements and how they can evaluate the quality of a complex component against a specification.

Scope of content

Complex machined components require the combination of a number of different features.

Learning outcome

The learner will:

LO1 understand equipment required for CNC operations on multi-axis CNC milling machines

Topics

1.1 CNC milling machine parts
1.2 Material loading and workholding devices
1.3 Tooling on multi-axis machines

Topic 1.1

Characteristics, function and considerations of multi-axis CNC milling machine parts and how they interrelate to achieve machining operations:

- Safety devices
- Tool holding devices
- Mechanical parts
- Electrical/electronic parts (DC and AC drives, controls).

Topic 1.2
Characteristics, function and considerations for the use of material loading and workholding devices:

- Robots
- Pallet changers
- Tooling columns (tombstones)
- Hydraulic vices
- Fixtures.

Topic 1.3
Function and limitations of different types of tooling used on multi-axis CNC milling machines:

- Cutting tools
- Sister tooling
- Preset tooling
- Qualified tooling
- Through coolant tooling.

Types of indexing:

- Materials
- Coding.

Learning outcome

The learner will:

LO2 understand how to produce complex components on multi-axis CNC milling machines

Topics

2.1 Safety issues
2.2 Component features
2.3 Mounting tools
2.4 CNC programs
2.5 Planning CNC operations

Topic 2.1
Safety issues associated with the use of multi-axis CNC milling machines and how they are controlled:

- Hazards (flying debris, entanglement, ejected workpieces, moving parts, sharp edges, heat, unscheduled cycle starts)
- Controls (safety checks, PPE, safe working practices, machine safety features).

Topic 2.2
Information required to create different types of complex component features:
Features:

- Faces (datum, flat, perpendicular, parallel, tapered)
- Slots (open, enclosed, helical, blind, through)

- Pockets (regular, complex, blind, through)
- Holes (drilled, reamed, blind, through, counterbored, countersunk, flat-bottomed, tapered)
- Complex profiles.

Information:
- Datum (datum shift)
- Coordinates
- Tooling
- Order of indexing.

Information sources:
- Engineering drawings
- Tables and charts
- International standards
- Calculations.

Topic 2.3
Techniques for mounting tools:
- Checking tools are fit for purpose
- Securing cutting tools in tool holding devices
- Set tool offset.

Topic 2.4
Use machine codes:
- Rapid motion
- Linear motions
- Circular motions
- Coolant
- Tool change
- Spindle start
- Spindle stop
- Program stop.

Use preparatory function codes:
- Absolute programming
- Incremental programming
- Feed per revolution
- Feed per minute
- Speed per revolution
- Speed per minute
- Metric
- Imperial.

Determine machine axes:
- Primary
- Secondary
- Auxiliary.

Determine coordinates:
- Absolute
- Incremental
- Polar
- Cartesian.

Define terminology:
- Part programs
- Word address
- Conversational
- Lead in
- Lead out
- Sub-routine/labels
- Canned cycles/process pages.

Limitations of methods of inputting program:
- Manual
- USB flash drive
- Intranet
- Direct Numerical Control (DNC).

Suitability of methods of proving part programs:
- Proof read
- Graphic simulation
- Single block
- Rapid override.

Topic 2.5
Principles of planning CNC operations:
- Critical path
- Sequence of operations
- Tooling collision
- Optimisation.

Learning outcome

The learner will:

LO3 understand how to meet quality requirements for advanced CNC milling operations

Topics

3.1 Monitoring machine performance
3.2 Evaluating components against specification requirements

Topic 3.1

Monitoring machine performance:

- Potential defects (symptoms, causes, resolution)
- In-process checks (probing, trial cuts, dimensions and tolerances of workpiece, surface finish of workpiece, condition of tools, timing, repeatability, effects of temperature).

Topic 3.2

Evaluating turned components against specification:

- Identify quality criteria (tolerance, surface finish, concentricity, parallelism) from engineering information (drawings, standards)
- Application of inspection techniques (measurement, visual).

Unit 309 Advanced manufacturing CNC milling techniques

Supporting Information

Unit guidance

This is a theory unit intended to underpin the development of practical skills. It is beneficial for learners to have prior knowledge of the use of CNC machines and/or basic machining operations. If this is not the case, it may be advantageous for learners to undertake introductory sessions related to basic machining techniques.

This unit is designed to be delivered alongside practical workshop or real work activities. The combination of theory and practice is more likely to reinforce the learning required.

It is recommended that learning is based on engineering information such as engineering drawings. From this learners can interpret the information presented and consider the appropriate tools, equipment and machinery required to create complex components. Learners can then consider the operational requirements and processes that will deliver the component in the engineering information.

Working with employers would enhance the delivery of the unit. This could be through the presentation of engineering information or programs which can be reviewed.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K1, K9, K10, B1
	1.2	K9, K10
	1.3	K9, K10
2	2.1	K1, B1
	2.2	K4, K5, K10, K11, K16
	2.3	K9
	2.4	K10
	2.5	K6
3	3.1	K12, K13, K19
	3.2	K4, K8, K12, K13, K14, K19

Unit 310 Advanced manufacturing techniques Computer Numerical Control (CNC)

Level:	3
GLH:	90
Assessment type:	Short-answer test
Aim:	This unit provides the learner with knowledge of the tools, equipment and machinery used to create complex components on multi-axis CNC machines. They will learn how machinery is set up and operated safely and the processes to be followed to create complex components. Learners will develop an understanding of quality requirements and how they can evaluate the quality of a complex component against a specification.

Scope of content

The unit requires learning to be focused on multi-axis CNC lathes and multi-axis CNC milling machines.

Complex machined components require the combination of a number of different types of features.

Learning outcome

The learner will:

LO1 understand equipment required for CNC operations on multi-axis CNC machines

Topics

1.1 CNC machine parts
1.2 Material loading and workholding devices
1.3 Tooling on multi-axis machines

Topic 1.1

Characteristics, function and considerations of multi-axis CNC machine parts and how they interrelate to achieve machining operations:

- Safety devices
- Tool holding devices

- Mechanical parts (beds, slideways, lead screws, conveyors)
- Electrical/electronic parts (DC and AC drives, controls).

Topic 1.2

Characteristics, function and considerations for the use of material loading and workholding devices:

- Bar feeders/pullers
- Face drivers
- Robots
- Pallet changers
- Tooling columns (tombstones)
- Hydraulic vices
- Fixtures.

Topic 1.3

Function and limitations of different types of tooling used on multi-axis CNC machines:

- Cutting tools
- Live tooling
- Sister tooling
- Preset tooling
- Qualified tooling
- Through coolant tooling.

Types of materials:

- Tungsten carbide
- Ceramic
- Coatings.

Types of indexing:

- Materials
- Coding.

Learning outcome

The learner will:

LO2 understand how to produce complex components on multi-axis CNC machines

Topics

2.1 Safety issues
2.2 Component features
2.3 Mounting tools
2.4 CNC programs
2.5 Planning CNC operations

Topic 2.1

Safety issues associated with the use of multi-axis CNC machines and how they are controlled:

- Hazards (flying debris, entanglement, ejected workpieces, moving parts, sharp edges, heat, radiation, unscheduled cycle starts)
- Controls (safety checks, PPE, safe working practices, machine safety features).

Topic 2.2

Information required to create different types of complex component features:

Features:

- Faces (datum, flat, perpendicular, parallel, tapered)
- Diameters (internal, external, bored, tapered, concentric, eccentric)
- Slots (open, enclosed, helical, blind, through)
- Pockets (regular, complex, blind, through)
- Holes (drilled, reamed, blind, through, counterbored, countersunk, flat-bottomed, tapered)
- Non-standard threads (multi-start, acme, square, non-standard pitch)
- Complex profiles.

Information:

- Datum (datum shift)
- Coordinates
- Tooling
- Order of indexing.

Topic 2.3

Techniques for mounting tools:

- Checking tools are fit for purpose
- Securing cutting tools in tool holding devices
- Set tool offset.

Topic 2.4

Use machine codes:

- Rapid motion
- Linear motions
- Circular motions
- Coolant
- Tool change
- Spindle start
- Spindle stop
- Program stop.

Use preparatory function codes:

- Absolute programming
- Incremental programming
- Feed per revolution
- Feed per minute
- Speed per revolution
- Speed per minute

- Metric
- Imperial.

Determine machine axes:
- Primary
- Secondary
- Auxiliary.

Define terminology:
- Word address
- Conversational
- Lead in
- Lead out
- Sub-routine/labels
- Canned cycles/process pages
- Tool locations.

Limitations of methods of inputting programs:
- Manual
- USB flash drive
- Intranet
- Direct Numerical Control (DNC).

Suitability of methods of proving part programs:
- Proof read
- Graphic simulation
- Single block
- Rapid override.

Topic 2.5
Principles of planning CNC operations:
- Critical path
- Sequence of operations
- Tooling collision
- Optimisation.

Learning outcome

The learner will:

LO3 understand how to meet quality requirements for advanced CNC operations

Topics

3.1 Monitoring machine performance
3.2 Evaluating components against specification requirements

Topic 3.1

Monitoring machine performance:

- Potential defects (symptoms, causes, resolution)
- In-process checks (probing, trial cuts, dimensions and tolerances of workpiece, surface finish of workpiece, condition of tools, timing, repeatability, effects of temperature).

Topic 3.2

Evaluating turned components against specification:

- Identify quality criteria (tolerance, surface finish, concentricity, parallelism) from engineering information (drawings, standards)
- Application of inspection techniques (measurement, visual).

Unit 310 Advanced manufacturing techniques Computer Numerical Control (CNC)

Supporting Information

Unit guidance

The unit requires learning to be focussed on multi axis CNC lathes and multi axis CNC milling machines.

This is a theory unit intended to underpin the development of practical skills. It is beneficial for learners to have prior knowledge of the use of CNC machines and/or basic machining operations. If this is not the case, it may be advantageous for learners to undertake introductory sessions related to basic machining techniques.

This unit is designed to be delivered alongside practical workshop or real work activities. The combination of theory and practice is more likely to reinforce the learning required.

It is recommended that learning is based on engineering information such as engineering drawings. From this learners can interpret the information presented and consider the appropriate tools, equipment and machinery required to create complex components. Learners can then consider the operational requirements and processes that will deliver the component in the engineering information.

Working with employers would enhance the delivery of the unit. This could be through the presentation of engineering information or programs that can be reviewed.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K1, K9, K10, B1
	1.2	K9, K10
	1.3	K9, K10
2	2.1	K1, B1
	2.2	K4, K10, K11, K16
	2.3	K9
	2.4	K11
	2.5	K6
3	3.1	K12, K13, K19
	3.2	K4, K8, K12, K13, K14, K19

Unit 311 CNC programming

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	This unit provides the learner with knowledge of the tools, equipment and machinery used to create components with CNC machines. They will learn how machinery is set up and operated safely and the processes to be followed to create components. They will learn about the information required to create a CNC program. Learners will also develop an understanding of quality requirements and how they can evaluate the quality of a milled and turned component against a specification.

Scope of content

This unit relates to the programming of a minimum three axis CNC milling and turning machines.

Learning outcome

The learner will:

LO1 understand equipment required for CNC machining

Topics

1.1 Machine parts
1.2 Equipment required

Topic 1.1
Characteristics, function and considerations of multi-axis CNC machine parts and how they interrelate to achieve machining operations:

- Safety devices
- Tool holding devices
- Mechanical parts
- Electrical/electronic parts.

Topic 1.2
Characteristics, function and considerations for the use of additional equipment for machines:

- Workholding
- Material loading
- Tools.

Learning outcome

The learner will:

LO2 understand how to produce programs for CNC machining

Topics

2.1 Safety issues
2.2 Component features
2.3 CNC programming
2.4 Planning CNC operations

Topic 2.1

Safety issues and how they are controlled by the program:

- Tool collision
- Tool change location
- Feed and speeds.

Topic 2.2

Features:

- Faces (datum, flat, perpendicular, parallel, tapered)
- Diameters (internal, external, bored, tapered, concentric, eccentric)
- Slots (open, enclosed, helical, blind, through)
- Pockets (regular, complex, blind, through)
- Holes (drilled, reamed, blind, through, counterbored, countersunk, flat-bottomed, tapered)
- Non-standard threads (multi-start, acme, square, non-standard pitch)
- Complex profiles (2D geometry).

Information:

- Datum (datum shift)
- Coordinates
- Tooling
- Feeds
- Speeds
- Material.

Information sources:

- Engineering drawings
- Tables and charts
- International standards
- Calculations.

Topic 2.3

Create programs:

- Sequence of operations
- Position (eg axis coordinates (x, y, z), absolute, incremental)
- Tooling and workholding (eg position, direction, amount of movement)
- Rates of change (eg feed rates, spindle rates)
- Preparatory functions (eg metric/imperial units, tool selection, cutting fluids, workpiece loading and holding, tool changing, safety).

Methods used to prove/evaluate the program:

- Data transfer
- Simulation
- Single block
- Rapid override.

Topic 2.4

Principles of planning CNC operations:

- Critical path
- Sequence of operations
- Tooling collision
- Optimisation
- Safety.

Unit 311 CNC programming

Supporting Information

Unit guidance

The unit requires learning to be focussed on two different types of machines from the following:

- CNC lathes
- CNC mills.

This is a theory unit intended to underpin the development of practical skills. It can be delivered alongside practical workshop or real work activities. The combination of theory and practice is more likely to reinforce the learning required.

It is recommended that learning is based on engineering information such as engineering drawings. From this learners can interpret the information presented and consider the appropriate tools, equipment and machinery required to create the components. Learners can then consider the programming requirements and processes that will deliver the component in the engineering information.

Working with employers would enhance the delivery of the unit. This could be through the presentation of engineering information or examples CNC programs that are used for milled and turned components.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K1, K9, K10, B1
	1.2	K9, K10
2	2.1	K1, K10, B1
	2.2	K4, K5, K10, K11, K16
	2.3	K10, K11
	2.4	K6

Unit 312 Specialist machining

Level:	3
GLH:	60
Assessment type:	Assignment
Aim:	This unit provides the learner with knowledge of the tools, equipment and machinery used to create complex components on specialist machines. They will learn how machinery is set up and operated safely and the processes to be followed to create complex components. Learners will develop an understanding of quality requirements and how they can evaluate the quality of a complex component against a specification.

Scope of content

Learners must develop understanding relating to one example specialist CNC machine from the following categories:

- Forming (press brakes, tube bending, spinning)
- Profiling (punch presses, laser, water, plasma, oxy-gas, broaching)
- EDM (spark eroding, wire eroding).

Complex components require the combination of a number of different types of features.

Learning outcome

The learner will:

LO1 understand equipment required for specialist machining

Topics

1.1 Specialist machine parts
1.2 Equipment required

Topic 1.1

Characteristics, function and considerations of specialist machine parts and how they interrelate to achieve machining operations:

- Safety devices
- Tool holding devices

- Mechanical parts
- Electrical/electronic parts.

Topic 1.2
Characteristics, function and considerations for the use of additional equipment required for manufacturing processes:
- Material loading
- Workholding devices
- Tools.

Learning outcome

The learner will:

LO2 understand how to produce complex components using specialist machines

Topics

2.1 Safety issues
2.2 Component features
2.3 Machining techniques
2.4 Planning machining operations

Topic 2.1
Safety issues associated with the use of specialist machines and how they are controlled:
- Hazards (flying debris, entanglement, ejected workpieces, moving parts, sharp edges, heat, radiation)
- Controls (safety checks, PPE, safe working practices, machine safety features).

Topic 2.2
Information required to create different types of component features:
Features:
- Faces
- Diameters
- Slots
- Pockets
- Holes
- Bends
- Profiles.

Information:
- Datum (datum shift)
- Coordinates
- Tooling
- Bend allowance
- Feeds
- Material.

Information sources:

- Engineering drawings
- Tables and charts
- International standards
- Calculations.

Topic 2.3

Techniques for machine operation:

- Checking equipment is fit for purpose
- Workholding
- Material loading
- Operating activities
- Securing workpiece
- Quality criteria.

Topic 2.4

Principles of planning machine operations:

- Sequence of operations
- Critical path
- Optimisation (time, material, safety, cost)
- Tooling collision
- Safety.

Learning outcome

The learner will:

LO3 understand how to meet quality requirements for advanced specialist machine operations

Topics

3.1 Monitoring machine performance

3.2 Evaluating components against specification

Topic 3.1

Monitoring machine performance:

- Potential defects (symptoms, causes, resolution)
- In-process checks (probing, trial cuts, size of workpiece, surface finish of workpiece, condition of tools, timing, repeatability, effects of temperature).

Topic 3.2

Evaluating components against specification:

- Identify quality criteria (tolerance, surface finish, GDT) from engineering information (drawings, standards)
- Application of inspection techniques (measurement, visual).

Unit 312 Specialist machining

Supporting Information

Unit guidance

The unit requires learning to be focussed on one specialist CNC machine from one of the following categories:

- Bending
- Profiling
- EDM.

This is a theory unit intended to underpin the development of practical skills. This unit will develop learners' knowledge of a range of specialist machining equipment, such as press brakes, water jet cutters and EDMs.

This unit is designed to be delivered alongside practical workshop or real work activities. The combination of theory and practice is more likely to reinforce the learning required.

It is recommended that learning is based on engineering information such as engineering drawings. From this learners can interpret the information presented and consider the appropriate tools, equipment and specialist machinery required to create components. Learners can then consider the operational requirements and processes that will deliver the component in the engineering information.

Working with employers would enhance the delivery of the unit. This could be through the presentation of engineering information or presentations on the types of specialist machinery and components.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K9, K10
	1.2	K9, K10
2	2.1	K1, B1
	2.2	K4, K6, K10, K11, K16
	2.3	K9, K10, K12
	2.4	K6
3	3.1	K12, K13, K19
	3.2	K8, K12, K13, K14, K19

Unit 313 CAD/CAM

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	This unit enables the learner to acquire the essential understanding of the importance of Computer Aided Engineering (CAE) and how to use Computer Aided Design (CAD) to create and analyse models of complex components. Learners will understand the relationship between CAD and Computer Aided Manufacture (CAM).

Scope of content

Complex designs are those that combine a range of features that are not classed as primitives eg box, cylinder, sphere.

Learning outcome

The learner will:

LO1 understand the application of Computer Aided Engineering (CAE)

Topics

1.1 Importance of a safe CAD working environment
1.2 Purpose, benefits and limitations of CAD/CAE
1.3 Importance of data management

Topic 1.1

Implications of the Health and Safety (Display Screen Equipment) Regulations:

- To employees
- To employers.

Risk assessments associated with the use of CAD/CAE in different environments:

- Office environments
- Workshop environments.

Topic 1.2

Purpose, benefits and limitations of CAD/CAE:

- Modelling (surface, solid, organic/freeform)
- Drawing

- Analysis (Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), Multi Body System (MBS))
- Visualisation (rendering, animation)
- Links to CAM.

Topic 1.3

Importance of CAD data management procedures:

- Labelling/file name conventions
- File format
- Version control
- Indexing
- Storage
- Security.

Learning outcome

The learner will:

LO2 understand how to operate CAD software to produce complex designs

Topics

2.1 Process and features used in part modelling
2.2 Process and features used in assembly modelling
2.3 Process and features used to create drawings with CAD software
2.4 Process and features used to analyse components

Topic 2.1

Process and features used in part modelling:

- Visual analysis (section, Zebra)
- Create geometry (extrude, revolve, loft, sweep, rib)
- Modify geometry (Boolean operations, shell, split (face, body))
- Constraints (coincident, concentric, parallel perpendicular, tangent).

Topic 2.2

Process and features used in assembly modelling:

- Visual analysis (section, Zebra, interference)
- Assemble part models (constraints, joints, position).

Topic 2.3

Process and features used to create drawings in CAD software:

- Create templates
- Use line types, styles and colour
- View placement (auxiliary, section, detail, break, breakout)
- Bill of Materials (BoM)
- Annotate (surface symbols, geometric dimensioning tolerancing (GDT) symbols, balloon, dimensions, tolerance, datum, hole tables, revision cloud/tag/table).

Topic 2.4
Process and features used to analyse individual components:

- Create a study (for FEA, CFD, MBS)
- Export a report.

Learning outcome

The learner will:

LO3 understand the use of CAD/CAM in machining

Topics

3.1 Applications of CAM
3.2 Suitability of using CAM in machining
3.3 Key functions of CAM software

Topic 3.1
Applications of different types of CAM equipment and how they work:

- Subtractive manufacturing (CNC machines, cutters)
- Additive manufacturing (Fusion Deposition Modelling (FDM), Stereo Lithography (SLA), Selective Laser Sintering (SLS), Multi Jet Modelling (MJM)).

Topic 3.2
Suitability of using CAM in machining:

- Speed
- Accuracy
- Repeatability
- Form complexity
- Links to CAD
- Equipment required.

Topic 3.3
Operation of CAM functions:

- Tool path generation
- Post processing
- Data transfer
- Simulation.

Unit 313 CAD/CAM

Supporting Information

Unit guidance

This is a theory unit intended to underpin the development of practical skills. It is recommended that learners have already studied and used CAD at an introductory/basic level before commencing this unit.

The unit can be delivered through the completion of practical activities. The combination of theory and practice is more likely to reinforce the learning required.

It is recommended that learning is based on unit 302 where learners gain knowledge of drawing standards. CAD operation can help learners gain knowledge of those standards.

Learning about CAD/CAE/CAM operations would also benefit from practical activities, for example using CNC equipment in machining. This would allow learners to appreciate the importance of CAD to CAM operations.

Working with employers would enhance the delivery of the unit. This could be through masterclasses on the use of CAD software or opportunities to observe CAM equipment operating.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K1, B1
	1.2	K4, K20
2	2.1	K4
	2.2	K4
	2.3	K4
	2.4	K4
3	3.1	K10, K11
	3.2	K10, K11
	3.3	K10, K11

Unit 314 Precision grinding techniques

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	This unit enables the learner to acquire the essential knowledge and understanding needed to develop precision grinding skills. This unit provides the learner with knowledge of the equipment and machinery used to create complex and precise components using a grinding machine. They will learn how to set up, operate and plan the use of grinding machinery to create precise components safely and efficiently. Learners will develop an understanding of quality requirements and how they can evaluate the quality of a precise component, produced using a grinding machine, against a specification.

Scope of content

Complex components require the combination of a number of different features.

Learning outcome

The learner will:

LO1 understand equipment needed for precision grinding

Topics

1.1 Parts of grinding machines
1.2 Workholding devices
1.3 Abrasive wheels

Topic 1.1

Characteristics, function and considerations of parts of different types of grinding machines:
Types of grinding machines:

- Cylindrical (internal, external)
- Surface (horizontal, vertical)
- Universal.

Machine parts:

- Safety features
- Grinding wheel mounts
- Mechanical parts (bed, slides, spindles, arbours)
- Hydraulic parts.

Topic 1.2

Characteristics, function and considerations for the use of workholding devices:

- Chucks (scroll, magnetic, collet)
- Vices (fixed, swivel, universal)
- V block and clamps
- Mandrels.

Topic 1.3

Characteristics, function and limitations of abrasive wheels:

- Wheel types (straight, cylinder, single taper, double taper, single concaved, straight cup)
- Characteristics (structure, grade, grit, shape, construction, material, bond type, treatment, classification)
- Effects of grinding fluids.

Learning outcome

The learner will:

LO2 understand how to produce complex components with grinding machines

Topics

2.1 Safety issues associated with the use of grinding machines
2.2 Information required to create different types of features with grinding machines
2.3 Techniques for preparing grinding machines for use
2.4 Techniques for maintaining abrasive wheels
2.5 Calculations required for grinding operations in different conditions
2.6 Principles of planning grinding operations

Topic 2.1

Safety issues associated with the use of a grinding machine and how they are controlled:

- Hazards (flying debris, entanglement, dust, sparks, explosion of wheel, ejected workpieces, moving parts, sharp edges, heat)
- Controls (safety checks, PPE, safe working practices, machine guards).

Topic 2.2

Features:

- Faces (datum, flat, perpendicular, parallel, angular)
- Diameters (internal, external)
- Steps
- Tapers
- Grooves/undercuts

- Slots/profiles.

Information
- Datum
- Sizes
- Material
- Wheel
- Measuring instruments
- Speeds and feeds.

Information sources
- Engineering drawings
- Tables and charts
- International standards
- Calculations
- Approved code of practice.

Topic 2.3
Techniques for preparing grinding machines for use:
- Mounting and removal of abrasive wheels into/from machine
- How to mount, secure and align workholding device.

Topic 2.4
Techniques for maintaining abrasive wheels:
- Trueing the wheel
- Dressing the wheel
- Forming the wheel.

Topic 2.5
Calculations required for grinding operations in different conditions:
- Speeds
- Feeds
- Depth of cut.

Topic 2.6
Principles of planning grinding operations:
- Critical path
- Sequence of operations
- Optimisation.

Learning outcome

The learner will:

LO3 understand how to meet quality requirements for precision grinding operations

Topics

3.1 Monitoring machine performance

Topic 3.1

Monitoring machine performance:

- Symptoms, causes and resolution of defects (wheel chatter, rough finish, wheel loading, short wheel life
- Effects of heat when grinding and possible remedies
- In-process checks (trial cuts, backlash, dimensions and tolerances of workpiece, surface finish of workpiece, condition of wheel).

Topic 3.2

Evaluating machined components against specification:

- Identify quality criteria (tolerance, flatness, squareness, surface finish, parallelism) from engineering information (drawings, standards)
- Application of inspection techniques (measurement, visual).

Unit 314 Precision grinding techniques

Supporting Information

Unit guidance

This is a theory unit intended to underpin the development of practical skills. It is beneficial for learners to have prior knowledge of grinding techniques. If this is not the case it may be advantageous for learners to undertake introductory sessions related to basic grinding techniques.

This unit is designed to be delivered alongside practical workshop or real work activities. The combination of theory and practice is more likely to reinforce the learning required.

It is recommended that learning is based on engineering information such as engineering drawings. From this learners can interpret the information presented and consider the appropriate equipment and machinery required to create precise components. Learners can then consider the operational requirements and processes that will deliver the precise component in the engineering information.

Working with employers would enhance the delivery of the unit. This could be through the presentation of engineering information or presentations on the types of machinery and components.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K1, K10, B1
	1.2	K9, K10
	1.3	K10
2	2.1	K4, K5, K10, K16, B1
	2.2	K4, K5, K10, K16
	2.3	K9, K10
	2.4	K17
	2.5	K5
	2.6	K6
3	3.1	K13, K14, K19
	3.2	K8, K13, K14, K19

Unit 315 Further maths

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	The purpose of this unit is for learners to understand the principles of further mathematics and apply these to solve engineering problems. They will learn the principles of trigonometry, calculus and algebra and how these can be applied in a range of engineering contexts.

Learning outcome

The learner will:

LO1 solve engineering problems using algebraic methods

Topics

1.1 Solve problems using equations
1.2 Solve problems using non-linear graphs
1.3 Solve engineering problems using complex numbers

Topic 1.1

Solve problems using equations:

- Resolving simultaneous equations
- Using quadratic equations.

Topic 1.2

Solve problems using non-linear graphs:

- Express equations of exponential and logarithmic functions using a graph
- Use formulae to determine numbers in a sequence or series (arithmetic, geometric, progression rules).

Topic 1.3

Solve engineering problems using complex numbers:

- Definition of complex numbers
- Addition and subtraction of complex numbers
- Convert between coordinates (Polar and Cartesian).

Learning outcome

The learner will:

LO2 solve engineering problems using trigonometric methods

Topics

2.1 Use trigonometric functions to solve problems
2.2 Use trigonometric identities to solve engineering problems
2.3 Identify characteristics of a sine wave
2.4 Express equations of simple trigonometric functions using a graph

---

Topic 2.1

Use trigonometric functions to solve problems:

- Inverse trigonometric functions
- Compound angles.

Topic 2.2

Use trigonometric identities to solve engineering problems:

- tan = sin/cos
- cot = 1/tan
- sec = 1/cos
- cosec = 1/sin.

Topic 2.3

Identify characteristics of a sine wave:

- Amplitude
- Periodic time
- Frequency.

Topic 2.4

Express equations of simple trigonometric functions using a graph:

- sin, cos, tan
- Degrees, radians.

Learning outcome

The learner will:

LO3 solve engineering problems using calculus

Topics

3.1 Rules of differentiation
3.2 Roles of integration

Topic 3.1

Apply rules of differentiation:

- Simple trigonometric functions (sin, cos, tan)
- Calculations involving a second derivative
- Product rule.

Topic 3.2

Apply rules of integration:

- Simple trigonometric functions (sin, cos, tan)
- Integration by substitution.

Unit 315 Further maths

Supporting Information

Unit guidance

This is a theoretical unit that is best taught through applied activities related to engineering contexts.

There are many opportunities to link the learning in this unit with practical machining activities. For example, calculating forces involved with machining activities.

Employers can be engaged to support delivery with examples of activities where the theory can be applied eg with engineering drawings or case studies.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K5, S9
	1.2	K4, K5, S9
	1.3	K5, S9
2	2.1	K5, S9
	2.2	K5, S9
	2.3	K4, K5, S9
	2.4	K4, K5, S9
3	3.1	K5, S9
	3.2	K5, S9

Unit 316 Engineering organisational efficiency and improvement

Level:	3
GLH:	60
Assessment type:	Assignment
Aim:	The purpose of this unit is for learners to gain an understanding of the key factors affecting organisational efficiency. They will gain an understanding of production management and the importance of human resources to effective production processes. Learners will develop an understanding of business improvement techniques and how they can be applied to improve the efficiency of production processes.

Learning outcome

The learner will:

LO1 understand production management

Topics

1.1 Methods of production
1.2 Stages of production
1.3 Production planning

Topic 1.1

Characteristics, considerations and suitability of types/methods of production for different scales of manufacture:

- One-off / Bespoke
- Batch
- Mass
- Continuous.

Topic 1.2

Activities involved and factors affecting efficiency in different stages of production:

- Design/Engineering
- Design for manufacture (DFM)/ Design for Assembly (DFA)

- Manufacturing
- Fabricating and assembling
- Finishing
- Quality.

Topic 1.3

How production planning affects efficient operations:

- Processes and layouts
- Tools and documentation
- Staffing involved
- Timescales
- Monitoring
- Health and safety
- Quality controls
- Scheduling.

Learning outcome

The learner will:

LO2 understand the application of business improvement techniques to production management

Topics

2.1 Business improvement techniques

2.2 Quality control and quality assurance

Topic 2.1

Characteristics, application and suitability of business improvement tools and techniques for production management:

Techniques:

- Lean
- Kaizen
- 6 sigma
- TQM.

Tools:

- Kanban
- JIT
- 6S
- Visual management
- Quick changeover (SMED)
- Value stream mapping.

Topic 2.2

- Purpose of quality standards

- Difference between quality assurance and quality control
- Effectiveness of quality management systems
- Roles and responsibilities of the Quality Manager.

Learning outcome

The learner will:

LO3 understand the relationship between human resources and production management

Topics

3.1 Characteristics, advantages and disadvantages of techniques for developing others
3.2 Team working
3.3 Leadership
3.4 Employee rights and responsibilities

Topic 3.1
Characteristics, advantages and disadvantages of techniques for developing others:

- Coaching
- Mentoring
- Performance reviews
- Training.

Topic 3.2
Characteristics of an effective team:

- Clear team goals
- Clear roles
- Clear lines of authority and decision making
- Group norms set for working together
- Trained and skilled members
- Good communication.

Benefits of an effective team:

- Increased efficiency
- Sharing of expertise
- Identification and development of talent
- Increased motivation
- Fostering innovation.

Topic 3.3
Characteristics of different leadership styles and their impact on:

- The business
- The leader
- Staff
- Other stakeholders.

Leadership styles:

- Behavioural
- Participative
- Autocratic.

Topic 3.4

Key legislation and statutory entitlements:

- Health and safety
- Equality and diversity
- Leave entitlement (holiday, sickness, maternity, paternity)
- Working hours
- Payment
- Union membership.

Impact of statutory entitlements on the business and employees.

Unit 316 Engineering organisational efficiency and improvement

Supporting Information

Unit guidance

This is a theory based unit that is best delivered in the context of real or realistic case studies. It is designed to be delivered once learners are working in a real manufacturing environment so that they can experience the implementation of business improvement techniques.

Working with employers would enhance the delivery of the unit. This could be through presentation of a problem and an exploration, with the employer, of how the use of business improvement techniques could improve efficiency.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K6, K18
	1.2	K12
	1.3	K1, K6, K12, B1
2	2.1	K21, K23
	2.2	K8, K12
3	3.1	K18, B3, B4, B5
	3.2	K18, B3, B4
	3.3	B4
	3.4	K1, B1, B2, B6

Unit 317 Engineering inspection and quality control

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	This unit provides learners with an understanding of quality management systems and the associated roles and activities for inspection, measurement and statistical process control (SPC).

Learning outcome

The learner will:

LO1 understand the principles and applications of quality management systems

Topics

1.1 Effects of quality management systems
1.2 ISO 9001
1.3 Principles of inspection and measurement

Topic 1.1

Effects of quality management systems on:

- The workforce
- Costs
- Efficiency/productivity
- Monitoring and identifying out of tolerance/rejected work
- Product performance.

Topic 1.2

ISO 9001:

- General requirements
- Application and processes
- Criteria and methods
- Availability of resources and information
- Monitoring, measuring and analysis of processes
- Continual improvement of processes.

Topic 1.3
Principles of inspection and measurement:

- Quality assurance
- Quality control
- Quality Manager
- Variation
- Repeatability
- Reproducibility
- Accuracy
- Tolerance
- Comparison
- Precision
- Gauging
- Limits and fits
- Capability of a measuring system
- Total system capability.

Learning outcome

The learner will:

LO2 understand the application of measurement techniques

Topics

2.1 Capabilities, suitability and applications of types of measuring instruments
2.2 Application of techniques used in inspections and measurement

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Topic 2.1
Capabilities, suitability and applications of types of measuring instruments:

- Gauge types
- Comparator types
- Mechanical measurement types.

Topic 2.2
Application of techniques used in inspection and measurement

- Linear measurement
- Surface texture measurement
- Straightness, squareness, flatness measurement
- Concentricity, eccentricity measurement
- Angular measurement.

Learning outcome

The learner will:

LO3 understand the application of Statistical Process Control (SPC) to manage product quality

Topics

3.1 SPC
3.2 Normal distribution curve
3.3 Process capability measures

Topic 3.1
SPC:

- Typical applications
- Advantages and disadvantages of SPC for managing quality.

Topic 3.2
Normal distribution curve:

- Characteristics of a normal distribution curve
- Determine the mean, variance and standard deviation.

Topic 3.3
Process capability measures:

- Calculate the values Cp, Cpk, Cpm
- Understand the meaning of values
- Setting tolerance bands.

Unit 317 Engineering inspection and quality control

Supporting Information

Unit guidance

This is a theory unit developing an understanding of quality assurance and quality control processes in engineering. It is best delivered when learners have experience of working in advanced manufacturing engineering and have grasped some of the concepts and processes.

The unit is designed to be delivered alongside practical workshop or real work activities. The combination of theory and practice is more likely to reinforce learning.

Working with employers would enhance the delivery of the unit. Employers can present case studies of quality assurance issues and how they were resolved and sample products that can be inspected and measured.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K12, K13, K19
	1.2	K8, K12, K13
	1.3	K12, K13
2	2.1	K12, K13, K14
	2.2	K12, K14, K19
3	3.1	K5, K12, K13
	3.2	K5, K12, K13
	3.3	K5, K12, K13

Unit 318 Engineering design process

Level:	3
GLH:	60
Assessment type:	Short-answer test
Aim:	This unit gives an overview of the design process and explores the different factors that can influence design. Learners will learn the main stages in the design process and the importance of a good product specification. They will also learn how ergonomics and functional considerations affect the design of a product. Learners will gain knowledge of different manufacturing processes and their suitability for meeting different design requirement.

Learning outcome

The learner will:

LO1 understand the design process

Topics

1.1 The design brief
1.2 Product specifications
1.3 Developing design ideas

Topic 1.1

The design brief:

- Reasons for developing new or improved products (market pull, technology push)
- Purpose of the design brief
- Analysis of the design brief (identifying customer, customer requirements, design constraints).

Topic 1.2

Product specifications:

- Purpose of the product specification
- Types of product requirements, the reasons for their inclusion in a product specification and how they can be evaluated (function, form, physical dimensions, aesthetics, cost, environmental considerations, safety).

Topic 1.3

Developing design ideas:

- Methods of presenting design ideas and their advantages and disadvantages (freehand sketches, virtual modelling, physical modelling)
- Produce freehand sketches to address product specification requirements
- Techniques used to evaluate designs against a specification
- Suitability of methods used to communicate final design solution.

Learning outcome

The learner will:

LO2 understand the factors considered when designing a product

Topics

2.1 How properties affect the selection of a material for a design
2.2 How ergonomics affect the design of a product
2.3 How mechanical requirements contribute to the design

Topic 2.1

How physical properties affect the selection of a material for a design:

- Density
- Mass
- Conductivity (thermal, electrical)
- Thermal expansion and contraction
- Corrosion resistance.

How mechanical properties affect the selection of a material for a design:

- Resistance to wear
- Mechanical strength (tensile, compressive, shear)
- Fatigue life
- Factor of safety.

Make calculations:

- Linear expansion and contraction
- Strength
- Factor of safety.

Topic 2.2

How ergonomic factors affect the design of a product:

- Meaning of ergonomics and human factors
- How anthropometric data influences design
- Safety considerations.

Topic 2.3

Characteristics of different types of movement:

- Linear
- Rotary

- Oscillating
- Reciprocating.

Methods of changing the direction of transmitted motion:
- Gears (simple and compound gear trains, spur, bevel, worm, rack and pinion)
- Cams (pear, eccentric, snail)
- Levers and linkages
- Chains and belt drives
- Pulley systems.

Learning outcome

The learner will:

LO3 understand how manufacturing processes influence design

Topics

3.1 Shaping processes
3.2 Forming processes
3.3 Joining processes

Topic 3.1
Characteristics and suitability of shaping processes:
- Casting
- Forging
- Extrusion
- Injection moulding.

Topic 3.2
Characteristics and suitability of forming processes:
- Vacuum forming of plastics
- Bending and piercing of sheet metal.

Topic 3.3
Characteristics and suitability of joining processes:
- Welding
- Soldering
- Mechanical fixings.

Unit 318 Engineering design process

Supporting Information

Unit guidance

This is a theoretical unit that is best taught through applied activities related to engineering contexts.

There are many opportunities to link the learning in this unit with practical activities such as product analysis, discussing products and design and different manufacturing processes, building on unit 303 Properties and applications of engineering materials.

Employers can be engaged to support delivery with examples of activities where the theory can be applied eg using different methods of manufacture or materials to see the results – good or bad.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K16, K17
	1.2	K16, K17
	1.3	K4, K16, K17
2	2.1	K5, K7, S9
	2.2	K22, B1
3	3.1	K10
	3.2	K10
	3.3	K10

Unit 319 Additive manufacturing processes

Level:	3
GLH:	60
Assessment type:	Assignment
Aim:	The purpose of this unit is for learners to understand the principles of additive manufacturing and the benefits and limitations of using additive manufacturing processes. Learners will develop an understanding of the technology and characteristics of additive manufacturing and finishing processes that are needed to manufacture a product or component. They will understand design changes required for an additive manufacturing process and the additional finishing processes that may be needed as a result.

Learning outcome

The learner will:

LO1 understand the technology of additive manufacturing processes as used in industry

Topics

1.1 Principles of additive manufacturing
1.2 Technologies used in additive manufacturing
1.3 Capacity considerations of additive manufacturing processes
1.4 Sustainability considerations
1.5 Material types used in additive manufacturing

Topic 1.1

- Definition of additive manufacturing
- Origins of additive manufacturing
- Main difference between subtractive and additive manufacturing.

Topic 1.2

Technology types:

- Photo polymerization
- Wire deposition
- Material extrusion
- Powder bed fusion.

Characteristics:

- Complexity

- Surface texture
- Tolerances.

Topic 1.3
Capacity of processes:
- Component size
- Manufacturing volume
- Manufacturing speed.

Topic 1.4
Sustainability of the processes:
- Recycling
- Waste
- Energy use.

Topic 1.5
Typical materials:
- Polymers
- Metals
- Composites.

Learning outcome

The learner will:

LO2 understand the component design considerations and finishing methods for additive manufacturing

Topics

2.1 Design considerations
2.2 Applications of additive manufacturing processes
2.3 Safe working practices in additive manufacturing
2.4 Component finishing techniques used in additive manufacturing
2.5 Benefits and limitations of using additive manufacturing processes

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Topic 2.1
Design considerations required for additive processes:
- Distortion
- Surface finish
- Support structures
- Scanning and modelling components.

Topic 2.2
Applications:
- Aerospace components
- Automotive components
- Rapid prototyping
- Digital manufacturing (industrial and consumer)
- Personalised fabrication

- Biomedical.

Topic 2.3
Safe working practices:
- Safety features of additive manufacturing equipment
- Hazardous substances (use and disposal)
- Personal protective equipment (PPE).

Topic 2.4
Component finishing techniques for different AM processes:
- Shot blasting
- Vibro-energy grinding
- Chemical processes
- Hot isostatic processing
- Machining (traditional subtractive process).

Topic 2.5
Benefits and limitations of using AM processes:
- Cost
- Time
- Design freedom
- Material choice
- Quantity/capacity
- Tooling
- Training requirements.

Unit 319 Additive manufacturing processes

Supporting Information

Unit guidance

This is a theoretical unit that is best taught through applied activities related to engineering contexts.

There are many opportunities to link the learning in this unit with practical machining activities. For example, selecting appropriate materials for machining based on their mechanical properties. Practical activities involving machining different types of materials can be used to discuss the atomic structure of these materials, as learners experience the ease and/or difficulty of working with them in different applications.

Employers can be engaged to support delivery with examples of activities where the theory can be applied eg costing materials for specific applications**.**

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K20
	1.2	K20
	1.3	K20
	1.4	K2, K3
	1.5	K7
2	2.1	K20
	2.2	K20
	2.3	K1
	2.4	K20
	2.5	B1

Suggested learning resources

- C Barnatt, 3D Printing (CreateSpace, 2016) ISBN 9781539655466
- Hopkinson N et al, Rapid Manufacturing: An Industrial Revolution for the Digital Age (Wiley, 2005) ISBN 9780470016138

Unit 320 Industry 4.0

Level:	3
GLH:	60
Assessment type:	Assignment
Aim:	The purpose of this unit is for learners to understand the principles of Industry 4.0 and its impact on the manufacturing environment. Learners will develop an understanding of the factors shaping Industry 4.0 and its benefits and limitations for manufacturing companies. They will also learn about the characteristics of a smart factory, and the factors that must be considered when transitioning from Industry 3.0 to Industry 4.0 and beyond.

Learning outcome

The learner will:

LO1 understand the principles of Industry 4.0

Topics

1.1 Definition and origin of Industry 4.0
1.2 Factors shaping Industry 4.0
1.3 Benefits and limitations of Industry 4.0

Topic 1.1
Definition - fourth industrial revolution

Topic 1.2
Factors:
- Social
- Economic
- Environmental
- Market pull/opportunities
- Technology push/development of new technologies
- Labour issues.

Topic 1.3
Main benefits and limitations to manufacturing companies of adopting Industry 4.0 approaches and technologies.

Benefits:
- Productivity and efficiency
- Flexibility

- Automation/reduced human error
- Production costs
- Waste production
- Quality control
- Collaborative working
- Compliance with standards and legislation
- Outcomes for clients/customers.

Limitations:
- Potential for reduced job opportunities
- Dependence on/potential failure of technology
- Initial purchase and setup costs of new technologies and equipment
- Time and cost of managing change and/or retraining staff.

Learning outcome

The learner will:

LO2 understand the features of an Industry 4.0 smart factory

Topics

2.1 Characteristics of a smart factory

2.2 Techniques relevant to smart factories

2.3 Technologies used in smart factories

Topic 2.1

Key characteristics:
- Flexibility
- Scalability
- Agility
- Autonomy
- Efficiency.

Topic 2.2

Techniques relevant to smart factories and how they are used:
- Data analytics
- Forecasting
- Data visualisation
- Quality control
- Agile manufacturing.

Topic 2.3

Technologies and their benefits, limitations and applications within a smart factory:
- Internet of things (IoT)
- Artificial intelligence (AI)
- Virtual reality (VR)
- Augmented reality (AR)
- Smart sensors
- Wireless communication technologies and protocols

- Big data and data analytics technologies
- Cloud computing
- Edge computing.

Learning outcome

The learner will:

LO3 understand the factors that affect the transition from Industry 3.0 to 4.0

Topics

3.1 Differences between Industry 3.0 and Industry 4.0
3.2 Factors that manufacturers need to consider when transitioning from Industry 3.0 to 4.0

Topic 3.1

Differences in terms of:

- Automation
- Connectivity
- Technologies used/required
- Use of data and data analytics.

Topic 3.2

Factors that need to be considered and how they affect transition:

- Data management (collection, storage, visualisation, analysis)
- Cyber-security issues (risk of hacking, integrated security, use of data encryption techniques)
- Effects on the workforce (training and upskilling, creating new roles, restructuring, effects on employment)
- Ensuring compliance with legislation, standards and safety requirements
- Change management
- Effects on supply chains
- Effects on customers
- Future-proofing (eventual transition to Industry 5.0).

Unit 320 Industry 4.0

Supporting Information

Unit guidance

This is a theoretical unit that can either be taught as a series of classroom-based activities, or through the use case studies and research activities to add context.

Employers can be engaged to support delivery eg manufacturing companies who have successfully transitioned to Industry 4.0 or are in the process of doing so. If a smart factory can be visited this would add useful context, or videos of smart factories in action could be used where this is not possible or practical.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K3, K20
	1.2	K20
	1.3	K2, K18, K20
2	2.1	K20
	2.2	K20
	2.3	K20
3	3.1	K2, K3, K18, K20
	3.2	K1, K8, K18, K20, B5

Unit 321 Environmental engineering and sustainability

Level:	3
GLH:	60
Assessment type:	Assignment
Aim:	The purpose of this unit is for learners to understand environmental engineering and sustainability in their sector and will cover the processes that can be used to reduce the environmental impact of an engineering process, product or system. Learners will develop an understanding of the current environmental issues that face engineers, including the use of finite resources and materials, the ways in which products are manufactured, and the disposal of engineered products at the end of their useful life. They will investigate the processes involved when completing a life cycle analysis and a system analysis and how these are applied.

Learning outcome

The learner will:

LO1 understand sustainability in engineering

Topics

1.1 Environmental issues faced by engineers
1.2 Protocols and agreements aimed to address environmental issues
1.3 Benefits and limitations of approaches to address environmental issues
1.4 Benefits and limitations of energy sources
1.5 Methods of storing energy
1.6 Approaches to reduce energy requirements

Topic 1.1

Environmental issues and their impact on manufacturing:

- Climate change
- Pollution
- Energy use
- Carbon emissions
- Carbon capture
- Use of finite natural resources (materials, fossil fuels, water resources).

Topic 1.2

The main requirements of key international and UK protocols and agreements and related initiatives:

- Paris Agreement
- Kyoto Protocol
- Climate Change Act
- Net Zero strategy
- UN Climate Change Conference.

Topic 1.3

Approaches:

- Low-carbon solutions
- Reductions in material and energy use
- Recycling
- Energy recovery
- Sustainable supply chains
- Methods of reducing pollution.

Topic 1.4

Energy sources:

- Fossil fuels (oil, gas and coal)
- Nuclear
- Solar
- Wind
- Tidal
- Geothermal
- Waste-to-energy
- Hydrogen fuel cells
- Hydro-electric power (HEP)
- Biofuels.

Topic 1.5

Methods:

- Batteries
- Mechanical storage (fuel storage tank, bio-mass pellet)
- Flywheels
- Pumped storage.

Topic 1.6

Internal and external approaches:

- Energy-saving schemes
- Smart meters
- Incentive schemes
- Energy management audits
- Use of hybrid vehicles (transportation of materials and goods)
- Electrification of railways (transportation of materials and goods).

Learning outcome

The learner will:

LO2 understand product life cycle and the process of carrying out environmental impact analysis

Topics

2.1 Product life cycle
2.2 Systems analysis and associated techniques
2.3 Environmental impact analysis

Topic 2.1

Stages of a product life cycle:

- raw material extraction
- processing/manufacturing/production
- transportation
- use/reuse
- end of life/recycling.

Methods of life cycle analysis:

- cradle to grave (whole life cycle)
- cradle to gate (carbon impact)
- cradle to cradle (redesign)
- well to wheel (greenhouse gas emissions).

Topic 2.2

Elements of a system to be analysed:

- inputs to the system
- system components
- connections between components
- outputs from the system
- connections to other systems
- consumables.

Associated system analysis techniques:

- block diagrams
- event trees
- cause-consequence diagrams
- SWOT analysis.

Topic 2.3

Stages of carrying out an environmental impact analysis:

- define the scope of the analysis
- analyse the problem
- analyse the requirements of the system/product
- interpret results (meeting objectives, identification of trends, opportunities to reduce environmental impacts, graphical representations of results)
- design/redesign the system/product
- assess designs

- propose a solution.

Learning outcome

The learner will:

LO3 understand approaches to reducing environmental impact

Topics

3.1 Energy-based approaches
3.2 Material-based approaches
3.3 Product-based approaches
3.4 Technology-based approaches

Topic 3.1

Energy-based approaches:

- Increased efficiency of plant and equipment
- Use of renewable energy sources
- Reduction in energy losses.

Topic 3.2

Material-based approaches:

- Use of renewable materials
- Use of recycled/recyclable materials
- Selecting materials with desirable properties to allow for a long service life
- Reduction in waste.

Topic 3.3

Product-based approaches:

- Utilising new parts with lower energy requirements
- Simplifying systems or products so there are fewer moving parts to lessen the need to cool and/or use oil-based lubrication
- Building energy storage into processes
- Reducing the number of components or parts
- designing for recycling
- Design for reuse.

Topic 3.4

Technology-based approaches:

- Use of advanced manufacturing techniques
- Use of newly developed materials
- Use of innovative technologies
- Use of modern manufacturing systems.

Unit 321 Environmental engineering and sustainability

Supporting Information

Unit guidance

This is a theoretical unit that is best taught through applied activities related to engineering contexts.

There are many opportunities to link the learning in this unit with practical machining activities. For example, selecting appropriate materials for machining based on their mechanical properties. Practical activities involving machining different types of materials can be used to discuss the atomic structure of these materials, as learners experience the ease and/or difficulty of working with them in different applications.

Extended learning opportunities exist around utilising environmental impact analysis results to produce a new design specification that reduces environmental impact of an engineered product or system.

Employers can be engaged to support delivery with examples of activities where the theory can be applied eg costing materials for specific applications.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K3, K18, B2
	1.2	K3
	1.3	K2, K3
	1.4	K2, K3
	1.5	K2, K3
	1.6	K3
2	2.1	K2
	2.2	K2
	2.3	K2
	2.4	K2, K3
3	3.1	K18, B2
	3.2	K18, B2
	3.3	K18, B2
	3.4	K18, B2

Suggested learning resources

Textbooks

- Allen D, Shonnard D – Green Engineering (Prentice Hall, 2016) ISBN 9780132657075
- Allen D, Shonnard D – Sustainable Engineering: Concepts, Designs and Case Studies (Pearson, 2011) ISBN 9780132756587
- Boyle G – Energy Systems and Sustainability: Power for a Sustainable Future, 3rd edition (Oxford University Press, 2021) ISBN 9780198767640
- Ciambrone, D – Environmental Life Cycle Analysis (CRC Press, 2018) ISBN 9781351450430
- Gibson A, Johnson A – Sustainability in Engineering Design (Elsevier, 2014) ISBN 9780124045910
- Gibson J et al – How to Do Systems Analysis (Wiley, 2007) ISBN 9780470130582
- Klemes, J – Assessing and Measuring Environmental Impact and Sustainability (Elsevier, 2015) ISBN 9780128022337
- Zindani D, Davim J – Sustainable Manufacturing and Design (Elsevier, 2021) ISBN 9780128221617

Websites

- https://eao.stanford.edu/life-cycle-assessment
  Background information about life cycle assessments
- https://medium.com/disruptive-design/quick-guide-to-sustainable-design-strategies-641765a86fb8
  Article introducing methods for sustainable design that could be applied to engineering systems and products
- https://sdgs.un.org/
  United Nations Sustainable Development Knowledge Platform
- https://www.carbontrust.com/
  Carbon Trust: information about carbon foot printing
- www.greenspec.co.uk/life-cycle-assessment-lca
  Background information about life cycle assessments
- www.tutorialspoint.com/system_analysis_and_design/system_analysis_and_design_overview.htm
  Overview of methods of completing a systems analysis

Unit 322 Simulation and digital twinning

Level:	3
GLH:	60
Assessment type:	Assignment
Aim:	The purpose of this unit is for learners to understand the application of simulation and digital twinning as used in advanced manufacturing and the knowledge needed to produce and simulate digital manufacturing process or system models. Learners will develop an understanding of the benefits and limitations of digital twinning and will consider the software and data collection implications for digital twinning. They will understand how to produce and simulate a digital twin model of a manufacturing process or system and will consider how to adjust parameters to improve its performance.

Learning outcome

The learner will:

LO1 understand the benefits and limitations of using digital twinning during advanced manufacturing

Topics

1.1 How digital twinning is used during advanced manufacturing
1.2 The benefits of digital twinning during advanced manufacturing
1.3 The limitations of digital twinning
1.4 Applications of digital twinning

Topic 1.1

Areas of use:

- Industry 4.0: enabling technologies
- Production of 3D digital twin models.

Topic 1.2

Benefits:

- Cost reductions (prototyping)
- Improvements to manufacturing processes
- Data analytics and forecasting
- Decision-making support and data visualisation

- Health and safety
- Quality and efficiency (workforce and machinery)

Topic 1.3

Limitations:

- Inaccurate modelling
- Inaccurate representation of an object
- Unrealistic/theoretical nature of the simulation
- Omission of unprecedented future scenarios in the workplace

Topic 1.4

Areas of applications:

- Component design and failure
- Assembly operation and monitoring
- System design and operation

Learning outcome

The learner will:

LO2 understand the software and data collection implications for digital twinning

Topics

2.1 Uses of simulation software when creating a digital twin
2.2 Characteristics of a smart factory for advanced manufacturing
2.3 Collection and use of data

Topic 2.1

How simulation software can be used to create a digital twin:

- Component design utilising 2D and 3D CAD Modelling software
- Assembly design utilising 2D and 3D CAD Modelling software
- System design utilising simulation software.

Topic 2.2

Characteristics:

- Connectivity
- Flexibility
- Scalability
- Agility
- Autonomy
- Efficiency
- Sensors and actuators
- Internet of Things (IoT) featuring Artificial Intelligence (AI)
- Wireless communication protocols
- Cloud computing.

Topic 2.3

Why successful digital twinning is based on the collection and use of appropriate data:

- Sources of data:
    - theoretical calculated values
    - sensors
    - cameras, other interface devices
    - reference to the digital virtual product
    - the physical product and the connection between both the digital and the physical product
    - AI
    - machine learning
    - IoT
    - health and safety
    - communication protocols
- Importance of data accuracy.

Learning outcome

The learner will:

LO3 understand how real-world data inputs affect digital twins

Topics

3.1 Real-world data sources used to modify a digital twin model of manufacturing processes and systems

3.2 Operation of manufacturing processes and systems using a digital twin model

3.3 Effects of updated digital twin output results

Topic 3.1

Data sources:

- Sensors
- Cameras or other interface devices
- Physical outputs
- System failures
- Machine learning.

Topic 3.2

Reasons why digital twin models are used to simulate manufacturing processes/systems:

- Determining the effect of changing parameters
- Accurate replication of all process/system activities
- Effects of adjusting parameters for the future prediction and prevention of system failures
- Optimal function of the manufacturing process/system.

Topic 3.3

Effects:

- Redesign of parts and systems
- Improved reliability
- Improved efficiency
- Improved quality
- Cost reductions.

Unit 322 Simulation and digital twinning

Supporting Information

Unit guidance

This is a theoretical unit that is best taught through applied activities related to engineering contexts.

There are many opportunities to link the learning in this unit with component design and in-service modification. For example, digital twin data could result in component modification such as changes to materials or reductions in service life. Practical activities involving design and Computational Fluid Dynamics (CFD) simulation using 3D CAD systems can be used to illustrate some of the elements of the function of digital twinning.

Employers can be engaged to support delivery with examples of activities where the theory can be applied eg during the component design process.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K20
	1.2	K20
	1.3	K20
	1.4	K20
2	2.1	K20
	2.2	K20
	2.3	K14, K20
3	3.1	K20
	3.2	K20
	3.3	K20

Suggested learning resources

Textbooks

- Gilchrist A – Industry 4.0: The Industrial Internet of Things (Apress, 2016) ISBN 9781484220467
- Tao F, Zhang M, Nee A – Digital Twin Driven Smart Manufacturing (Academic Press, 2019) ISBN 9780128176306

- Yanez F – The 20 Key Technologies of Industry 4.0 and Smart Factories: The Road to the Digital Factory of the Future (Independent Publisher, 2017) ISBN 9781973402107

Websites

- www.challenge.org/insights/digital-twinning/
  What is the meaning of digital twinning and how it is applied
- www.ibm.com/topics/what-is-a-digital-twin
  What is a digital twin?
- https://www.i-scoop.eu/internet-of-things-iot/industrial-internet-things-iiot-saving-costs-innovation/digital-twins/
  Digital twins and digital twin technology in an industrial context
- www.networkworld.com/article/3280225/what-is-digital-twin-technology-and-why-itmatters.html
  What is a digital twin and why it's important to IoT

Unit 323 Cyber security for engineers

Unit level:	3
GLH:	60
Assessment type:	Assignment
Aim:	The aim of this unit is for learners to develop their knowledge of how cyber security impacts on their role and their responsibilities for maintaining a secure working environment. They will also learn about the legislation and standards that govern the use of systems within an engineering environment.

Learning outcome

The learner will:

LO1 understand the common threats to systems and organisations

Topics

1.1 Common threat actors that are involved in attempts to breach cyber security in organisations

1.2 Vulnerabilities that can be exploited to compromise cyber security

1.3 The types of attacks that are commonly used against organisations and individuals in an attempt to compromise cyber security

1.4 Types of malware

1.5 The impact of breaches in cyber security

Topic 1.1

Threat actors:

- State sponsored
- Cyber terrorists
- Cyber criminals
- Hackers
- Disgruntled employees.

Topic 1.2

Vulnerabilities that can be exploited during attempts to compromise systems:

- Human behaviour
- Misconfigured devices
- Unencrypted data

- Weak passwords
- Coding errors.

Topic 1.3

Types of attacks used to compromise cyber security and their impacts:

- Denial of service (DOS)
- Distributed denial of service (DDOS)
- Social Engineering
- Tailgating
- Phishing
- Spear phishing
- Vishing
- Smishing
- Man in the Middle
- Brute force attack
- Bluejacking.

Topic 1.4

Common types of malware and their impact on systems:

- Ransomware
- Trojan
- Viruses
- Worms
- Adware
- Spyware
- Rootkits
- Fileless malware.

Topic 1.5

Impact on organisations

- Loss of revenue
- Loss of sensitive data
- Prosecution for non-compliance with legislation.

Learning outcome

The learner will:

LO2 understand security methods that can be used to prevent or reduce the impact of a cyber security breach

Topics

2.1 Security methods used to prevent or reduce the impact of a cyber security breach

2.2 Benefits and limitations of different security methods

Topic 2.1

Methods:

- Passwords
- File permissions
- Biometrics
- Muti factor authentication
- Anti-virus/malware software
- Firewalls
- Encryption
    - Wireless Equivalent Privacy (WEP)
    - Wi-Fi Protected Access (WPA) WPA2 WPA3.

- Disabling the broadcasting of SSIDs
- Physical security

Topic 2.2

Benefits:

- Controlling unauthorised access to data
- Controlling ability to download software
- Compliance with legislation
- Controlling unauthorised access to hardware

Limitations:

- Human behaviour
- Password complexity and ageing
- Misconfigured software
- Out of date software

Learning outcome

The learner will:

LO3 understand the current key legislation that applies to cyber security in an engineering environment

Topics

3.1 The main requirements of key legislation

3.2 The main requirements of key standards

Topic 3.1

Key legislation:

- Data Protection Act incorporating the General Data Protection Regulations
- Computer Misuse Act
- The Copyright, Designs and Patents Act
- The Communications Act
    - piggybacking
    - threatening behaviour online
    - offensive and indecent images.

Topic 3.2

Key standards:

- National Cyber Security Centre (NCSC) Cyber essentials
- Minimum Cyber Security Standard (MCSS)

Unit 323 Cyber security for engineers

Supporting Information

Unit guidance

This is a theoretical unit that is best taught as a standalone unit for learners that require to develop an understanding of cyber security.

There are many opportunities to link the learning in this unit with machining activities. For example, researching the types of attacks that can affect the systems that they are working with and how these can be countered.

Employers can be engaged to support delivery with examples of activities where the theory can be applied eg configuring wireless devices on a network.

When discussing legislation the most up-to-date versions must be used.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K20
	1.2	K20
	1.3	K20
	1.4	K20
	1.5	K20
2	2.1	K18, K19
	2.2	K18, K19
3	3.1	K8
	3.2	K8

Suggested learning resources

- The National Cyber Security Centre (NCSC) - https://www.ncsc.gov.uk
- IT Governance - https://www.itgovernance.co.uk
- Minimum Cyber Security Standards - https://www.gov.uk/government/publications/the-minimum-cyber-security-standard

Unit 324 Data analytics/Big data

Level:	3
GLH:	60
Assessment type:	Assignment
Aim:	The purpose of this unit is for learners to understand how engineering organisations use data to manage and improve performance in manufacturing. Engineering organisations collect vast amounts of data from a wide range of sources about their operations, products and customers. The resulting data sets can be so large that they are now known as big data. This data can be analysed and used to monitor manufacturing performance, compare performance against competitors and to identify areas where improvement is needed. Learners will investigate how and why engineering organisations collect data in manufacturing and how this data is analysed and used.

Learning outcome

The learner will:

LO1 understand the role of data analytics to manage and improve performance in a manufacturing environment

Topics

1.1 Types of data
1.2 The benefits of data analytics at an organisational level
1.3 Applications of data analytics in manufacturing

Topic 1.1

Types of data:

- Big data
- Quantitative
- Qualitative.

Topic 1.2

Benefits:

- Decision making
- Efficient operations
- Customer service
- Managing performance
- Benchmarking performance against competitors.

Topic 1.3

Applications of data analytics:

- Identifying trends
- Monitoring performance
- Identifying potential for improvement
- Benchmarking performance against related processes.

Learning outcome

The learner will:

LO2 understand key performance indicators used in manufacturing

Topics

2.1 Key performance indicators (KPIs) used in manufacturing
2.2 How the data used to calculate KPIs is collected
2.3 Variables that affect KPI results
2.4 KPIs used in manufacturing

Topic 2.1, 2.4

What is represented by key performance indicators (KPIs):

- Throughput
- Changeover time
- Cycle time
- Total processing time
- Scrap material
- Yield
- Capacity utilisation
- Operating Equipment Effectiveness
- Lead time
- On time delivery.

Topic 2.2

Data collection:

- Time and motion studies
- Data sources (machines, tool suppliers, back office functions)
- Inspection reports.

Topic 2.3

Variables that affect KPIs and their impact:

- Tooling
- Workholding
- Machinery
- Material
- Suppliers
- Machine programme
- Sequence of operations
- Standard operating procedures.

Topic 2.4

Calculation of KPIs used in manufacturing using provided formulae:

- Throughput = number of products manufactured / time
- Total processing time to manufacture a product = sum of processing time on the processes carried out
- Scrap % = (number of scrap products / total number of products produced) x 100/1
- Yield % = (number of acceptable products / total number of products produced) x 100/1
- Capacity utilisation % = (output achieved / potential output) x 100/1
- Operating Equipment Effectiveness = (Number of good products made x ideal processing time / planned production time) x 100/1
- On time delivery % = (Quantity of products delivered on time / total quantity of products) x 100/1

Learning outcome

The learner will:

LO3 understand what is represented by statistical process control data in manufacturing

Topics

3.1 Why statistical process control (SPC) may be used in preference to 100% measurement
3.2 Difference between types of data used in control charts
3.3 Control chart datum values
3.4 Characteristic trends shown on control charts

Topic 3.2

Types of data:

- Attribute
- Variable.

Topic 3.3

Interpretation of datum values:

- The centre line (nominal value)
- Upper control limit (UCL)
- Lower control limit (LCL)

- Upper action limit (UAL)
- Lower action limits (LAL).

Topic 3.4

Analysis of a control chart:

- In control
- The difference between common and special causes of variation
- Causes of variation (tool wear, vibration, coolant, environmental changes, human error)
- Rule of seven.

Unit 324 Data analytics/Big data

Supporting Information

Unit guidance

This is a theoretical unit that can be effectively taught through applied activities and case studies related to engineering contexts. Employers can be engaged to support delivery with examples of activities where data and measurements are used.

There are many opportunities to link the learning in this unit with practical machining activities. For example, recording the outputs of machining processes or measuring batches as part of quality control.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K20
	1.2	K20
	1.3	K20
2	2.1	K21
	2.2	K14, K16, K21
	2.3	K21
	2.4	K5, K21
3	3.1	K5, K12
	3.2	K5, K12
	3.3	K5, K12
	3.4	K5, K12

Unit 325 Autonomous systems

Level:	3
GLH:	60
Assessment type:	Assignment
Aim:	The purpose of this unit is for learners to understand the increasing role autonomous systems play in advanced manufacturing. By learning these topics, they will better understand how the software and hardware are integrated. Learners will develop an understanding of the benefits and limitations of these types of systems and how software and hardware can be utilised to design and realise autonomous system solutions that meet advanced manufacturing requirements. They will also understand the health and safety requirements of autonomous systems.

Learning outcome

The learner will:

LO1 understand the concept, applications, benefits and limitations of autonomous systems used in advanced manufacturing

Topics

1.1 Principles of autonomous systems
1.2 Applications of autonomous systems
1.3 Benefits of autonomous systems
1.4 Limitations of autonomous systems

Topic 1.1

Principles of autonomous systems:

- Purpose of autonomous systems
- Definition of autonomous manufacturing
- Data driven
- Definition of robotic process automation

Topic 1.2

Use of:

- Robotics
- Intelligent systems

- 3D modelling and simulation
- Virtual reality
- CNC machinery.

Topic 1.3

Benefits:

- Efficiency
- Limited human intervention
- Productivity
- Accuracy
- Precision
- Repeatability
- Consistency.

Topic 1.4

Limitations:

- Creativity
- Independent thinking
- Decision making
- Adaptivity
- Cost.

Learning outcome

The learner will:

LO2 understand the integration of software and hardware in autonomous systems

Topics

2.1 Characteristics of smart technologies
2.2 Integration of software and hardware
2.3 Elements of integrated autonomous systems
2.4 Approaches to the use of data

Topic 2.1

Characteristics:

- Connected devices
- Data usage
- Automation robotics
- Internet of Things (IoT)
- Simultaneous engineering.

Topic 2.2

The integration of hardware and software:

- Data security
- Data input methods
- Exchange of data
- Compatibility of hardware and software.

Topic 2.3
Elements of integrated autonomous systems and their applications:

- Co-bots
- Automated guided vehicles
- Barcodes/QR codes
- Conveyor belts
- Sensors.

Topic 2.4
Approaches and how they are used:

- Use of data to improve processes
- Use of data to guide actions.

Learning outcome

The learner will:

LO3 understand the health and safety requirements of autonomous systems

Topics

3.1 Legislation requirements applicable to autonomous systems
3.2 Safe working practices for autonomous systems

Topic 3.1
Legislation:

- Industrial Robot Safety (HSG43)
- Provision and Use of Work Equipment Regulations (PUWER)
- Lifting Operations and Lifting Equipment Regulations (LOLER).

Topic 3.2
Safe working practices within:

- Installation
- Maintenance
- Operation.

Unit 325 Autonomous systems

Supporting Information

Unit guidance

This is a theory based unit that is best delivered in the context of real or realistic case studies. It is designed to be delivered once learners are working in a real manufacturing environment so that they can experience the implementation of autonomous systems.

Working with employers would enhance the delivery of the unit. This could be through presentation of a problem and an exploration, with the employer, of how the use of autonomous systems could improve efficiency.

Mapping to the ST1305 Machining Technician apprenticeship standard

The mapping grid is a guide only. Additional KSBs could be covered during the assessment of the unit.

Learning outcome	Topic	KSB(s)
1	1.1	K20
	1.2	K20
	1.3	K20
	1.4	K20
2	2.1	K20
	2.2	K20
	2.3	K11, K20
	2.4	K20
3	3.1	K1, K20
	3.2	K1, K17, K20
	3.3	K8, K20

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 ***Centre Document Library*** on ***www.cityandguilds.com*** or click on the links below:

Quality Assurance Standards: Centre Handbook
This document is for all approved centres and provides guidance to support their delivery of our qualifications. It includes information on

- Centre quality assurance criteria and monitoring activities
- Administration and assessment systems
- Centre-facing support teams at City & Guilds / ILM
- Centre quality assurance roles and responsibilities.

The Centre Handbook should be used to ensure compliance with the terms and conditions of the Centre Contract.

Quality Assurance Standards: Centre Assessment
This document sets out the minimum common quality assurance requirements for our regulated and non-regulated qualifications that feature centre assessed components. Specific guidance will also be included in relevant qualification handbooks and/or assessment documentation.

It incorporates our expectations for centre internal quality assurance and the external quality assurance methods we use to ensure that assessment standards are met and upheld. It also details the range of sanctions that may be put in place when centres do not comply with our requirements, or actions that will be taken to align centre marking/assessment to required standards. Additionally, it provides detailed guidance on the secure and valid administration of centre-assessments.

Access arrangements - When and how applications need to be made to City & Guilds
provides full details of the arrangements that may be made to facilitate access to assessments and qualifications for candidates who are eligible for adjustments in assessment.

The ***Centre Document Library*** also contains useful information on such things as:

- Conducting examinations
- Registering learners
- Appeals and malpractice

Useful contacts

Please visit the Contact Us section of the City & Guilds website, ***Contact us***

City & Guilds

For over 140 years we have worked with people, organisations and economies to help them identify and develop the skills they need to thrive. We understand the life changing link between skills development, social mobility, prosperity and success. Everything we do is focused on developing and delivering high-quality training, qualifications, assessments and credentials that lead to jobs and meet the changing needs of industry.

We partner with our customers to deliver work-based learning programmes that build competency to support better prospects for people, organisations and wider society. We create flexible learning pathways that support lifelong employability, because we believe that people deserve the opportunity to (re)train and (re)learn again and again – gaining new skills at every stage of life, regardless of where they start.

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